TCRS Strategic Plan

Evidence-based Roadside Engineering White Paper

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AUTHORS’ NOTE

As a matter of convenience, this document assumes that the two AASHTO Publications which the TCRS is currently charged with, the Roadside Design Guide (RDG) and the Manual for Assessing Safety Hardware (MASH), will continue to be updated and published under the same titles in the future. This document outlines a five to ten year plan for the TCRS, therefore, when reference is made throughout the text to either of these documents, the reference should be understood to mean future versions of these documents.
CHAPTER 5
EVIDENCE-BASED ROADSIDE ENGINEERING

This chapter is a stand-alone white paper offered in support of mission statement 3, monitor the effectiveness of implementation guidance and testing standards to assess the progress being made and make changes as needed to continue moving toward zero roadside fatal and incapacitating-injury roadway departure crashes. The third mission statement provides a measure of how the TCRS is doing in achieving their vision and what can be done to advance that vision. Strategies and actions suggested for advancing the mission are discussed. Research needs and activities which should be programed for the continued support of the stated mission are shown in the Appendix C.

The days of making decisions to conduct research or implement research based purely on a perceived problem or a vague hope of improved performance are gone. The tools, techniques, and data exist to make informed decisions and assess these decisions. The evidence-based process shown in Figure 1 is represented by a series of questions which are punctuated by the same beginning and ending question: "What is the risk of a severe or fatal lane departure crash? How do you know the risk? What can be done to reduce the risk?"

![Figure 1. Evidence-based Roadside Engineering.](image)

This paper presents a formalized process for maintaining the Roadside Design Guide (RDG) and the Manual for Assessing Safety Hardware (MASH) through the evaluation of hardware and hazards and the evaluation of guidance and standards to ensure the community’s desired goals are being achieved. The process also dictates that this community (1) justify the request for research dollars and guidance changes with a prediction of the expected impact on safety and/or risk reduction; (2) document the gap which the requested research or guidance change will fill; and (3) document how the research or guidance change will be implemented. The intent of this long-range plan is to ensure the focus remains on researching and implementing guidance and standards where measurable gains can be achieved.

TCRS is envisioned as playing a leadership role in roadside design. While maintaining and improving the RDG and MASH are certainly key aspects of providing leadership, TCRS
should also be the focal point for resolving roadside safety issues. For example, the NTSB frequently makes suggestions on improving roadside safety. States often have specific design related issues for which they need guidance. The FHWA also frequently solicits the assistance of TCRS in developing better guidance. These groups provide input that generally arises from issues originating in field observations – catastrophic crashes in the case of NTSB; installation, maintenance and design issues from the States and field performance issues from FHWA. Input from these roadside safety partners provides important direction for identifying the questions that need to be answered by collecting and examining field data.

BACKGROUND
The TCRS vision, mission, objectives, and publication roles, as outlined in the 2015 TCRS strategic plan are provide here for reference. This section also summarizes published comments in support for an evidence-based approach, examples of other studies where data was used to direct policy, and data needs identified by the TRB AFB20, the National Transportation Safety Board (NTSB), and the TCRS.

TCRS Strategic Plan
Vision: Lead roadside policy development, support safety innovations, and be an information resource to promote a decline in roadway departure related deaths and incapacitating injuries.

Mission: In support of the AASHTO SCOH and SCOD Strategic Plans, (1) develop, implement, and maintain guidance which will reduce fatal and incapacitating-injury roadway departure crashes, (2) develop, implement, and maintain evaluation standards to support roadside safety innovation and decision making, and (3) monitor the effectiveness of implementation guidance and testing standards to assess the progress being made and make changes as needed to continue moving toward zero roadside fatal and incapacitating-injury roadway departure crashes.

Objectives proposed in support of the TCRS vision and three mission statements:
A. Critique and improve the underlying assumptions within the RDG and MASH through the analysis of field performance and assessment of available data.
B. Identify guidance that is outdated, lacking, or not supported by recent evidence within the current RDG and MASH that should be addressed in upcoming revisions and conduct research to satisfy those needs.
C. Keeping up with the dynamic changes in roadside policy can be costly (i.e., budget and schedule); make changes to the RDG and MASH only when the change is likely to result in measurable gains in the field.
D. Provide tools which support making design and policy decisions.
E. Determine the most effective means to communicate the MASH standards and RDG guidance to promote consistency in interpretation and implementation in the field.
F. Develop and publish a RDG and MASH which are based on quantifiable performance measures and specific design goals.
G. Identify and implement methods which will foster innovation in hardware development.

