Sign Effectiveness Guide

October 2016

Iowa LTAP
Local Technical Assistance Program

IOWA STATE UNIVERSITY
Institute for Transportation

Sponsored by
Iowa Highway Research Board
(IHRB Project TR-686)
Iowa Department of Transportation
(InTrans Project 15-527)

About Iowa LTAP

The mission of the Iowa Local Technical Assistance Program (LTAP) is to foster a safe, efficient, and environmentally sound transportation system by improving skills and knowledge of local transportation providers through training, technical assistance, and technology transfer, thus improving the quality of life for Iowans.

About InTrans

The mission of the Institute for Transportation (InTrans) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, reliability, and sustainability while improving the learning environment of students, faculty, and staff in transportation-related fields.

Disclaimer Notice

Non-Discrimination Statement

Iowa Department of Transportation Statements

The preparation of this report was financed in part through funds provided by the Iowa Department of Transportation through its "Second Revised Agreement for the Management of Research Conducted by Iowa State University for the Iowa Department of Transportation" and its amendments.

Technical Report Documentation Page

1. Report No.	**2. Government Accession No.**	**3. Recipient's Catalog No.**	
IHRB Project TR-686			
4. Title and Subtitle Sign Effectiveness Guide		**5. Report Date** October 2016	
		6. Performing Organization Code	
7. Author(s) David Veneziano (orcid.org/0000-0002-1578-9564) and Keith Knapp (orcid.org/0000-0002-8790-7304)		**8. Performing Organization Report No.** InTrans Project 15-527	
9. Performing Organization Name and Address Iowa Local Technical Assistance Program Iowa State University 2711 South Loop Drive, Suite 4700 Ames, IA 50010-8664		**10. Work Unit No. (TRAIS)**	
		11. Contract or Grant No.	
12. Sponsoring Organization Name and Address Iowa Highway Research Board Iowa Department of Transportation 800 Lincoln Way Ames, IA 50010		**13. Type of Report and Period Covered** Guide	
		14. Sponsoring Agency Code IHRB Project TR-686	
15. Supplementary Notes Visit www.intrans.iastate.edu for color pdfs of this and other research publications.			

16. Abstract

A large number of sign installation decisions based on engineering judgment are allowed by the *Manual on Uniform Traffic Control Devices for Streets and Highways* (the MUTCD). The information needed to make these installation decisions is based on a number of factors (e.g., MUTCD content, measured sign effectiveness). At the same time, signing represents a significant investment for transportation agencies.

The purpose of this project was to compile information on sign effectiveness and impacts (while also attempting to define the robustness and applicability of research results), as well as guidance on the installation, maintenance, and removal of signs to aid in decision-making. Tis guide includes a literature review, which critically evaluated, summarized, and rated existing research on a variety of static and/or enhanced regulatory and warning signs; an overview of sign removal considerations; a review and summary of sign installation, management, and maintenance components; and, a description of legal considerations in Iowa connected to traffic control devices that was acquired. Material was found, reviewed, and summarized for the following signs: stop, yield, speed limit, horizontal alignment warning (e.g., chevrons, curve warning), playground, children at play, deer crossing, ice warning, road may flood, and enhanced stop, unsignalized intersection conflict warning, and signalized intersection advance warning systems.

Based on the work completed during the project, it was concluded that the impacts of very few commonly used static signs have been studied and documented—to any great extent—with an approach that would meet the current state-of-the-practice for highly robust research results. However, this does not mean that a sign is not effective in the accomplishment of its various objective(s), including notification to drivers and increased awareness of regulations or hazards essential to roadway safety and operations.

Maintenance and management activities are also critical to ensuring that signs continue to meet the objectives that they were installed to accomplish. In addition, the legal information provided to the research team about traffic control devices indicated that, once a traffic control device has been installed, the jurisdiction must properly and adequately maintain it. The information summarized in this guide should be of value during sign-related decision-making based on engineering judgment on a case-by-case basis.

17. Key Words		**18. Distribution Statement**	
crash mitigation—intersection safety—local road safety—safety countermeasures—sign installation—sign removal—traffic sign effectiveness		No restrictions	
19. Security Classification (of this report)	**20. Security Classification (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified	Unclassified	108	NA

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

SIGN EFFECTIVENESS GUIDE

October 2016

Principal Investigator
Keith Knapp, Director
Iowa Local Technical Assistance Program, Iowa State University

Authors
David Veneziano and Keith Knapp

Sponsored by
Iowa Highway Research Board
and Iowa Department of Transportation
(IHRB Project TR-686)

Preparation of this guide was financed in part
through funds provided by the Iowa Department of Transportation
through its Research Management Agreement with the
Institute for Transportation
(InTrans Project 15-527)

A guide from
Iowa Local Technical Assistance Program
and Institute for Transportation
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-8103 / Fax: 515-294-0467
www.intrans.iastate.edu

Contents

Figures

Tables

Acknowledgments

This project was sponsored by the Iowa Highway Research Board and the Iowa Department of Transportation (DOT). The authors want to thank the technical advisory committee members—Nicole Fox of the Iowa DOT Office of Local Systems, Mills County Engineer Kevin Mayberry, Greene County Engineer Wade Weiss, and Kurtis Younkin of the Iowa DOT Office of Traffic and Safety—for their guidance and participation on this project.

Executive Summary

A large number of sign installation decisions based on engineering judgment are allowed by the *Manual on Uniform Traffic Control Devices for Streets and Highways* (the MUTCD). The information needed to make these decisions can depend on the content of the MUTCD, field characteristics, and a knowledge of the expected impact of a particular sign on human behavior, traffic operations, and/or roadway safety, among other things.

Signing represents a significant investment for all government agencies, and this has become more obvious with the requirement to implement an assessment and management plan for the maintenance of minimum sign retroreflectivity. The amount of sign replacement (due to retroreflectivity requirements) will is likely increase, and, as a result, a need existed to summarize the available information on the effectiveness, installation, maintenance, and removal of signs, in general.

The goals of this project were to compile information on sign effectiveness and impacts (while also considering the robustness of research results) and provide guidance on the installation, maintenance, and removal of signs.

The work summarized in this guide included the collection and review of information on sign effectiveness, including the purpose of each sign, relevant information from the MUTCD, potential safety, operational and/or behavioral impacts as identified by past research, alternatives (increased enforcement, pavement markings, etc.) that could be considered in lieu of a particular sign, and removal suggestions. This review also included an assignment by the research team of the robustness of the research results.

This guide also includes information about the different aspects that may factor into sign installation and maintenance: sign program policies, approaches to sign inventories, retroreflectivity requirements, and additional signing considerations. A summary of legal information related to traffic control devices in Iowa was also obtained and is provided in an appendix. Finally, *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties* was reviewed to identify content that may need to be updated.

The MUTCD provides standards, guidance, options, and support information that is used to install and maintain traffic control devices (TCDs) on all roadways open to public travel. It applies to the determination and use of traffic control devices, including signs, in the state of Iowa. The purpose of TCDs is to "…promote highway safety and efficiency by providing for the orderly movement of all road users." In addition, the function of TCDs, and particularly signs, is to notify roadway users of regulations and/or to provide them with warning and guidance (FHWA 2012). In this context, signs play a critical role along roadways, and their proper use is essential in garnering the respect and compliance of drivers. The overuse of signs can lead drivers to disregard them.

During the course of this work, published safety and operational research documentation about 11 static and enhanced signs was reviewed, summarized, and rated. The researchers documented the following static or enhanced signs and warning systems in this guide: stop, yield, speed limit, horizontal alignment warning (e.g., chevrons, curve warning), playground and children at play, deer crossing, ice warning, road may flood, and enhanced stop, unsignalized intersection conflict warning, and signalized intersection advance warning.

The research team also rated the research results for these different signs to characterize the level of confidence placed on the robustness of the findings. The safety research ratings were based on the star rating approach employed by the Crash Modification Factors (CMF) Clearinghouse. A similar approach was also used to rate operational research and focused on how rigorous the analysis was and the application value of the results. In both cases, studies were assigned Low, Medium, or High ratings to provide a subjective measure of the research-based value of the results from each particular study.

The research documentation that focused on the safety and operational impacts of the 11 signs showed a wide variety of results. The ratings assigned to the studies were provided to address this characteristics in the results and provide more guidance to the users of this information. For example, safety research on the use of speed limit signs were of Low and Medium robustness, with one study finding crash rates increased as speed variability increased, another finding crash rates rose following increases or decreases in posted speed limits, and a third finding no evidence that crash experience changed with increases or decreases in posted speed limits. Operationally, only one study of Medium robustness was identified, which found little to no evidence that driver speeds changed when speed limits were increased or decreased.

