ATTACHMENT F

White Paper: Data-Informed Decision Making

NCHRP 20-07(360)

March 2014

Christine E. Carrigan, P.E., Ph.D.
Malcolm H. Ray, P.E., Ph.D.

RoadSafe LLC
P.O. Box 312
12 Main Street
Canton, Maine 04221

CHAPTER 5
DATA INFORMED DECISION MAKING

This chapter is a stand-alone white paper offered in support of mission statement 3, *monitor the effectiveness of implemented policies and testing standards to assess the progress being made and implement changes as needed to continue moving toward zero fatal and serious lane departure injuries*. 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 data-informed 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. Data-informed Roadside Safety Process.

This paper presents a formalized process for maintaining the Roadside Design Guide (RDG) and the Manual for the Assessment of Safety Hardware (MASH) through the evaluation of hardware and hazards and the evaluation of policies 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 policy or guidance changes with a prediction of the expected impact on safety and/or risk reduction; (2) document the gap which the requested research or policy change will fill; and (3) document how the research or policy change will be implemented. The intent of this long-range plan is to ensure the focus remains on researching and implementing policies 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, as shown in earlier Chapters, 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 and policy. 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, and objectives, as outlined in the 2015 TCRS strategic plan are provide here for reference. This section also summarizes published comments in support for a data informed 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 lane departure related deaths and serious injuries.

Mission In support of the AASHTO SCOH and SCOD Strategic Plans,
(1) develop, implement, and maintain policies which reduce fatal and serious-injury lane departure crashes, (2) develop evaluation standards to support roadside safety innovation and decision making, and (3) monitor the effectiveness of implemented policies and testing standards to assess the progress being made and implement changes as needed to continue moving toward zero roadside fatal and serious-injury lane 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 standards that are outdated, lacking, or not supported by current data analysis 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 when the change is likely to result in measurable gains.
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.

Published Support for Data-Informed Decision Making

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 re-writing 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

In "Guidance for Implementation of the AASHTO Strategic Highway Safety Plan, Volume 6: A Guide for Addressing Run-Off-Road Collisions," Neuman *et al.*, provided graphics compiled from FARS 1999 data to provide "a general description of the [ROR]problem." [Neuman03]

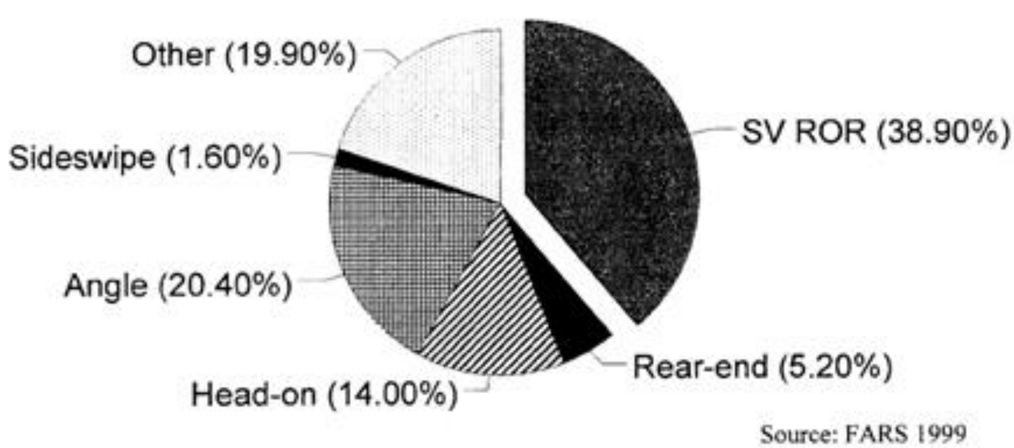

EXHIBIT III-1. Single-Vehicle ROR Crashes as a Percentage of All Fatal Crashes [Neuman03]