Publication Roles: Define MASH as a primary assessment of roadside hardware tool. Define ISPEs are for the assessment of hardware performance in the field. Define the RDG as set of strategies for how to address roadway departure crashes and as resource for hardware installation.
guidelines. Clarifying the primary purpose of these documents would eliminate the need for future implementation agreements whenever MASH or the RDG changes.

Published Support for Evidence-based Engineering

The 2011 RDG encourages the use of data assessment to support the decision-making process. For example, the preface states “…it is important that significant deviations from the guide be based on operational experience and objective analysis.” Section 1.2 of the 2011 RDG notes that “crash reports, site investigations, and maintenance records offer starting points for identifying [areas that offer the greatest safety enhancement potential]” [AASHTO11]

Crash test and evaluation criteria have been updated regularly over the last 30 years (e.g., NCHRP Report 230, NCHRP Report 350 and now MASH). One recurring theme in each rewriting is the recommendation of in-service performance evaluations (ISPE). Michie et al. first recommended ISPEs in the crash testing procedures documented under Report 230 and published in 1981. [Michie81] The importance and need for ISPEs has been reiterated in Report 350 as well as in the latest crash testing procedures, the Manual for Assessing Safety Hardware (MASH). [Michie81; Ross93; AASHTO09] Although ISPEs are widely recognized as an essential element of the overall design evaluation process and procedures for performing ISPE were developed and published a decade ago in NCHRP Report 490 [Ray03], relatively few ISPEs are performed.

The Federal Highway Administration (FHWA) says “ideally, all highway agencies should know precisely what has been incorporated into its roadway/roadside infrastructure and be able to monitor the performance of individual components of its highway system. Asset management has become a primary means of accomplishing this goal in many states. However, there remains one area where in-service evaluation or performance monitoring seems to be minimal at best, and that is the area of roadside safety features” (See http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/policy_memo/memo111705/).

Examples of High-Level Data Analysis


EXHIBIT III-1. Single-Vehicle ROR Crashes as a Percentage of
All Fatal Crashes [Neuman03]

EXHIBIT III-2. Distribution of Single-Vehicle ROR Fatalities on Two-Lane, Undivided, Noninterchange, Nonjunction Roads by Highway Type. [Neuman03]

EXHIBIT III-3. Distribution of Single-Vehicle ROR Fatalities for Two-Lane, Undivided, Noninterchange, Nonjunction Roads by First Harmful Event. [Neuman03]
EXHIBIT III-4. Distribution of Single-Vehicle ROR Fatalities for Two-Lane, Undivided, Noninterchange, Nonjunction Roads by Most Harmful Event. [Neuman03]

Figure 2-4. Distributions of NASS GES rollovers and KA injuries in rollovers by first harmful event. [Digges14]
Digges et al. reviewed NASS GES data from 2000-2011 while considering the vehicle model year (e.g., new models have stability control). The researchers isolated all crashes which included a rollover crashes in any sequence of events. Digges et al. found that “64% of fatal rollovers involve run-off-the-road events.” [Digges14]

These graphics, particularly Exhibits III-3 and III-4 indicate that narrow fixed objects (i.e. trees and poles) and roadside terrain (i.e., overturn, embankment, ditch) crashes represent the largest share of fatal ROR crashes and the greatest potential to reduce fatal and severe injury crashes and achieve the TCRS vision. A more detailed review of the rollover problem by Digges et al. indicated that, when rollover crashes are limited to ROR events, culverts, curbs, and ditches should receive focus. This short analysis of current literature is presented to demonstrate the complexities of the roadside environment and that no single feature should be ignored, but we should focus on the development of tools and methods which support the analysis and reduction of risk across the roadside and evaluate our progress.

Identified Areas Where Data is Needed

An improved understanding of some aspects of roadside risk is needed to help move the TCRS closer to their vision to lead roadside policy development, support safety innovations, and be an information resource to promote a decline in roadway departure related deaths and incapacitating injuries and ultimately address the question “what is the risk of fatal and incapacitating injury road departure crashes?” Needs, knowledge gaps, and gaps in available data for forming and assessing roadside guidance and standards have been summarized here. Research Needs Statements (RNS) identified by the TRB AFB20 committee were reviewed from 2009 through 2014 and needs identified through this effort and outreach to the community are also discussed. The recommendations made by the National Transportation Safety Board (NTSB) were reviewed, however, there were no recommendations made relative to data and/or risk assessment.

Encroachment data has been a long recognized data need, as encroachment data is at the foundation of the guidance and standards published by the TCRS and has not been successfully updated since 1976. RNS have been identified four out of five years and include the call to collect encroachment data at a variety of traffic volumes, across a range of vehicle types, highway types, and within work zones.