A review of Iowa county signing policy content found that the sign assessment or management approaches used included the calibration signs assessment method and the expected sign life management method. (Other methods are also employed in Iowa, but were not used among the agencies summarized.) Additional county policy content discussed sign inspection and replacement, and inventory.

Sign inventory methods available to agencies range from simple (paper or spreadsheet-based files) to sign management software. Regardless of the inventory approach used, a critical component is the tracking of sign retroreflectivity characteristics/condition.

Local agencies are required to have a sign assessment or management method in place and implemented to track retroreflectivity to meet those minimums. Retroreflectivity includes the phenomenon of a vehicle's headlights striking a sign and being redirected back to the driver. At present, the MUTCD provides guidance on a number of methods that can be used to meet established retroreflectivity requirements for signs. Assessment methods include the calibration signs procedure, the comparison panels procedure, the consistent parameters procedure, and direct retroreflectivity measurement. Management methods include expected sign life, blanket replacement, control signs, and combinations of methods Additional signing considerations are also discussed in the text and include general maintenance for signs, such as cleaning and repair.

A legal opinion on the use and maintenance of traffic control devices was also obtained, it is included in its entirety in an appendix, and users are encouraged to review it. The information provided indicated that once a traffic control device has been installed, the jurisdiction must properly and adequately maintain it, which appears to support what has been generally understood about traffic control installation and maintenance in Iowa. Understanding the content and details of the information provided is valuable; however, it is also important to confirm its validity and potential updates with jurisdictional legal counsel after the publication of this guide when sign-related decision-making is occurring. The MUTCD, with a few changes, is the accepted document for the application of traffic control devices in Iowa.

Several conclusions and recommendations were developed based on the tasks completed during this project. The review of past research found that very few traditional static signs that are used on a regular basis have had their safety (e.g., crash frequency or severity), operational (e.g., speed), and/or driver behavior (e.g., increased attention or compliance) impacts rigorously studied. A lack of research in one or more of these areas with respect to the effectiveness of a particular sign, however, does not mean that that it cannot accomplish its objective(s), including driver notification and increased awareness of regulations or hazards essential to the safety and operations of the transportation system.

A number of static and enhanced signs are currently being studied, and it is expected that many more will be in the future (particularly with the relatively new driver behavior databases being created). The information summarized in this guide, along with new results as they are published, should be of value during sign-related decision-making, based on engineering judgment on a case-by-case basis. The researchers recommend that the ratings and research results detail (which are also included in quick reference tables in an appendix) be considered in combination when applied during sign-related decision-making.

The researchers also recommend that future studies should evaluate the safety and operational effectiveness of various signs in a rigorous manner. This includes work that is comprehensive in terms of the analysis methodology employed, the location and number of sites studied, the duration of the study period, etc. Ideally, these evaluations should occur at a variety of locations (i.e., urban and rural), and at a large enough number of sites to develop sound statistical conclusions regarding sign impacts.

The literature review showed that there is little information or documentation about sign removal methodologies. The researchers propose that a policy investigation be completed to evaluate and synthesize more information about sign removal processes. This investigation should include documentation of the processes employed leading up to sign removal, as well as a safety and operational analysis of the changes that occur. An investigation and creation of sample sign removal policies for different sign or traffic control types may also be appropriate. The researchers recommend that any sample sign removal policies created be reviewed by legal counsel.

Chapter 1. Introduction

A large number of sign installation decisions based on engineering judgment are allowed by the *Manual on Uniform Traffic Control Devices for Streets and Highways* (the MUTCD). The information needed to make these sign installation decisions can depend on, among other things, the content of the MUTCD, field characteristics, and a knowledge of the expected effectiveness of a particular sign on human behavior, traffic operations, and/or roadway safety. The absence of one or more of these pieces of information may result in signs that have been installed but may not be necessary, or missing signs at locations where they might be needed.

Traffic signing is also a significant investment for all governmental agencies. In addition, the significance of this investment has become more obvious with the need for public agencies to implement an assessment and management plan for the maintenance of minimum sign retroreflectivity.

Several approaches can be used for these sign assessment and management plans (which are explained later in this guide) and their application will likely increase the amount of sign replacement that occurs. Therefore, a need existed for decision-making guidance that summarizes the information available about the installation and maintenance of roadway signs, along with any documented research on their effectiveness.

Purpose and Use of Document

Development of this guide had several purposes. These included compiling the information available on sign effectiveness and/or impacts, while also considering the value and applicability of research results. This guide includes a critical evaluation and summary of the documented safety, operational, and/or behavioral research for a variety of signs used by local public agencies in Iowa. It also presents information on sign installation, maintenance, removal, and alternatives.

This guide, along with the MUTCD and field evaluation, can be used by transportation professionals during their determination about whether a particular sign can be expected to produce an impact on safety and/or operations. In doing so, agencies may be able to better manage their sign installation and maintenance budgets. The information provided in this guide is focused on the needs of local roadway agencies, but it is also relevant to many other users.

MUTCD Introduction

The MUTCD, which is issued by the Federal Highway Administration (FHWA), defines the standards, guidance, options, and support used to install and maintain traffic control devices (TCDs), including signs, along all roads open to public travel. The purpose of TCDs is to "promote highway safety and efficiency by providing for the orderly movement of all road users." (FHWA 2012) In addition, the function of TCDs, and particularly signs, is to notify roadway users of regulations and/or to provide them with warning and guidance (FHWA. 2012). In this context, signs play a critical role along roadways, and their proper use is essential in commanding the respect and compliance of drivers. The overuse of signs, however, can lead to disregard on the part of drivers.

The current edition of the MUTCD was published in 2009 and revised in 2012. It incorporates several changes with compliance dates attached to them. Some of the most notable are the compliance items related to signs (listed in Table I-2 of the MUTCD), which include the provision to implement an assessment or management method to maintain minimum sign retroreflectivity and the replacement of those regulatory and warning signs that do not meet requirements (FHWA 2012).

The MUTCD, with one exception, applies within the state of Iowa (per Iowa Code Title VIII, Subtitle 2, Section 321.252) (Iowa Code 2015a). The one exception in Iowa pertains to the use of portable (roll-out) stop signs in school zones. Iowa Code Title VIII, Subtitle 2, Section 321.249 in part states that "…[a]ll traffic-control devices provided for school zones shall conform to specifications included in the manual of traffic-control devices adopted by the department, except the provision prohibiting the use of portable or part-time stop signs." (Iowa Code 2015b) It also indicates that they can only be used at the limits of school zones.

The remainder of this guide is largely based on the content of the MUTCD.

Document Content

Chapter 1 provides an introduction and an overview of the need for this guide to cover the installation, maintenance, and effectiveness of signs.

Chapter 2 presents information on sign effectiveness including safety and operational and/or behavioral impacts as identified by past research and a rating of the robustness of that past work.

Chapter 3 describes some of the more important aspects that may factor into a sign program. These aspects include sign installation and maintenance policies, approaches to sign inventories, retroreflectivity requirements, and additional signing considerations.

Chapter 4 describes the content of a letter acquired that focuses on a legal interpretation of Iowa Tort Law as it applies to traffic control devices. (This letter is included in Appendix F.)

Chapter 5 presents conclusions that were drawn from the information presented throughout the guide, along with recommendations on how the content of this guide might be used, as well as future research recommendations.

Chapter 5 is followed by a Master References List for this guide and seven appendices:

A. Summary Tables of Sign Studies
B. Clinton County, Iowa Sign Policy
C. Woodbury County, Iowa Sign Policy
D. Sample National Association of County Engineers Sign Policy
E. Retroreflectometer Guide
F. Traffic Control Devices – Understanding Liability from the Perspective of a Municipality

G. *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties*

A cursory review of *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties* was completed to identify content that might need to be updated due to changes in the MUTCD that have occurred between the time the Iowa manual was published and today. The information that may need to be updated is the content presented in Appendix G.

References

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

Iowa Code. 2015a. *State of Iowa Code. 321.252, Department to Adopt Sign Manual. Title VIII, Subtitle 2, Section 321.252, Motor Vehicles and Law of the Road*. Des Moines, IA.

Iowa Code. 2015b. *State of Iowa Code. 321.249, School Zones Title VIII, Subtitle 2, Section 321.249, Motor Vehicles and Law of the Road*. Des Moines, IA.