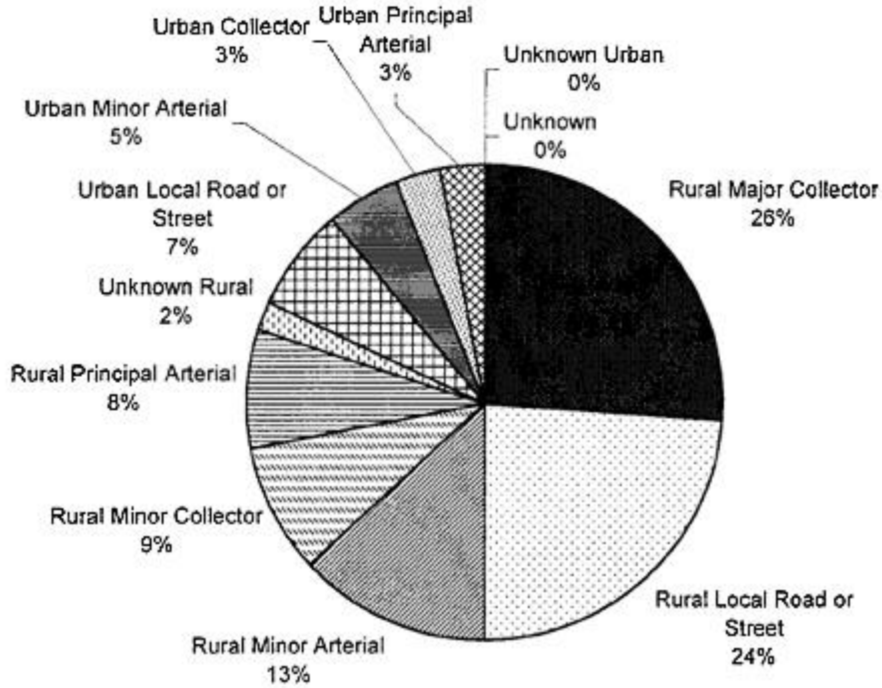

EXHIBIT III-2. Distribution of Single-Vehicle ROR Fatalities on Two-Lane, Undivided, Noninterchange, Nonjunction Roads by Highway Type. [Neuman03]

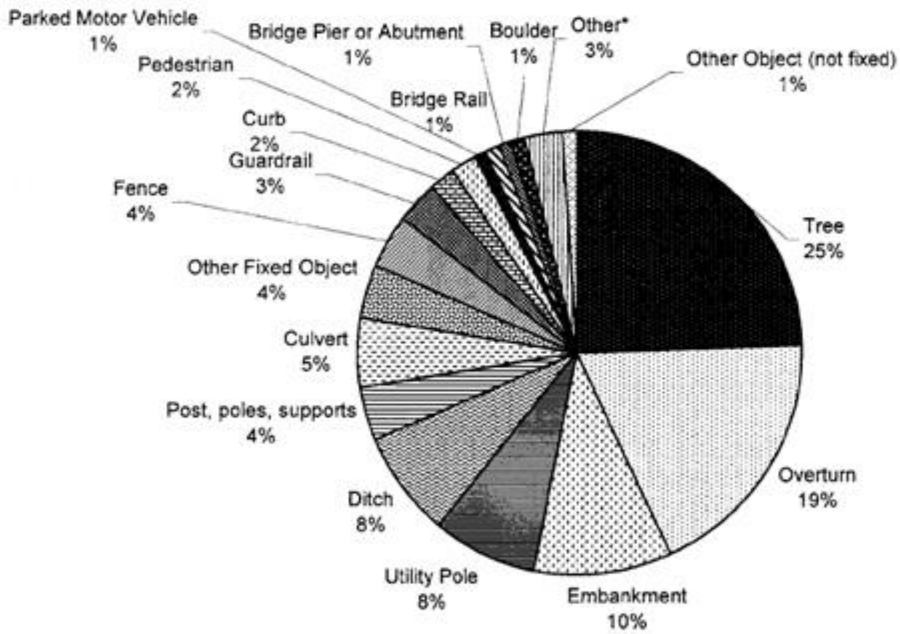

EXHIBIT III-3. Distribution of Single-Vehicle ROR Fatalities for Two-Lane, Undivided, Noninterchange, Nonjunction Roads by First Harmful Event. [Neuman03]