Injury and fatality causation and the relationship with various roadside hazards, including trees, barriers, and slopes repeatedly appear indicating an improved understanding of the outcome of a crash with any roadside hazard is needed. Slope traversibility and the causes of vehicle rollovers also appear, however, there is ongoing research which may satisfy these needs.

The field performance of longitudinal barriers on curves, with different vehicle types, within work zones, and at different heights is unknown. The field performance of terminals is unknown. Each year a different RNS is proposed to address one of these unknowns.

Many different knowledge gaps have been identified by the community. Both the RDG and MASH acknowledge the importance of evidence-based engineering, however, this approach has never been formalized or widely implemented. A formal approach is proposed herein.

PROPOSED EVIDENCE-BASED ROADSIDE ENGINEERING APPROACH

This document has been conceived and presented as a long-range plan for working toward an organization which has the data and knowledge to (1) easily react to the quickly-
evolving safety advances, (2) can answer the questions “what is the risk and how do you know;” and (3) provide tools which support the end users in making the decisions using evidence rather than relying on engineering judgment and intuition. It is anticipated, that in time, the tools developed and supported in this effort would address concerns such as: “what if we can’t install the ideal solution?” and alleviate the need to rely primarily on engineering judgment to prioritize local improvements, policy changes, and research needs. Two separate, but related strategies are proposed:

- Institutionalize In-Service Performance Evaluations (ISPEs); and
- Develop and support tools, methods, and techniques for the prediction, analysis, and evaluation of progress toward the reduction of roadside risk.

**Institutionalize In-Service Performance Evaluations (ISPEs)**

Should hardware be designed to pass a crash test or designed to meet the needs of what is observed in the field? Roadside hardware is not currently assessed on its field performance, therefore, neither the crash testing standard’s ability to assess a new design is evaluated, nor are the designers of roadside hardware afforded the data to improve their designs. Furthermore, variations in performance by region which could be the result of construction, maintenance, or atmospheric disparities go unrecognized.

The performance of roadside hardware in the field should be more important than its performance in a few crash tests performed under controlled circumstances using carefully constructed test installations. A field performance review makes the leap from a handful of specific impact speeds, angles and vehicle types assessed during a crash test to the wide array of actual impact conditions observed in the field.

Each crash testing specification has assessed hardware safety performance based on the vehicles believed to be current at that time. MASH notes in the Appendix A – Commentary: “there is no assurance that a safety feature will perform acceptably with other vehicle types presently in service or those vehicle types that may come into use during the normal service life of the device.” In-service performance evaluation could detect these changes as they emerge in the field. Many excuses are offered even within MASH for condoning the continued apathy toward ISPEs.

Inventory and asset management has become standard in most other DOT operations. For example, a particular state DOT has a materials division specification that tracks the placement of each batch of glass beads on pavement markings. The state monitors who purchased the beads, who manufactured the beads, and where the beads went on each job. The Materials Division monitors the Contractor’s operation by ensuring the contractor collects and reports this information and ensures that Manufacturer’s certifications are maintained. One might ask, if this is possible for pavement markings, why is this not considered possible for roadside hardware? [VDOT14]

Another example of currently inventoried hardware are signs. FHWA established three important compliance dates to ensure implementation and continued use of an assessment or management method to maintain traffic sign retro reflectivity at or above the established minimum levels (See: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_431.pdf). Again, if DOTs can maintain inventories of signs to monitor retroreflectivity why are roadside hardware inventories so elusive? There is simply no excuse in this day and age for not maintaining an inventory of roadside hardware.
Institutionalize ISPEs through cooperation

Institutionalizing ISPEs in the roadside safety process will require the collaboration of hardware designers, AASHTO TCRS, the States, manufacturers, FHWA and researchers. Hardware designers are invested in the design of roadside hardware, participating in ISPEs is a natural means to improve hardware designs. The AASHTO TCRS is responsible for maintaining the crash test and evaluation standards and should be invested in ensuring the standards reasonably replicate the range of conditions encountered in the field. While each State may purchase previously designed and crash tested hardware, it is paramount to assess the State’s own ability to successfully construct and maintain that hardware. FHWA has a long history of establishing hardware policy with little understanding of the actual field performance.

Simply stated, each member of the community has a vested interest in the performance of hardware on the roadside and each member can play a valuable role in the institutionalization of ISPEs. States may be best suited to collect the inventory, manufactures may provide a portion of funds from the sale of hardware and researchers may conduct analysis when granted access to the data. The TCRS may provide the leadership to change the collective mindset from crash testing as the gold standard of safety evaluation to field performance as the gold standard. Funding agencies such as the FHWA or NCHRP may provide the catalyst to outline the cooperative action and conduct any initial setup.