Chapter 2. Sign Applications and Research Results

This chapter includes an overview and summary of the application and documented crash reduction and/or operational impacts of a variety of regulatory and warning signs. The following information, if available, is provided for each sign:

- Purpose, use, and installation information (from the MUTCD and other references)
- Safety (e.g., crash frequency, crash type, crash severity) impact research results
- Operational (e.g., driver behavior such as vehicle speed or red-light-running, travel time savings) impact research results
- Alternatives

The information is provided in a summary format that is intended to allow for quick review to assist users in their decision-making process for each sign of interest. This chapter provides summaries only for signs that may be used regularly by local transportation agencies and have been the focus of published safety and/or operational impact research.

Note that very few of the traditional static signs that are used on a regular basis have had their safety, operational, and/or driver behavior impacts rigorously studied. Users also referred to the current MUTCD for additional information about the signs summarized in this chapter and for those that have not been studied in any manner.

The lack of rigorous research about a sign does not mean that it is not effective, does not have an impact, or is not needed. Best practices, engineering judgment, driver expectations, and a need to raise drivers' attention or awareness to a situation are just some of the other reasons for roadway signs. In addition, an increase in driver attention or awareness may or may not have an impact on their actions (e.g., vehicle speed), and can be a difficult aspect of signing to study.

Sign Usage and Application

The MUTCD identifies those signs that "shall" be installed along with those that "should" or "may" be used (i.e., those for which usage is more discretionary). If a decision is made to install those that "should" or "may" be used, however, most have to be installed in a consistent manner required by the MUTCD (FHWA 2012). The application of regulatory and warning signs are described in Part 2 of the MUTCD. The regulatory and warning signs that the MUTCD indicates "shall" be installed are identified below. It should be recognized, however, that just because the MUTCD allows some discretion in the installation of a signs does not mean they are not effective in their purpose or unnecessary, or that the driving public does not expect them along the roadway. It simply means that the MUTCD has allowed some engineering discretion in their application.

The MUTCD indicates four regulatory signs that "shall" be installed. These signs include the speed limit sign (within an established speed zone), one way/do not enter sign, turn prohibition sign, and all-way stop plaque. These signs need to be installed at particular locations in relevant situations. The remaining regulatory signs that exist, such as stop, yield, no parking, etc. "should" or "may" be installed based on agency policy, engineering studies, engineering judgment, or other considerations. Guidance for these decisions is provided in the MUTCD, and through the content of this guide.

Four warning signs "shall" also be installed according to the MUTCD. These signs include the railroad crossing, low clearance, advance traffic control (when limited sight distance is present), and no train horn signs (FHWA 2012). These signs "shall" be used at particular locations in relevant situations. The remaining warning signs "should" (e.g., lane ends, divided highway) or "may" (e.g., no passing pennants, chevrons) be based on engineering judgment or studies (FHWA 2012). Similar to some regulatory signs, the remaining warning signs "should" or "may" be installed based on established agency policy, engineering study, engineering judgment, or other considerations.

Overall, the MUTCD allows a significant amount of engineering judgment, discretion, and flexibility in the installation of signs. The authors of this guide recommend that the decisions to install these types of signs should be documented to have a record of the decision-making process and rationale, in case questions arise in the future about the continued value of the sign.

Table 1 provides a list of some of the most common signs used along local roads in Iowa, along with a summary of whether the signs are required in some manner by the MUTCD and whether they have been studied for safety or operational impacts.

Table 1. MUTCD requirement for and research on common signs in Iowa

Sign	MUTCD Requirement	Safety Study	Operations Study
Stop	X	X	X
Yield		X	X
Speed Limit	X		X
Chevron	X*	X	X
Curve Warning	X*	X	
Advisory Speed Plaque	X*	X	X
Playground or Children at Play			X
Deer Crossing		X	X
No Passing Zone			
Do No Pass			
Large Arrow	X*		
Road Narrows			
Narrow/One-Lane Bridge			
Pavement Ends			
Signal Ahead/Be Prepared to Stop	X*		
Stop/Yield Ahead	X*		
Speed Reduction			

* Based on specific site conditions. See the current MUTCD for additional details.

Results Rating System

An opinion about our confidence in the signing research results is included in this chapter for each of the studies reviewed (with additional study details listed in tables in Appendix A). The authors recommend that users review appendix material during their decision-making to determine if the sites studied (rural or urban, number of lanes, etc.) are similar to their location.

The authors rated research results for both safety and operational studies, if they exist, as Low, Medium, or High for confidence in their application value. Application of the different research results for a sign's effectiveness should take into account not only the rating of the study, but also how the site characteristics that were examined compare to those where a sign is being considered. The next sections discuss the approaches used to assign the ratings.

Safety Research Ratings

The safety research (crash frequency, severity, etc.) ratings were developed based on the star assigned in the Crash Modification Factors (CMF) Clearinghouse (FHWA 2016a). The clearinghouse assigns a star value from zero to five to the safety results of research that evaluates crash impacts (e.g., reductions or increases) of various safety improvements (e.g., turn lanes, signs, rumble strips).

For studies summarized in this guide that have not been rated by the CMF Clearinghouse, the authors employed their own judgment by considering the same factors as those used by the clearinghouse. These factors include study design, sample size, standard error, potential bias, and data source (FHWA 2016a). Additional details are provided on the clearinghouse website at www.cmfclearinghouse.org/sqr.cfm. As noted on the website, this approach requires judgment and some subjectivity on the part of the authors. The safety study results summarized in this guide were assigned the following levels of confidence:

Low – 0 or 1 star rating in the CMF Clearinghouse or with the authors' application. The use/application of these results should be with caution and probably only when no other studies of higher quality exist.

Medium – 2 or 3 star rating in the CMF Clearinghouse or with the authors' application. The use/application of these results are best applied to sites with similar characteristics.

High – 4 or 5 star rating in the CMF Clearinghouse or with the authors' application. The results from this type of study, when appropriate, can have wide applications.

Operational Research Ratings

The authors also created a rating system for the operational results (speed changes, etc.) summarized. In this case, the focus of the rating was based on how rigorous the analysis was and that application value of the results. The authors considered the following factors: number of sites examined, characteristics of the sites (e.g., all rural, all urban, or mix of rural and urban), and whether and which type of statistical analysis was performed. Based on these considerations, the authors assigned the following ratings to the results of the operational research summarized:

Low – Limited number and/or low site-characteristic diversity (e.g., only urban or rural locations considered) and no statistical evaluation performed. The use/application of these results should be with caution and probably only when no other studies of higher quality exist.

Medium – Small number of sites and/or low site-characteristic diversity (e.g., only urban or rural locations), but rigorous statistical evaluation performed. As with all research, the use/application of these results are best applied to sites with similar characteristics.

High – Multiple sites with a diversity of site characteristics (e.g., urban and rural locations) and a rigorous statistical evaluation. The results from this type of study, when appropriate, can have wide applications.

The intent of these ratings is to provide the user with a subjective measure of confidence in the results of a particular study. These levels of confidence should be taken into account when the results are being considered for use at a given site.

References

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

FHWA. 2016a. Crash Modification Factors Clearinghouse. Federal Highway Administration, U.S. Department of Transportation, Washington, DC. www.cmfclearinghouse.org/sqr.cfm.

Static Signs – Regulatory

The static signs described in this section have research documentation for them and the information included is for the signs without being electronically enhanced (e.g., with beacons) to increase their conspicuity. However, information on the signs may include the signs being enhanced with pennants or flags:

- Stop signs
- Yield signs
- Speed limit signs

Stop Signs

Purpose, Use, and Installation

Stop signs (R1-1) (as shown in Figure 1) are a traffic control option that is installed for various reasons (sight-distance restrictions, high traffic volumes, etc.) as summarized in the MUTCD. Stop signs are used to control movements at intersections where it has been determined that a full stop on an approach or the approaches is required (FHWA 2012).

David Veneziano, Iowa LTAP

Figure 1. Stop sign

Sections 2B.04 through 2B.07 of the MUTCD describe the use of stop signs. In the MUTCD, the conditions and criteria where stop signs should be considered are noted, but the user is also cautioned that the overuse of stop signs can disrupt traffic flow, increase delay, fuel use and pollution, and possibly lead to noncompliance by drivers (FHWA 2012). The MUTCD also notes that stop signs should not be used for speed control, and studies have supported this conclusion (Beaubien 1976 and 1989).