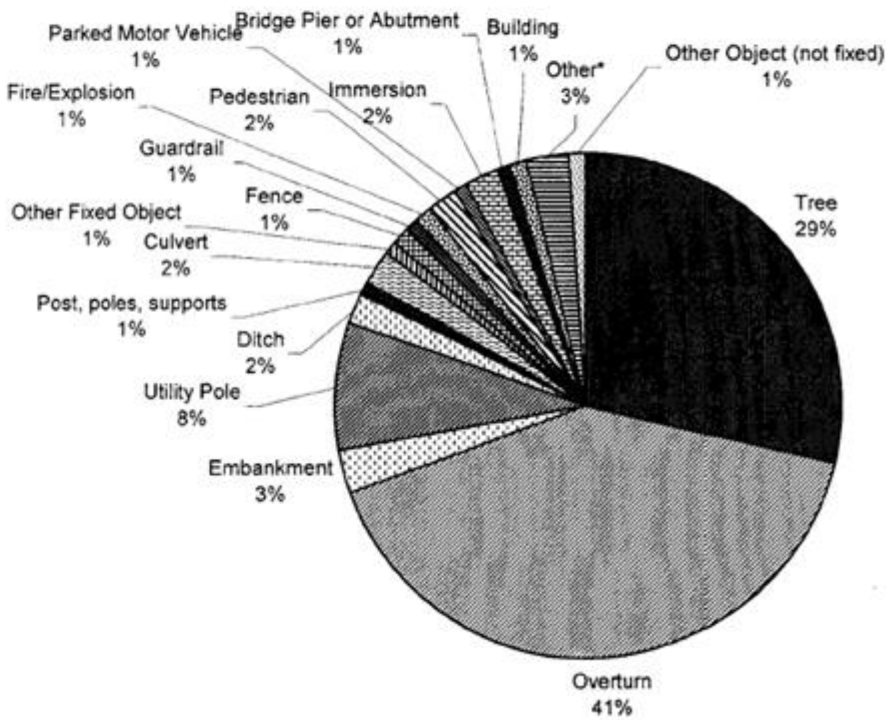

EXHIBIT III-4. Distribution of Single-Vehicle ROR Fatalities for Two-Lane, Undivided, Noninterchange, Nonjunction Roads by Most Harmful Event. [Neuman03]