Ensure improvements are motivated by field observations

The FHWA issues roadside safety policy changes for NHS roadways based primarily on observations from crash tests rather than field performance (e.g., 31” guardrail). The user agencies have little idea of how the funds spent updating their hardware will impact their road users’ risk. While there may be no question that the updated hardware preforms better under the crash testing specifications, it is unclear how many fewer fatal or incapacitating injuries might result from deploying the improved hardware.

Implementing the results of these changes is often costly to the implementing agency. Improvements should not, therefore, be adopted without considerable forethought. Crash tests are the roadside safety equivalent of “experiments” which are conducted to an established standard to ensure repeatability of the tests and comparability between tests. The variability of vehicles, occupants and impact conditions are controlled in the testing environment but cannot be controlled in-service. Field conditions, common installation/repair mistakes or maintenance issues are not observed by crash tests. Variability in occupants are not observed in crash tests. Driver reactions and behaviors are not observable in crash tests. The range of vehicle size, impact speed, and angles are thought to be addressed by crash tests but this has not been verified. Each of these variability’s can be assessed through the in-service review of roadside hardware.

Conversely, there is precious little data available regarding the field performance of hardware, so crash testing remains the gold standard. It is proposed that prior to any policy change, a review of the in-service performance of the outgoing hardware be performed. If the hardware is found to be preforming acceptably [each State or TCRS to define acceptable through research], then the ISPE may be offered in place of changing the hardware policy. If the performance is judged to be unacceptable, then steps to improve or change the test and evaluation criteria (i.e., MASH) or the site design and installation recommendations (i.e., RDG) should be initiated.
The budget necessary to collect and maintain a hardware inventory could be balanced by the potential savings which may be realized by not implementing hardware upgrade policies that have little measurable effect in the field.

NCHRP 490 “In-Service Performance of Traffic Barriers” should be updated to reflect advancements in data collection and assess management over the last 12 years to support this effort.

Research Needs Statement
• Develop Cooperative Approach to ISPEs with supporting tools.

Develop and support tools, methods, and techniques for the prediction, analysis, and evaluation of progress toward the reduction of roadside risk.

Understand of the frequency and nature of roadside events
The need for improved understanding of the nature and frequency of roadside encroachments across the entire vehicle fleet and a range of traffic volumes is widely recognized. Encroachment data are the fundamental backbone of each part of the RDG and MASH. Improving this understanding is paramount to all other research. This understanding will provide opportunities to focus efforts where needed within the RDG and assure accurate guidance is given, provide opportunities to improve upon the evaluation standards within MASH to ensure evaluations reflect critical impact scenarios observed in the field, and enhance existing assessment tools (i.e., RSAPv3).

Understand the roadside characteristics
While many states maintain a road-based database of roadway geometric features such as centerline miles, horizontal curvature, vertical grade, shoulder width, etc. very few states maintain a database of any roadside characteristics. The need exists to collect and maintain an inventory of roadside features such as slopes, fixed object density, and roadside hardware. This inventory will allow for a continual monitoring of not only safety hardware, but all roadside hazards and potentially lead to new discoveries about how to most effectively design roadsides. The possibility exists that we install too many barriers and flatten too many slopes. Maybe there is a better slope/fixed object density relationship? The collection of data is needed before the research can take place and the policies can be improved. This collection, however, should be systematic and well informed to ensure the data collected can be used effectively. It is recommended that a general strategic list of features be developed for the collection of data which will prove to be valuable.

Injury and fatality causation and the relationship with various roadside hazards
A critical need to improve the understanding of how each roadside feature and vehicle type individually interact is needed. For example, what is the probability of roll over on various slopes? Does that probability change at different speeds? Does the severity of rollover crashes change on different slopes or at different speeds? These same questions can be extended to just about any roadside hazard, including barriers. Many assumptions are currently made for the speed/severity relationship and how the severity increases for each interaction with a hazard in a crash or for different vehicle types. It is recommended that these assumptions be critically reviewed. Specifically, it is recommended that the probability and resulting severity of rollover be studied at different speeds for different vehicle types across a range of slopes: the severity
distribution of different roadside hazards for different vehicle type should be considered; and the change in crash severity as events in a sequence increase be studied.

**Research Needs Statement**
- Collect encroachment data across a range of traffic volumes, highway types, and vehicle types.
- Develop a comprehensive list of hazards and methods for collecting and storing roadside inventory.
- Determine the probability and resulting severity of rollover at different speeds for different vehicle types across a range of slopes.
- Determine the severity distribution of different roadside hazards for different vehicle type.
- Determine the change in crash severity as events in a sequence increase.

**Summary**
While guidance and evaluation standards could be improved in isolation of field performance, an opportunity exists to investigate perceived problems with specific hazards or hardware. Improved standards will aid in quantifying the extent of the problems. Field assessment will aid in identifying compounding issues including: non-conforming roadside designs, mis-installed or repaired hardware; and/or opportunities to improve current design and testing guidance.