Stop sign use should be based on a need to enforce right-of-way, maintenance of through traffic flow, context (e.g., proximity to other intersections), entering volumes (including vehicles, bikes, and pedestrians), available sight distance, and crash history (FHWA 2012). Additionally, the MUTCD indicates that stop signs should be used at intersections if one or more of the following conditions exist:

- An intersection of a less important road with a main road where application of the normal right-of-way rule would not be expected to provide reasonable compliance with the law
- A street entering a designated through highway or street
- An unsignalized intersection in a signalized area
- The combined vehicular, bicycle, and pedestrian volume entering the intersection from all approaches averages more than 2,000 units per day
- The ability to see conflicting traffic on an approach is not sufficient to allow a road user to stop or yield in compliance with the normal right-of-way rule if such stopping or yielding is necessary
- Crash records indicate that five or more crashes that involve the failure to yield the right-of-way at the intersection under the normal right-of-way rule have been reported within a 3-year period, or that three or more such crashes have been reported within a 2-year period (FHWA 2012)

Safety Effectiveness

Several studies have been completed that focused on the safety impacts of two-way stop controlled and all-way stop-controlled intersections (Beaubien 1976 and 1989, Stockton et al. 1981). The results of these studies are summarized below along with the confidence we have in their results. Table A.1 of Appendix A includes additional details about the studies.

- Increasing the level of control (i.e., yield to stop control) did not significantly reduce crashes at 48 low-volume sites in New York, Texas, and Florida (Stockton et al. 1981). The authors rate this study as having Medium robustness.

- The crash rate of ultra-low volume (in both directions) roadway intersections were not significantly different than those with no control (Souleyrette et al. 2005). The authors rate this study as having Medium robustness.

- The conversion of minor roadway stop control to all-way stop control resulted in a 68.1 percent reduction in total crashes (Simpson and Hummer 2010). The authors rate this study as having High robustness.

- The safety performance of uncontrolled ultra-low volume intersections in terms of crash rate appears to decline compared to all-way stop-controlled intersections above 150 daily entering vehicles (DEV) (Souleyrette et al. 2005). The authors rate this study as having Medium robustness.

Operational Effectiveness

Observational field studies of 48 sites indicated that 19 percent of drivers voluntarily stopped at two- and four-way stop-controlled sites (Stockton et al. 1981). The authors rate this study as having Medium robustness.

Alternatives

Some of the alternatives to stop signs include the following:

- No control
- Yield signs
- Traffic signals
- Traffic calming approaches (bulbouts, roundabouts, minor approach closures, etc.)
- Increased law enforcement

References

Beaubien, R. 1976. Stop Signs for Speed Control? *Traffic Engineering*, Vol. 46, No. 11, pp. 26-28.

Beaubien, R. 1989. Controlling Speeds on Residential Streets. *ITE Journal*, Vol. 59, No. 4, pp. 37-39.

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

Simpson, C. L. and J. E. Hummer. 2010. Evaluation of the Conversion from Two-Way Stop Sign Control to All-Way Stop Sign Control at 53 Locations in North Carolina. *Journal of Transportation Safety and Security*, Vol 2, No. 3, pp. 239-260.

Souleyrette, R., R. Tenges, T. McDonald, and T. Maze. 2005. *Guidelines for Removal of Traffic Control Devices in Rural Areas*. Center for Transportation Research and Education, Iowa State University, Ames, IA.

Stockton, W., R. Brackett, and J. Mounce. 1981. *Stop, Yield, and No Control at Intersections*. Texas Transportation Institute, College Station, TX.

Yield Signs

Purpose, Use, and Installation

Yield signs (as shown in Figure 2) control movements at intersection approaches where drivers must prepare to stop if necessary to yield the right-of-way (FHWA 2012). Yield signs assign right-of-way on approaches to intersections where drivers need to reduce their vehicle speed to a speed that is reasonable for existing conditions or to stop to avoid interfering with conflicting traffic (FHWA 2012).

David Veneziano, Iowa LTAP

Figure 2. Yield sign

MUTCD Sections 2B.08 and 2B.09 describe the use of yield signs. The MUTCD stresses that yield signs shall not be used at an intersection where stop signs are located on another approach, nor shall they be placed on all approaches to an intersection (with the exception of roundabouts) (FHWA 2012).

The use of yield signs should be based on a need to enforce right-of-way, where maintenance of through traffic flow is needed, context (e.g., proximity to other intersections), entering volumes (including vehicles, bikes, and pedestrians), available sight distance, and crash history (FHWA 2012). Additionally, the MUTCD indicates that yield signs may be used at intersections if one or more of the following conditions exist:

- On the approaches to a through street where conditions are such that a full stop is not always required
- At the second crossroad of a divided highway where the median is 30 feet or greater
- For a channelized turn lane separated from the adjacent travel lanes by an island
- At an intersection where a special problem exists and engineering judgment indicates it correctable by use of a yield sign
- Facing the entering road for a merge-type movement if engineering judgment indicates that control is needed (FHWA 2012)

Safety Effectiveness

Only one study on yield signs and safety was found in the literature search. This study focused on the conversion from stop signs to yield signs. The results are summarized here, and Table A.2 in Appendix A provides additional details.

This study focused on 141 intersections in Pueblo, Colorado; Saginaw, Michigan; and Rapid City, South Dakota that were converted from stop- to yield-control. The study found that these intersections typically experienced an increase in crash frequency, especially at higher traffic volumes (average daily traffic/ADT of 2,000 or greater) (McGee and Blankenship 1989). The expected crash increase due to the conversion was approximately one crash every two years. However, it was noted that crash severity did not appear to change following the stop to yield conversions. The authors rate this study as having Low robustness.

Operational Effectiveness

Limited documentation on the operational impacts of yield signs was identified. One study found that yield signs produced travel time savings greater than stop control or no control at 48 low-volume intersections in Florida, New York, and Texas (Stockton et al. 1981). These savings however, were small, at 2 to 4 seconds per vehicle. The authors rate this study as having Medium robustness.

Alternatives

Some of the alternatives to yield signs include the following:

- No control
- Stop signs
- Traffic signals
- Traffic-calming approaches (e.g., bulbouts, roundabouts, minor approach closure)
- Increased law enforcement

References

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

McGee, H. and M. Blankenship. 1989. *NCHRP Report 320: Guidelines for Converting Stop to Yield Control at Intersections*. National Cooperative Highway Research Program, Washington, DC.

Stockton, W., R. Brackett, and J. Mounce. 1981. *Stop, Yield, and No Control at Intersections*. Texas Transportation Institute, College Station, TX.

Speed Limit Signs

Purpose, Use, and Installation

The purpose of a speed limit sign (R2-1) (as shown in Figure 3) is to provide drivers with information about the speed limit established by law, ordinance, or regulation or as adopted by an authorized agency based on an engineering study (FHWA 2012). Speed limits are posted as statutory limits that are established by state code, or regulatory limits established by the authorities responsible for the roadway.

In general, research completed on vehicular speeds typically indicates that speed variability is what has an impact on crashes (Solomon 1964). The objective, therefore, is to have a speed limit that represents the speed at which most vehicles are traveling (e.g., the 85th percentile speed) (Forbes et al. 2012). The physics of vehicular travel, however, does support the idea that higher speeds result in a higher severity of crashes (Forbes et al. 2012).

MUTCD

Figure 3. Speed limit sign

Speed limit signs are discussed in Section 2B.13 of the MUTCD. Maximum speed limits for rural and urban areas are established either statutorily (a maximum speed limit applicable to a particular class of road, such as a freeway or city street) or as altered speed zones (e.g., based on engineering studies) (FHWA 2012).

In Iowa, the statutory speed limits for paved roadways are 20 miles per hour (mph) in business districts, 25 mph in residential and school districts, 45 mph in suburban districts, 55 mph during the day and 50 mph at night on rural highways (which are also the highest reasonable and proper speed limits on unpaved, secondary roads between sunrise and sunset), 65 mph on selected multilane highways and 70 mph on interstates (Iowa DOT n.d.).

The MUTCD states that "…[s]peed zones (other than statutory speed limits) shall only be established on the basis of an engineering study… and shall include an analysis of the current speed distribution of free-flowing vehicles" (FHWA 2012). It further states that speed limit signs shall be posted at locations where posting is required by law and:

- Posting is required by law;
- At the points of change from one speed limit to another;
- At the downstream end of a the section to which the speed limit applies;

- Beyond major intersections or where necessary to remind road users of the speed limit;
- At the entrances to the State and, where appropriate, at jurisdictional boundaries in urban areas.