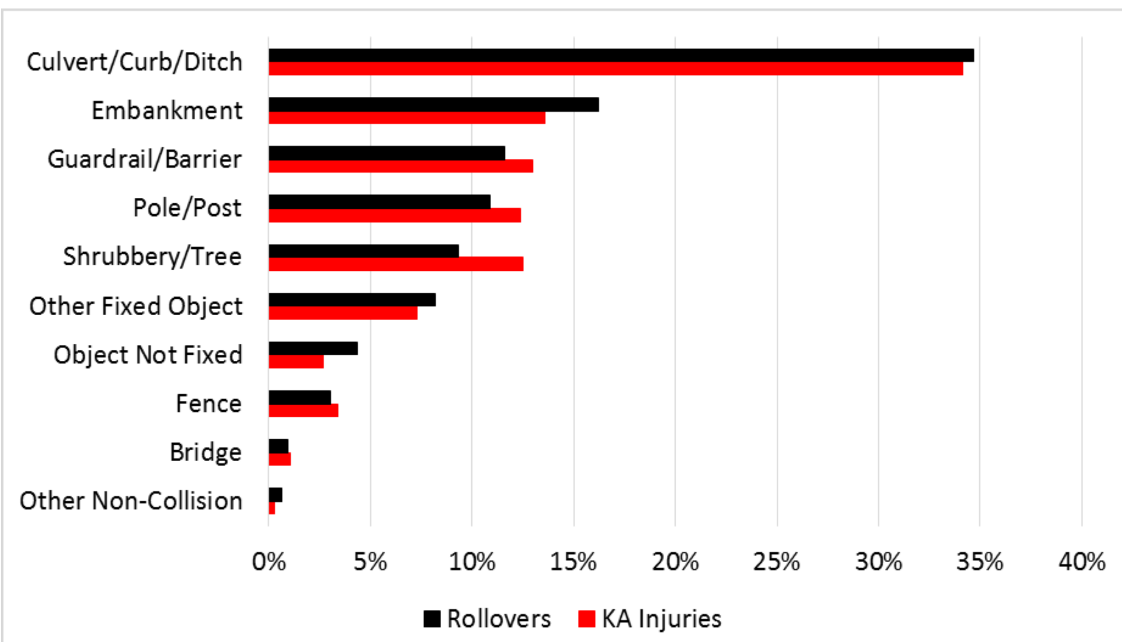

Figure 2-4. Distributions of NASS GES rollovers and KA injuries in rollovers by first harmful event. [Digges14]

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 lane departure related deaths and serious injuries* and ultimately address the question "what is the risk of severe or fatal run-off-road crash?" 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 many of the policies and standards of 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 traversbility 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 data-informed decision making, however, this approach has never been formalized or widely implemented. A formal approach is proposed herein.

PROPOSED DATA-INFORMED DECISION MAKING 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 data 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, however, 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 your 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 user's 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 severe 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], 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 policies that have little measurable effect in the field.

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 and 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 lane departure related deaths and serious injuries." The proposed third mission of the TCRS, in support of the vision, is to "monitor the effectiveness of implemented policies and testing standards to assess the progress being made and implement changes as needed to continue moving toward zero roadside fatal and serious lane departure injuries." 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 standards that are outdated, lacking, or not supported by current data analysis 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 when the change is likely to result in measurable gains; (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. A data-informed approach to policy governance values decisions that are informed by data and an approach to guidance and standards development that favors decisions which can be verified. Data-informed decision making 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 data-informed 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.

APPENDIX C:

Research Needs Statements in Support of Mission 3 are listed in priority order.

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) identify and train early adopting parties and assist in their progress; (4) 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.

REFERENCES

AASHTO09 Technical Committee for Roadside Safety, "Manual for Assessing Safety Hardware," American Association of State Highway and Transportation Officials, Washington, D.C., 2009.

AASHTO11 AASHTO, Roadside Design Guide, 4th Ed., American Association of State Highway and Transportation Officials, Washington, D.C., 2011.

Neuman03 Neuman, T.R., PFefer, R., Slack, K.L., Hardy, K.K., Council, F., McGee, H., Prothe, L., Eccles, K., "Guidance for Implementation of the AASHTO Strategic Highway Safety Plan, Volume 6: A Guide for Addressing Run-Off-Road Collisions," National Cooperative Highway Research Program Report 500, Transportation Research Board, 2003 accessed online http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v6.pdf, accessed December 2014.

Digges14 Digges, K.H., Samaha, R.R., Ozkan, D., Kim, E.Y., Eskandarian, A., "Influence of Highway Features on Rollover Crashes: In-Depth Crash Data Analyses and Focused Study," Federal Highway Administration, U.S. Department of Transportation, Draft DTFH61-09-D-00001, TOPR No. 7, draft dated May 2014.

Michie81 Michie, J.D., "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances," NCHRPReport 230, Transportation Research Board, Washington, D.C. , 1981.

Ray03 Ray, M. H., J. A. Weir, J. A. Hopp, "In-Service Performance of Traffic Barriers," National Cooperative Highway Research Program Report No. 490, National Academy of Sciences, Washington, D.C., 2003

Ross93 H. E. Ross, Jr., D. L. Sicking, R. A. Zimmer and J.D. Michie, "Recommended Procedures for the Safety Performance Evaluation of Highway Features," Report 350, National Cooperative Highway Research Program, Transportation Research Board, Washington, D.C., 1993.

VDOT14 Appendix B VDOT Acceptance of Materials, Inventory Tracking Program and Manual of Instructions, accessed online http://www.virginiadot.org/business/resources/bu-mat-PaveMarkAppB.pdf, undated, accessed December 12, 2014.