**CONCLUSION**
The proposed vision of the TCRS is to “Lead roadside policy development, support safety innovations, and be an information resource to promote a decline in roadway departure related deaths and incapacitating injuries.” The proposed third mission of the TCRS, in support of the vision, is to “monitor the effectiveness of implementation guidance and testing standards to assess the progress being made and make changes as needed to continue moving toward zero roadside fatal and incapacitating-injury roadway departure crashes.” The TCRS strategic plan suggests seven objectives for in support of the vision and mission: (1) critique and improve the underlying assumptions within the RDG and MASH through the analysis of field performance and assessment of available data; (2) identify guidance that is outdated, lacking, or not supported by recent evidence within the current RDG and MASH that should be addressed in upcoming revisions and conduct research to satisfy those needs; (3) keeping up with the dynamic changes in roadside policy can be costly (i.e., budget and schedule); make changes to the RDG and MASH only when the change is likely to result in measurable gains in the field; (4) provide tools which support making design and policy decisions; (5) determine the most effective means to communicate the MASH standards and RDG guidance to promote consistency in interpretation and implementation in the field; (6) develop and publish a RDG and MASH which are based on quantifiable performance measures and specific design goals; (7) identify and implement methods which will foster innovation in hardware development.

**What is the risk of severe or fatal run-off-road crash?** An understanding of the actual risks associated with roadside hardware and hazards is needed to help move the TCRS closer to their vision. The evidence-based approach to guidance governance values decisions that are informed by data and an approach to guidance and standards development that favors decisions which can be verified. Evidence-based roadside engineering is an approach to research
programing which will focus research to areas which will provide the greatest improvement to roadside safety. It is an approach to roadside design which will focus efforts where the greatest improvements to safety can be achieved.

How do you know the risk? The success of the evidence-based approach is reliant upon the quality of the data gathered and the effectiveness of its analysis and interpretation. An understanding and agreement on appropriate data gathering techniques, analysis methods and tools, and interpretation of the results will allow all involved to be able to address the second question: “how do you know the risk?” and empower all to be able to answer that question themselves with the collection and analysis of their data. Currently, when actual guidance is lacking, designers frequently are left with nothing to support their decisions other than engineering judgment and “tradition” when faced with questions from governing bodies, the media and advocacy groups. The focus of this effort will be to develop and support tools which can be used in place of engineering judgment across the life-cycle of a highway (i.e., planning, design, construction, operation and maintenance) to provide a solid engineering basis for decisions.

What can be done to reduce the risk? Most prominently, when one understands the existing roadside risks, has their own data and access to assessment and analysis techniques, each of us will be empowered to make informed decisions on improvements. Funding can be focused explicitly on the areas where the largest risks exists.
REFERENCES


APPENDIX C

Research Needs Statements in Support of Mission 3 are listed in priority order. A star (*) next to the title indicates a complete problem statement has been developed and is included at the end of this appendix.

**Title**: *Develop Cooperative Approach to ISPEs with supporting tools.*

**Objective**: The objective of this research is to (1) identify and publish the roles of the collective community, through discussions, in the conduct of ISPEs; (2) develop the necessary support tools for the collection and analysis of data; (3) update NCHRP 490 to reflect advancements in data collection and asset management protocols; (4) identify and train early adopting parties and assist in their progress; (5) organize a conference to report early adopting parties results.

**Title**: *Collect encroachment data across a range of traffic volumes, highway types, and vehicle types.*

**Objective**: The objective of this research is to better understand roadside encroachments at a variety of traffic volumes and speeds across the entire vehicle fleet. Roadside encroachment data will be collected for roadways with a range of ADT values and a range of vehicle types. This data will include the pre-encroachment conditions (i.e., on-road conflict, distracted driving, drowsiness, etc.) and highway characteristics. It will be used to improve and synthesize encroachment probability based procedures and crash testing procedures. It is the objective of this research to collect both reported and unreported roadside encroachments which result in a crash and observe intentional and unintentional encroachments within the identified sections of road concurrently.

**Title**: Develop a comprehensive list of hazards and methods for collecting and storing roadside inventory.

**Objective**: The objective of this research is to (1) develop a comprehensive data collection profile which can be adopted by any state wishing to establish a roadside inventory and (2) assess and recommend a range of data collection methods appropriate for use with state crews and private teams.

**Title**: Determine the probability and resulting severity of rollover at different speeds for different vehicle types across a range of slopes.