Speed zones are established on the basis of an engineering study that has included an analysis of the current speed distribution of free-flowing vehicles (FHWA 2012). Such engineering studies can consider the 85th percentile speed (the speed that 85 percent of observed drivers are driving at or below), risk on a segment (consideration of segment/site characteristics and/or crash history), optimal speeds (speed limit to yield a minimum total cost to society), or injury minimization (consideration of the tolerance of the human body to injury during a crash) (Forbes et al. 2012).

Safety Effectiveness

The authors didn't find any documented research studies on the safety or crash impacts due to just the existence or implementation of a speed limit sign (e.g., a before-and-after analysis of nearby crashes with and without a speed limit sign). This conclusion was supported by the *Highway Safety Manual*, which listed regulatory signs, such as speed limit signs, as one of the treatments with unknown crash effects (AASHTO 2010).

The non-interstate studies that have looked at the impacts to changes in speed limits have produced conflicting results (Wilmot and Jayadevan 2006, Parker 1997, Preston et al. 1998). In one case (Preston et al. 1998), the study focus was not on the impact of speed limit signs and their implementation, and included confounding factors that could have impacted the results. Generally, as speed variability increases, crashes (and crash severities) increase. The confidence we have in the results of related research studies are noted below. Table A.3 of Appendix A includes additional details about each study.

- A study of speed variability shows that crash involvement is lowest at speeds slightly above average traffic speeds (Solomon 1964). Total crash rates increase as the variability in vehicle speeds increase and/or an individual vehicle deviates from the typical roadway speeds (Solomon 1964). The authors rate this study as having Low robustness.

- Along two-lane rural highways, another study (statewide in Louisiana) found that the average crash rate (per 100 million vehicle miles traveled) following speed limit changes rose from 21.06 to 37.92 (Wilmot and Jayadevan 2006). In addition, the total number of crashes for run-off-the-road and rear-end crash injuries, along with run-off-the-road, rear-end, and property-damage-only crashes increased following different speed limit increases. The authors rate this study as having Medium robustness.

- A study along a combination of urban and rural roadways in 22 states found no evidence that crash experience changes with posted increases or decreases (Parker 1997). The authors rate this study as having Medium robustness.

Again, none of these results are included in the current *Highway Safety Manual*, but it is currently being updated and new research may address the current knowledge gaps that exist with regard to speed limit signs.

Operational Effectiveness

From an operational and human behavior point of view, it can be assumed that drivers need regular postings of the speed limit and/or may not know the statutory speed limit along a particular roadway.

Results of a speed variability study using data from 98 sites in 22 states indicated little to no evidence that driver speeds change when a speed limit is raised or lowered (Parker 1997). The changes in speed limits considered were reductions of 5, 10, 15, or 20 mph and increases of 5, 10, and 15 mph. When sites were grouped by the amount of speed limit change, the differences in percentile speeds for each speed group were less than 1.5 mph, regardless of whether the speed limit was raised or lowered. The authors rate this study as having Medium robustness.

Alternatives

No alternatives to static speed limit signs were found. Enhancements, however, might be the addition of flashing beacons or deployment of changeable message signs or radar-actuated speed-feedback signs that can be used as a reminder of actual speed and/or the speed limit at a particular location. Some of these enhancements are portable and those that can be installed often also include the static speed limit sign.

References

AASHTO. 2010. *Highway Safety Manual (HSM).* 1st Edition. American Association of State Highway Officials, Washington, DC.

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways.* 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

Forbes, G. J., T, Gardner, H. McGee, and R, Srinivasan. 2012. *Methods and Practices for Setting Speed Limits: An Informational Report.* Federal Highway Administration Office of Safety and Institute of Transportation Engineers, Washington, DC.

Iowa DOT. No date. *Speed Limit Questions? Here's Your Answer.* Iowa Department of Transportation Office of Traffic and Safety, Ames, IA.

Parker, M. R., Jr. 1997. *Effects of Raising and Lowering Speed Limits on Selected Roadway Sections*. FHWA-RD-97-084, Federal Highway Administration, Research and Development, Turner-Fairbank Highway Research Center, McLean, VA.

Preston, H., R. Newton, D. Keltner, and C. Albrecht. 1998. *Statistical Relationship Between Vehicular Crashes and Highway Access.* MN/RC-1998-27. Minnesota Department of Transportation, St. Paul, MN.

Solomon, D. 1964. *Accidents on Main Rural Highways Related to Speed, Driver, and Vehicle.* Traffic Systems Research Division, Office of Research and Development, U.S. Department of Commerce, Bureau of Public Roads, Washington, DC.

Souleyrette, R., R. Tenges, T. McDonald, and T. Maze. 2005. *Guidelines for Removal of Traffic Control Devices in Rural Areas.* Center for Transportation Research and Education, Iowa State University, Ames, IA.

Wilmot, C. G. and A. S. Jayadevan. 2006. *Effect of Speed Limit Increase on Crash Rate on Rural Two-Lane Highways in Louisiana*. Technical Assistance Report No. 07-1TA. Louisiana Transportation Research Center, Louisiana State University, Baton Rouge, LA.

Static Signs – Warning

The following warning signs are described in this section:

- Horizontal alignment warning signs
- Playground and children at play signs
- Deer crossing sign
- Ice warning sign
- Road may flood warning signs

Horizontal Alignment Warning Signs

Purpose, Use, and Installation

Horizontal alignment warning signs include curve warning, chevron, and advisory speed plaque signs see Figure 4).

David Veneziano, Iowa LTAP (left) and Bob Sperry, Iowa LTAP (right)

Figure 4. Curve warning and advisory speed plaque (left) and chevron signs (right)

Curve warning and chevron signs (W1-1 through W1-11 and W1-15) are used to advise drivers of a change in horizontal roadway alignment. Curve warning and chevron signs should be used to warn of a horizontal alignment change along a roadway, particularly when that change may not be readily apparent to approaching drivers. Advisory speed plaques may be used at horizontal curves to supplement warning signs and provide notice of the determined curve advisory speed. Advisory speed plaques may also be used in conjunction with a wide variety of other warning signs.

MUTCD Sections 2C.06 through 2C.15 specifically discuss the use of different combinations of curve warning and chevron signs. Section 2C.08 discusses the use of advisory speed plaques. MUTCD Table 2C-5 includes recommendations, requirements, and options for horizontal alignment sign installations. The information from these tables is summarized in Table 2.

Table 2. Horizontal alignment sign selection guidance

Type of Horizontal Alignment Sign	Difference Between Speed Limit and Advisory Speed				
	5 mph	10 mph	15 mph	20 mph	25 mph or more
Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), Winding Road (W1-5), and Combination Horizontal Alignment/Intersection (W10-1) (see Section 2C.07 to determine which sign to use)	Recommended	Required	Required	Required	Required
Advisory Speed Plaque (W13-1P)	Recommended	Required	Required	Required	Required
Chevrons (W1-8) and/or One Direction Large Arrow (W1-6)	Optional	Recommended	Required	Required	Required
Exit Speed (W13-2) and Ramp Speed (W13-3) on exit ramp	Optional	Optional	Recommended	Required	Required

Required = The sign and/or plaque shall be used
Recommended = The sign and/or plaque should be used
Optional = The sign and/or plaque may be used
See Section 2C.06 for roadways with less than 1,000 ADT

Source: MUTCD Table 2C-5 (FHWA 2012)

Additional factors to consider in the installation of these signs include traffic volume, functional classification, 85th percentile speeds, and engineering judgment (FHWA 2012).

Section 2C.06 in the MUTCD for horizontal alignment signs indicates that these signs shall be installed "In advance of horizontal curves on freeways, on expressways, and on roadways with more than 1,000 AADT that are functionally classified as arterials or collectors, horizontal alignment warning signs shall be used in accordance with Table 2C-5 based on the speed differential between the roadway's posted or statutory speed limit or 85th-percentile speed, whichever is higher, or the prevailing speed on the approach to the curve, and the horizontal curve's advisory speed. Horizontal alignment warning signs may also be used on other roadways or on arterial and collector roadways with less than 1,000 AADT based on engineering judgment." (FHWA 2012) The application of Table 2C-5 content to roadways that don't meet the functional class or volume requirements noted above is advisory, but is still considered the best information for horizontal alignment sign installation available. It should also be noted that the MUTCD also requires an engineering study for the proper determination of curve advisory speeds (FHWA 2012). In addition, the technologies and accepted engineering practice for this application have changed over time (see Section 2C.08 of the MUTCD).

Safety Effectiveness

A number of studies have focused on the safety impacts related to the installation of curve warning signs, chevrons, and/or advisory speed plaques. The robustness of these studies varies as noted below, and Table A.4 of Appendix A provides additional details about the studies.

- The installation of curve warning signs and chevrons at 228 locations in Connecticut and Washington produced an 18 percent reduction in injury and fatal crashes, 27.5 percent reduction in nighttime crashes, and 25 percent reduction in nighttime lane-departure crashes (Srinivasan et al. 2009). The authors rate this study as having High robustness.

- The installation of chevrons produced a 50 percent reduction in crash frequency based on a simple before-and-after comparison at three study sites (Lalani 1992). The authors rate this study as having Low robustness.

- A third study also considered the installation of chevrons at 5 sites and showed a 2.6 percent reduction in total crashes; the installation of curve warning signs and chevrons at 6 sites produced a 40.8 percent reduction in total crashes; and finally, the installation of curve warning signs, chevrons, and flashing beacons at 4 sites produced 47.6 percent reduction in total crashes (Montella 2009). The authors rate this study as having Medium robustness.

- Another study was found that focused on the horizontal curve advisory speed plaque impact on crashes. It was determined that they had a positive impact on reducing crashes along two-way, two-lane rural roadways, but the impact was small in comparison to other factors such as traffic volume, horizontal curve length, etc. (Dixon and Avelar 2011). The authors rate this study as having Medium robustness.

- Mendocino County, California, achieved a 42.1 percent reduction in crashes between 1992 and 1998 by an initial installation of curve warning signs (Peaslee 2005). The authors rate this study as having Low robustness.

Note that an ongoing study in Iowa is considering the impacts of the addition of large chevrons and the addition of post-mounted delineators on chevron posts.

Operational Effectiveness

Other studies have also considered the potential vehicle speed impacts of chevrons and speed advisory plaques (generally as a surrogate of increased safety). The results of these studies are summarized below.

- The addition of chevrons at two locations produced an average 1.28 mph reduction in mean vehicle speeds; the installation of chevrons with reflective posts at two different locations produced a 2.20 mph reduction in mean vehicle speeds (Re et al. 2010). The authors rate this study as having Medium robustness.

- The installation of chevrons at five sites produced mean vehicle speed reductions between 0.17 and 4.08 mph, depending on the study site and lane of travel (Chrysler et al. 2009). The authors rate this study as having Medium robustness.

- The use of progressively larger (i.e., 24 by 30, 26 by 32, 27 by 33, 28 by 34, and 30 by 36 inch) chevron signs through curves at two sites produced mean vehicle speed reductions of 0.50 to 1.75 mph during the day and 3.0 mph at night (Bullough et al. 2012). The authors rate this study as having Medium robustness.

- One study found that average horizontal curve speeds exceed the posted advisory speed when the advisory speed was less than 40 mph, but speeds were generally the same as the posted advisory speed when it was at 40 to 50 mph (Ritchie 1972). Overall, another study found that more than 60 percent of drivers exceeded the posted advisory speed at a point approximately one-third of the way into a horizontal curve (Dixon and Avelar 2011). The authors rate both of these studies as having Medium robustness.

Note that these results may be related to the method used to determine the advisory speed and not a conclusion about the human behavior or attention value of advisory speed plaques and their potential impact on roadway safety. One additional point to consider is that just because drivers are not driving at the posted advisory speed does not mean that the sign is wrong; it may mean that the set up was wrong (e.g., a ball bank study with incorrect results used).

Supplemental Alternatives

In most cases, horizontal curve warning signs and chevrons are a basic signing application at a curve. However, a number of treatments can also be implemented to supplement them. These supplemental alternatives include the following:

- Pavement marking using wording and/or directional arrows
- Curve approach rumble strips
- Flags or flashing beacons to enhance existing advance warning signs or additional signs (e.g., on both sides of the roadway) (FHWA 2012)
- Reflective post-mounted delineators on chevron posts

There are no alternatives to advisory speed plaques at horizontal curves.

References

Bullough, J., N. Skinner, J. Brons, and M. Rea. 2012. *Using Lighting and Visual Information to Alter Driver Behavior*. Rensselaer Polytechnic Institute, Rensselaer, NY.

Chrysler, S., J. Re, K. Knapp, D. Funkhouser, and B. Kuhn. 2009. *Driver Response to Delineation Treatments on Horizontal Curves on Two-Lane Roads*. Report FHWA/TX-09/0-5772-1, Texas Transportation Institute, College Station, TX.

Dixon, K and R. Avelar. 2011. *Safety Evaluation of Curve Warning Speed Signs*. Oregon State University, Corvallis, OR.

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

Lalani, N. 1992. Comprehensive Safety Program Produces Dramatic Results. *ITE Journal*, Vol. 61, No. 10, pp. 31-34.

Montella, A. 2009. Safety Evaluation of Curve Delineation Improvements. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2103, pp. 69-79.

Peaslee, G. 2005. Signs Show the Way to Cost-Effective Rural Safety. *Public Roads*, Vol. 68, No. 4.

Re, J., G. Hawkins, and S. Chrysler. 2010. Assessing Benefits of Chevrons with Full Retroreflective Signposts on Rural Horizontal Curves. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2149, pp. 30-36.

Ritchie, M. 1972. Choice of Speed in Driving Through Curves as a Function of Advisory Speed and Curve Signs. *Human Factors*, Vol. 14, No. 6, pp. 533-538.

Srinivasan, R., J. Baek, D. Carter, B. Persaud, C. Lyon, K. Eccles, F. Gross, and N. Lefler. 2009. *Safety Evaluation of Improved Curve Delineation*. Report No. FHWA-HRT-09-045, Federal Highway Administration, Research, Development, and Technology, Turner-Fairbank Highway Research Center, McLean, VA.

Playground and Children at Play Signs

Purpose, Use, and Installation

Resident concerns related to the safety of children and others can sometimes produce requests for playground, children at play, or similar signs (see Figure 5).

MUTCD (left) and St. Mary's County, Maryland (right)

Figure 5. Playground (left) and children at play (right) signs

Requests for these signs are based on the belief that they will alert drivers to the presence of children and increase safety. It has generally been concluded, particularly with the children at play sign, that these types of signs may only provide the perception of increased safety or a false sense of security (CTC & Associates 2007).

The installation of children at play signs is not specifically addressed in the MUTCD. However, the development and installation of a warning sign (with wording not addressed specifically) is allowed (FHWA 2012 Section 2A.06). The general understanding of the impact of these and similar signs are described below, and the MUTCD indicates that "…use of warning signs should be kept to a minimum, as the unnecessary use of warning signs tends to breed disrespect for all signs" (FHWA 2012 Section 2C.02).

The playground warning sign (Figure 5 left) is addressed in Section 2C.51 of the MUTCD. This section of the MUTCD indicates that the playground warning sign should be installed in advance of a designated children's playground. Therefore, the guidance on the installation of this type of sign is for a very specific location. More general information on the application of warning signs is presented in Section 2C.02 (FHWA 2012).

Safety Effectiveness

No documented studies on the attention value and crash or speed impacts of children at play warning signs were found. A synthesis of available information on this subject in the US in 2007 was found; it generally indicated that there was no evidence that these signs were effective (CTC & Associates 2007). However, the published information available generally provided accepted engineering practice and judgment on the effectiveness of these signs rather than specific safety analyses.

The installation of children at play signs is not generally supported for the reasons previously mentioned. The signs may provide only a perceived increase in safety, resulting in inappropriate actions, and similar signs (e.g., the playground sign) have been shown to have little impact on vehicle speed (see below). The playground warning sign also has not been studied for its safety impact.

Aside from these signs, research has examined crosswalks and enhancements to them (Zegeer et al. 2005, Fitzpatrick et al. 2007). The use of crosswalks has been controversial for many years, and the two references cited are ones that the authors consider valuable when considering crosswalks, signs, and other enhancements. Both of these documents provide guidance in application, in addition to the MUTCD, and Fitzpatrick et al. (2007) discuss crosswalk enhancements to improve safety.

Operational Effectiveness

A study at three sites found that playground warning signs produced no effect on mean vehicle speeds at one site and decreased mean vehicle speeds by 0.9 and 1.5 mph at two other sites (Davis et al. 2012). The magnitude of these vehicle speed differences, although statistically significant, are not significant in a practical manner or for safety purposes.

It was concluded in this study that if this type of sign, which is installed next to locations with a playground or something similar (at which children play regularly), did not reduce vehicle speeds at any practical level, that it was likely that warning signs with a more general message (e.g., children at play) would have a similar or even less impact. The authors rate this study as having Medium robustness, and Table A.5 of Appendix A provides additional details about the study.