**Objective**: The objective of this research is to use the data collected above to determine how the probability and severity of rollover varies by slope and speed. This research would be conducted after sufficient data was available from state roadside characteristics data sets.
Title: Determine the severity distribution of different roadside hazards for different vehicle type.

Objective: The objective of this research is to use the data collected above to determine how the severity of crashes change by vehicle type and by hazard type and size. This research would be conducted after sufficient data was available from state roadside characteristics data sets.

Title: Determine the change in crash severity as events in a sequence increase.

Objective: The objective of this research is to determine if the severity how/if the severity of crash increases with each event in the sequence of events (e.g., hit barrier, hit tree, rollover is different in severity from hit barrier by what relationship?). This research would be conducted after sufficient data was available from state roadside characteristics data sets.
I. PROBLEM NUMBER

To be assigned by NCHRP staff.

II. PROBLEM TITLE

Development of a Collaborative Approach for Multi-State In-Service Evaluations of Roadside Safety Hardware

III. RESEARCH PROBLEM STATEMENT

Roadside safety hardware (e.g. guardrail, bridge rail, crash cushion, etc.) is installed along the roadways to reduce the risk of serious and fatal injuries to motorists in inadvertent road departures. Impact performance criteria for roadside hardware are detailed in MASH, based on full scale crash testing. MASH prescribes a set of specific crash tests which are limited to frontal crashes of cars, light trucks, and selected heavy vehicles. The tests are conducted under ideal site conditions, (e.g. non-sloped surfaces, idealized soils for post embedment, installation by expert installers and carefully controlled impact conditions). MASH tests represent only a fraction of the potential types of crashes and site conditions which motorists may experience in the field. While an important means of checking impact performance, the tests are limited in what they can tell us about field performance where vehicles and occupants experience a broad range of site, impact and field conditions.

Since NCHRP Report 230 was published in 1981 through the current testing guidelines in MASH, in-service evaluation has been recommended as the final step in evaluating roadside hardware including end terminals. NCHRP Report 490, published in 2003, provided detailed procedures and guidelines for performing in-service evaluations including in-service evaluations of roadside safety hardware. Although the roadside safety community has agreed for 30 years about the importance of in-service evaluations and procedures have been available for nearly a decade, relatively few in-service performance evaluations have been completed and their role in making decisions about roadside safety is not well defined.

Arguably the biggest challenge to conducting in-service evaluations has been the lack of resources, both financial and technical expertise, needed for these studies. To date, the few ISPEs which have been conducted have been performed by states in isolation from one another. These isolated ISPEs, however, suffer from several challenges. A single state study may not provide meaningful information about the performance of roads hardware nationwide. Because of regional differences in installation, maintenance, repair and traffic conditions, the findings of a study in one region of the country may not apply to other regions. Because serious injury crashes are fortunately relatively rare, sample sizes from a single state are likely to be too small for statistically significant findings.
Finally, budget constraints only permit ISPEs to be conducted for a limited time period. These isolated ISPEs can become dated very quickly. A much enhanced approach would be a multi-state, multi-region study which could combine the efforts of several states in a cohesive and sustained manner to evaluate hardware on a long term or continuing basis.

The need to fully understand the actual real world performance of existing and new roadside hardware safety devices has been underlined by recent concerns over guardrail end terminal performance. However, end terminals are only one example of the many types of engineered roadside systems which are crash tested and widely deployed, but for which little is known about field performance. The development of a more proactive approach, which incorporates the efforts of all affected state DOTs is urgently needed to evaluate the actual in service performance of the full range of roadside safety hardware currently in service on the nation’s highway system.

IV. LITERATURE SEARCH SUMMARY

Procedures for performing in-service evaluations of roadside safety features were developed by Ray, Weir and Hopp and have been presented in NCHRP Report 490. This report provides a methodology for conducting in-service evaluations that is directly applicable to the proposed project. Report 490 provides guidelines for how to select data collection sites, the number of cases that are needed and the types of inventory, traffic and crash data that should be collected during an in-service evaluation study.

Only a few ISPEs have been conducted in recent years. A selected set of ISPEs of guardrail systems and end terminals are referenced below:

References
- Abu-Odeh, A., K. M. Kim and R. P. Bligh, Guardrail Deflection Analysis, Phase I, Texas Transportation Institute, College Station, TX, August 2011.
- Final Report SENTRE Guardrail End Treatments Experimental Project No. 7 February 1988 Indiana DOT
V. RESEARCH OBJECTIVE

The objective of this research is to:

- Work with the states to identify the opportunities, challenges, institutional barriers, and costs of a multi-state ISPE.
- Develop the necessary collaborative support tools for multi-state collection and analysis of ISPE data.
- Update NCHRP 490 to reflect advancements in data collection and asset management protocols.
- Identify and train early adopting States in an enhanced multi-state ISPE protocol.
- Demonstrate the new protocol by working with selected States to identify a common problem of interest (e.g. an in-service performance study of 27” vs. 31” guardrails, or MASH tested end terminals) and assisting in their conduct of this ISPE.
- Organize and conduct a workshop or conference as a forum for early adopting parties to report results.
- Determine possible procedures for use of the results of conducted in-service performance evaluations.
- Determine appropriate measures of effectiveness such as comparing to other non-engineered hazards.