Alternatives

Some alternatives to using children at play signs could include increased speed enforcement in the area or the deployment of a temporary device, such as a portable radar-actuated speed display sign on a trailer. Similar approaches could be used as alternatives to the playground signs.

References

CTC & Associates. 2007. *Effectiveness of "Children at Play" Warning Signs*. Wisconsin Department of Transportation, Madison, WI.

Davis, G.. K. Knapp, and J. Hourdos. 2012. *Vehicle Speed Impacts of Occasional Hazard (Playground) Warning Signs*. Minnesota Department of Transportation, St. Paul, MN.

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

Fitzpatrick, K., S. Turner, M. Brewer, P. Carlson, B. Ullman, N. Trout, E. S. Park, J. Whitacre, N. Lalani, and D. Lord. 2007. *Improving Pedestrian Safety at Unsignalized Crossings*. TCRP Report 112/NCHRP Report 562. Transit Cooperative Research Program and National Cooperative Highway Research Program, Washington, DC.

Zegeer, C. V., J. R. Stewart, H. H. Huang, P. A. Lagerwey, J. Feaganes, and B. J. Campbell. 2005. *Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines*. FHWA-HRT-04-100, Federal Highway Administration, Research, Development, and Technology, Turner-Fairbank Highway Research Center, McLean, VA.

Deer Crossing Signs

Purpose, Use, and Installation

Deer crossing signs provide drivers with warnings of locations where deer are likely to be encountered (see Figure 6). The purpose of a deer crossing warning sign is to warn drivers of vehicles that they are traveling along a roadway segment where deer may commonly cross (FHWA 2012).

David Veneziano, Iowa LTAP

Figure 6. Deer crossing warning sign

The MUTCD describes the installation of non-vehicular warning signs, including deer crossing signs, in Section 2C.50. No information specific to deer crossing signs (W11-3) is provided, but optional assistance statements are offered for their installation. These statements include placement of these types of signs in advance of locations where unexpected entries to the roadway of deer, etc. might occur, as well as the use of warning beacons in conjunction with these types of signs (FHWA 2012).

No specific installation guidance for deer crossing signs is provided in the MUTCD, but general practice has been to install signs at locations for a variety of reasons (e.g., public request, natural resources input, observation) (Yi 2003). Knapp and Yi also suggested a seven-step process might be used to guide installation (2006). One or more of the following steps could be applied.

1. Hold a site visit and define the roadway segments between the proposed sign pair and for two miles on each end of the proposed sign pair.

2. Collect deer-vehicle crash (DVC) data (minimum of three years) “for the site defined in Step 1 (i.e., the potential outer limit locations of the sign pair) plus two miles in each direction. The location of each crash should be identified. County and state DVC frequency and rate averages should be calculated” (Knapp and Yi 2006).

3. Calculate the measures of safety such as DVC frequency and rate per mile per year and per 100 million vehicle miles traveled for quarter mile intervals in each roadway segment between and two miles on each end of the proposed sign pair.

4. "Compare the site DVC measures to the DVC averages for the entire state and county. If either the average frequency or rate between the proposed sign pair is less than the state average, the installation of the signing should be reconsidered. If both measures are greater than the state average, they should then be compared to the county DVC averages. If either the average DVC frequency or rate between the proposed signs is less than the county average, the installation of the signs should be reconsidered." (Knapp and Yi 2006)

5. "Compare the between to outside sign pair DVC measure ratios calculated for the site to the average ratio from the county (if available). The ratios should be greater than one. Proceed to Step 6 if both ratios are greater than the average calculated for that county. If either ratio is less than one or the calculated county average the installation of the sign pair should be reconsidered." (Knapp and Yi 2006)

6. "Use the 1/4-mile plots of the DVC measures to determine whether the proposed location is a positive sign location. A positive sign location has its peak total 1/4-mile frequency and rate and peak average segment frequency and rate all occurring between the signs of the proposed installation site. If the sign requirements are met, the proposed sign installation should be considered feasible. If these requirements are not met, a redefinition of the proposed site may be appropriate in Step 7." (Knapp and Yi 2006)

7. If sign installation is not determined to be feasible, redefine the proposed sign locations by shifting the sign locations in both directions until the peak quarter-mile crash frequency and rate are included between the signs; if a maximum length of five miles is reached, the value of installing these signs for this general location should be re-evaluated (Knapp and Yi 2006).

Safety Effectiveness

Several studies have focused on different deer crossing warning sign installations. The results from three of these studies follow. Our confidence level in the robustness of the results from these studies is noted, and Table A.6 of Appendix A provides additional details on these studies.

- "A t-test found the overall average DVC frequencies and rates (for 22 sites) between W11-3 signs were statistically higher than those along the adjoining roadway segments. However, about half of these sites had higher DVC frequencies and/or rates along at least one of the adjoining segments than between the W11-3 signs." (Knapp and Yi 2006) The general conclusion of this study was that deer crossing sign locations should be based on crash data and the locations of the signs should be re-considered on a regular basis. The authors rate this study as having Medium robustness.

- Another study indicated that deer crossing signs did not have any impact on reducing crash rates after the installations were in place for as many as 10 years (depending on the site) when compared to before the installation occurred (Meyer 2006). The authors rate this study as having Medium robustness.

- A deer-vehicle crash reduction of 51 percent was calculated during a study of signs equipped with flashing beacons in areas of mule deer migration (Sullivan et al. 2004). The study used negative binomial regression for analysis. The authors rate this study as having Medium robustness.

Operational Effectiveness

The operational impacts of various deer crossing signs have also been studied. Three of these are summarized below.

- The use of seasonal signs were found to reduce the likelihood of high vehicle speeds in the short term. It was found, however, that the signs had the most impact when placed in locations where local drivers knew the period and specific time period of migratory mule deer and trusted the signs (Sullivan et al. 2004). The authors rate this study as having Medium robustness. The impact of a similar signing approach in Michigan, however, was different. There, it was determined that the non-migratory pattern of white-tail deer produced less of a driver response to signs (Allen et al. 1976).

- A simulator study of different signing combinations found a statistically significant 2.32 mph speed reduction within 500 feet of a beacon-enhanced deer crossing sign that would be actuated when deer were present (Hammond and Wade 2004). The authors rate this study as having Medium robustness.

- A different simulator study also found speed decreases and braking increased when deer warning signs were enhanced (beacons, message signs, etc.) (Stanley et al. 2006). The authors rate this study as having Medium robustness.

Alternatives

A number of alternatives to deer crossing signs may or may not have an impact on the number of deer-vehicle crashes. Some of these include vegetation management, fencing, hunting or herd reduction, and wildlife crossings.

References

Allen, R. E. and D. R. McCullough. 1976. Deer-Car Accidents in Southern Michigan. *Journal of Wildlife Management*, Vol. 40, No. 2, pp. 317-325.

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

Hammond, C. and M. Wade. 2004. *Deer Avoidance: The Assessment of Real World Enhanced Deer Signage in a Virtual Environment.* MN/RC-2004-13. Minnesota Department of Transportation, St. Paul, MN.

Knapp, K. and X. Yi. 2006. Crash Data and Deer Crossing Sign Installation. ITE Journal on the Web, pp. 69-73, May 2006.

Meyer, E. 2006. *Assessing the Effectiveness of Deer Warning* Signs. University of Kansas, Topeka, KS.

Stanley, L., A. Hardy, and S. Lassacher. 2006. Responses to Enhanced Wildlife Advisories in a Simulated Environment. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1980, pp. 126-133.

Sullivan, T. L., A. F. Williams, T. A. Messmer, L. A. Hellinga, and S. Y. Kyrychenko. 2004. Effectiveness of Temporary Warning Signs in Reducing Deer-Vehicle Collisions during Mule Deer Migrations. *Wildlife Society Bulletin*, Vol. 32, No. 3, pp. 907-915.

Yi, X. 2003. Deer-Vehicle Crash Patterns and Deer Crossing Sign Placement. Master's Thesis, University of Wisconsin, Madison, WI.

Ice Warning Signs

Purpose, Use, and Installation

Ice warning signs (W8-5, W8-5aP, and W8-13) (see Figure 7) are posted to warn drivers of the potential for ice in locations where it may not necessarily be expected (curves, bridges, etc.). The purpose of ice warning signs is to alert drivers to the presence of the potential for icing conditions.