VI. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

**Recommended Funding:**
It is estimated that the proposed research will require approximately $650,000 in funding.

**Research Period:**
It is estimated that the proposed research will require approximately three years to complete.

VII. URGENCY, PAYOFF POTENTIAL, AND IMPLEMENTATION

**Urgency** – MASH was published in 2009. The AASHTO/FHWA joint implementation plan called for MASH testing to be required for the development of new hardware beginning January 1, 2011. Without in-service performance evaluations of roadside safety hardware it will not be possible to determine how well crash test performance
translates into the field. Making informed decisions about MASH implementation requires that in-service performance evaluations be performed to develop policy.

**Potential Payoff** – The primary payoff is better information that can be used in making policy decisions about selecting between the range of upcoming MASH tested road safety hardware. The cost of this research is a tiny fraction of what a whole-sale technology replacement would cost if a particular device type proves unacceptable in the field. This type of study also will provide invaluable feedback to roadside hardware designers and manufacturers in developing new safety hardware. ISPE data will also help to evaluate the relevancy of the MASH crash tests and allow for improvements and changes in crash testing procedures that would thereby improve field performance in the future.

**Implementation** – This research would likely result in improved recommendations in the Roadside Design Guide and would also likely provide valuable information for the FHWA and the States in developing up-grade, retrofit and replacement policies regarding end terminals. Finally, a comprehensive multi-region ISPE program would provide the real-world foundation to modify MASH to make crash testing more representative of actual crashes in the field.

VIII. PERSON(S) DEVELOPING THE PROBLEM

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IX. PROBLEM MONITOR

TBD

X. DATE AND SUBMITTED BY

August 7, 2015

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I. PROBLEM NUMBER

(To be assigned by NCHRP staff)

II. PROBLEM TITLE

Roadside encroachment data for all vehicle types across a range of traffic volumes

III. RESEARCH PROBLEM STATEMENT

Run-off-road (ROR) traffic crashes account for almost one-third of the deaths and serious injuries each year on US highways. Effective design of roadways, including the placement of roadside safety devices, can reduce the frequency and/or severity of these crashes but requires an understanding of the nature and frequency of roadside encroachments. Unfortunately, the best quality encroachment data currently available was collected in the 1960’s and 1970’s [Hutchinson and Kennedy, 1966; Cooper, 1980] and was collected only for passenger vehicles. The age of these data sets indicates that they are no longer representative of the current vehicle fleet or highway conditions. Further, each of these data sets has some significant limitations, including specific exclusion of heavy vehicles and motorcycles, and a very limited range of traffic volumes (i.e., less than 20,000 vehicles per day), that have fostered much debate over the value of findings from either study.

There is a critical need to collect new roadside encroachment data to understand the frequency and nature of encroachments across the entire vehicle fleet. There has been immense progress in both the development of new roadside safety devices and in the improvement of existing devices since the 1960’s. Proper development, testing, and placement of these devices along the roadside, however, is required to maximize their effectiveness. The guidelines for development, testing, and placement of these devices rely heavily on roadside encroachment data across a range of traffic volumes and vehicle types. Collection of new encroachment data would be used to refine current crash testing procedures as well as update the Roadside Design Guide (RDG).

IV. LITERATURE SEARCH SUMMARY AND BACKGROUND

Roadside encroachment data is currently available from two sources: a study conducted by Hutchinson and Kennedy [Hutchinson, 1962; Hutchinson and Kennedy, 1966] in Illinois and a study conducted by Cooper [De Leuw Cather, 1978; Cooper 1980] in Canada. Hutchinson and Kennedy collected data on approximately 300 passenger vehicle median encroachments on two rural interstate highways, I-74 and I-57, between July 1960 and April 1964. A majority of the data was obtained from a 25-mile stretch of I-74 which had 40-foot wide turf medians and predominately tangent sections. The 85th percentile speed was reported to be 75 mph with an ADT of 1,900 vehicles per day (vpd) at beginning of the study and 6,000 vehicles per day by end of the study period. In general, data from this study represented year round conditions on predominately straight roads with a high travel speed and very low traffic volume.

Slightly more recent encroachment data was collected by Cooper over a five month period from June to October 1978. Although data was collected for a shorter time period, the study incorporated a wide variety of highway classes and traffic volumes. The collection area included nearly 3,000 miles of roadway including both two-lane undivided highways and four-lane divided
The ADTs on these roadways ranged from 700 vehicles per day to nearly 20,000 vpd and the 85th percentile speeds ranged from 57 to 67 mph. In general, data from this study represent non-winter conditions on roads with high travel speed and a wider spectrum of traffic volumes although the volumes were still relatively light and this study was limited to passenger vehicles.

Both of these roadside encroachment data sets and methods of data collection have been scrutinized by several researchers. Although most of these analyses focused upon encroachment lengths used to develop layout criteria, some questions were raised about the appropriateness of the data collection procedures as well as inconsistencies between the two studies. In order to resolve some of these issues, Calcote et al. [1985] attempted to utilize electronic monitoring systems to collect off-road encroachment data in the early 1980s. This study used media photography and tape switches placed along the shoulder to identify vehicle excursions at the point of lane departure. Although more than 7000 run-off-road excursions were identified, researchers were unable to discern which encroachments were intentional and which were uncontrolled. Most of the observed encroachments did not extend beyond the edge of the shoulder. Unfortunately, both the length of the roadway included in the study and the duration of the data collection process were relatively short and the number of observed encroachments extending beyond the edge of the shoulder was very low.

The advancement of electronic and video monitoring technologies in the intervening 30 years should provide much more sophisticated methods for collecting run-off-road encroachment data. Sophisticated video monitoring systems have proven to be able to identify both vehicle speed and position in or adjacent to the roadway. There are other technologies available today, such as inexpensive ground mounted detectors and stereoscopic video systems which can accurately determine vehicle trajectory, speed, and deceleration rates during a roadway departure. The advantage of these systems is the automation of the data collection procedures which greatly reduces overall project costs.

**References**


**V. RESEARCH OBJECTIVE**

The objective of this research is to provide a current understanding of roadside encroachments at a variety of traffic volumes and posted speeds across the entire vehicle fleet. Roadside encroachment data will be collected for roadways with a range of ADT values and a range of vehicle types. This data will include the pre-encroachment conditions (i.e., on-road conflict, distracted driving, drowsiness, etc.) and highway characteristics. It will be used to study the need
for the incorporation of buses and other heavy vehicles into various guidelines within the RDG, as requested by the NTSB. It is anticipated that this study collect both reported and unreported roadside encroachments which result in a crash and observe intentional and unintentional encroachments within the identified sections of road concurrently.

VI. STUDY TASKS

1. Conduct literature review of existing and potential methods for the collection of encroachment data. This should include modern electronic surveillance techniques.
2. Identify agencies willing to participate in this study through sharing their crash databases, road inventory data, and allowing the project team to monitor encroachments.
3. Design a data collection procedure/system intended to monitor encroachments on a given roadway segment. This should include a cost estimate for implementing the procedure/system as well as the size of the expected encroachment database.
4. Interim report describing findings from Tasks 1-3 with work plan for project completion.
5. Collect encroachment data using the approved work plan and participating agencies.
6. Analyze the resulting encroachment database:
   a. to determine encroachment frequency for a range of traffic volumes
   b. to determine how the encroachment frequency is impacted by the highway characteristics, including but not limited to horizontal and vertical alignments, Level-of-Service, number of lanes, lane width, access density, etc.
   c. to understand reported and unreported crash thresholds for various roadside hazards and features, and
   d. to determine if heavy vehicles, buses, and motorcycles encroach differently than passenger vehicles and should therefore be specifically addressed within the RDG and MASH crash testing procedures.
7. Prepare a final report that documents the entire research effort with recommendations for the refinement of the RDG and MASH.

VII. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Recommended Funding: $675,000

Research Period: 60 months

VIII. URGENCY, PAYOFF POTENTIAL, AND IMPLEMENTATION

There is an immediate need to collect roadside encroachment data at these higher volumes and across the vehicle fleet to understand how frequently vehicles depart the traveled way and their trajectory after departure. The AASHTO TCRS has recently emphasized the need to collect updated roadside encroachment data in their draft 2015 strategic plan, noting this need as a top research priority.

There is little known about the nature of roadside encroachments for the range of vehicles on our nation’s roadways and for highways with high traffic volumes. The recent NCHRP 22-12(03) project to develop bridge rail selection guidelines notes that the available encroachment data is limited to passenger vehicles and it was necessary to make assumptions about heavy vehicle behavior to develop the bridge rail guidelines. Research is underway for pier protection guidelines and median barrier guidelines which will have to make the same assumptions, however, these guidelines are structured in such a way that the RDG will be able to implement this research without requiring updating the guidelines.
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