ROAD TRAFFIC SIGNS (left) and MUTCD (right)

Figure 7. Ice warning sign

Section 2C.32 of the MUTCD discusses various surface condition signs, including ice warning signs. These particular signs are used to advise road users of conditions that typically are present during the winter months. The MUTCD notes that these signs may be removed or covered during seasons of the year when the message is not relevant (FHWA 2012).

The installation guidance provided in the MUTCD on ice warning signs states that they should be placed in advance of the beginning of an affected section of roadway and at appropriate intervals if the condition is present along a longer segment (FHWA 2012). While it is not noted in the MUTCD, a study (crash data evaluation, field observations, etc.) to determine whether an icing problem is present probably could also be completed. .

Safety and Operational Effectiveness

The authors found only one study in the literature that considered the safety impacts of ice warning signs. This study did not find that their installation had a statistically significant impact on the frequency or severity of ice-related crashes (Carson and Mannering 2001). The study did not consider the vehicle speed impact of these signs. Our rating of the results from this study is Medium. Table A.7 of Appendix A provides additional details about the study.

No studies have been completed that have evaluated the operational impacts of ice warning signs.

Alternatives

Alternatives or supplements to the installation of ice warning signs have been pennants, the addition of high friction surface treatments, and/or the addition of fixed automated spray technologies (FAST) for spot treatments.

References

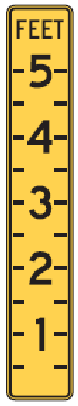
Carson, J. and F. Mannering. 2001. The Effect of Ice Warning Signs on Ice-Accident Frequencies and Severities. *Accident Analysis and Prevention*, Vol. 33, pp. 99-109.

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

Road May Flood Warning Signs

Purpose, Use, and Installation

Signs pertaining to water on the roadway (W8-18 and W8-19) (see Figure 8) are used to inform drivers that a location or roadway segment is prone to flooding.



MUTCD

Figure 8. Road may flood sign (left) and depth gauge (right)

The purpose of road may flood warning signs (left side of Figure 8) is to caution drivers that a downstream segment of roadway is subject to frequent flooding (FHWA 2012). The depth gauge sign (right side of Figure 8) is to show drivers the depth of the water at the deepest point on the roadway (FHWA 2012). Both signs alert drivers to the potential of water on the roadway (particularly after a weather event or during melting/runoff periods) in order to increase their vigilance about the potential of encountering water over the pavement.

Section 2C.35 of the MUTCD indicates that this type of sign may be used at relevant locations. The W8-18 sign (left side of Figure 8) may be used to warn drivers of a section of roadway that is subject to frequent flooding. The W8-19 sign, (right side of Figure 8) if used, however, must only be installed in addition to the W8-18 sign (FHWA 2012). The depth gauge sign may be located to indicate the depth of water at the deepest point along the roadway (FHWA 2012).

Guidance that was developed for low water stream crossings in Iowa recommended that signs such as flood area ahead and impassible during high water be installed at least 750 feet in advance of the water crossing or at the last turnaround location for vehicles (Lohnes et al. 2001).

Safety and Operational Effectiveness

No studies have been completed that have evaluated the safety impacts of road may flood warning signs. However, it was shown in one study that the presence of static warning signs did not significantly impact the decisions of focus group participants to continue along roadways shown with water covering them (Balke et al. 2011). The focus group participants indicated that they instead look for clues from the roadway and surroundings regarding water depth and the potential safety of the roadway at the water crossing. This study, therefore, recommended that the depth gauge be installed at each low water crossing. Our rating of the results of this work is Low. Table A.8 of Appendix A provides additional details about the study.

Alternatives

Mitigation of the flooding problem is an alternative.

References

Balke, K., L. Higgins, S. Chrysler, G. Pesti, N. Chaudhary, and R. Brydia. 2011. *Signing Strategies for Low-Water and Flood-Prone Highway Crossings*. Report FHWA/TX-12/0-6262-1, Texas Transportation Institute, College Station, TX.

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

Lohnes, R., R. Gu, T. McDonald, and M. Jha. 2001. *Low Water Stream Crossings: Design and Construction Recommendations*. Center for Transportation Research and Education, Iowa State University, Ames, IA.

Enhanced Signs – Regulatory

The majority of the sign research completed in the past was typically initiated to evaluate the enhancement of static signs (either regulatory or warning). The enhancements considered are intended to increase the conspicuity of the sign and driver awareness of the sign's message. The overall objective is to increase the attention of drivers to the message and ultimately change their behavior (e.g., reduce their driving speeds). Some of these enhancements are continual (e.g., a constantly flashing beacon) and others are activated or actuated in real-time for a particular situation (e.g., flashing beacons or messages when a vehicle is present).

Two examples of enhancements that have been used in Iowa are the use of light-emitting diodes (LEDs) on stop signs and the use of activated beacons on signal-ahead warning signs to indicate when the traffic signal is changing to red. The results of research on three different types of enhancements that have been used by local agencies in Iowa are described in this guide. The installation of the components in these enhanced systems (e.g., static sign or beacon) are described in the MUTCD.

Enhanced Stop Signs

Purpose, Use, and Installation

Several methods are used to enhance stop signs. Two of the more common electronic enhancements include stop signs equipped with flashing beacons and those with LEDs (see Figure 9).

David Veneziano, Iowa LTAP (left) and InTrans (right)

Figure 9. Stop sign enhanced with flashing beacon (left) and with LEDs (right)

The purpose of a stop sign remains the same as that described previously for the static sign (i.e., to control movements at intersections where it has been determined that a full stop on an approach or the approaches is required), but the enhancements are believe to draw more attention to the message conveyed.

Sections 2B.04 through 2B.07 of the MUTCD describe the use and installation of stop signs. The use of flashing beacons, on the other hand, are discussed in Section 4L.05. Section 4L.05 states that flashing beacons "…shall be used only to supplement a stop sign." The use of LED borders is described in Section 2A.07 of the MUTCD. This section states that LEDs "…may be used individually within the legend or symbol of a sign and in the border of a sign… to improve the conspicuity, increase the legibility of sign legends and borders, or provide a changeable message" (FHWA 2012). The beacons themselves "shall be flashed at a rate of not less than 50 or more than 60 times per minute" as per Section 4L.01.

Installation guidance and the conditions for installation of stops signs remain the same as those for static unenhanced stop signs. These details are described in Sections 2B.04 through 2B.07 of the MUTCD. Additional details on the electronics of the beacons and LEDs are provided in Section 4L.01.

Safety Effectiveness

Several different studies have examined the safety impacts of beacons or LEDs on stop signs. The results of these studies are described below along with the authors' rating of their confidence in them. Table A.9 of Appendix A provides additional details about the studies.

- The addition of a flashing LED (constant flash) border on minor-leg stop signs at 15 intersections in Minnesota produced a 41.5 percent reduction in angle crashes (Davis et al. 2014). The authors rate this study as having High robustness.

- The installation of standard stop-sign-mounted beacons (constant flash) at five sites in North and South Carolina produced a 58.2 percent reduction in angle crashes (Srinivasan et al. 2008). The authors rate this study as having High robustness.

- The use of overhead beacons (constant flash) at 34 two-way stop-controlled intersections in North Carolina produced a 12 percent reduction in total crashes, a 40 percent reduction in injury crashes, and a 26 percent reduction in crashes where vehicles did not stop at the stop sign (Murphy and Hummer 2007). The authors rate this study as having Medium robustness.

- Research from Minnesota indicated that before-and-after comparisons of crash data "did not strongly support the effectiveness" of overhead flashers (and that crash rates fell from 1.29 to 0.78 per million entering vehicles) (Stackhouse and Cassidy 1996). The authors rate this study as having Low robustness.

- An evaluation of beacons installed on stop signs (constant flash) and intersection-ahead signs (constant flash) at 4 sites in Minnesota found that total crashes were reduced by 40 percent (Stackhouse and Cassidy 1996). The authors rate this study as having Low robustness.

Note that the Iowa DOT has a program to replace overhead red-flashing beacons at two-way stop-controlled intersections with stop sign-mounted red beacons for minor road traffic and yellow flashing beacons on the advance warning signs for major road traffic (www.iowadot.gov/traffic/flashingbeacon.html). In addition, ongoing research in Iowa is evaluating the safety impact of dynamically activated stop signs with beacons or LEDs.

Operational Effectiveness

Only a limited amount of research has examined the operational effects of LED borders (constantly flashing) on stop signs. In fact, only one documented research project was found. That research examined installations at a three-legged intersection in Virginia and it showed that LED stop signs produced a 0.9 to 3.75 mph speed reduction in advance of the study intersections during the day and a 0.91 to 4.81 mph decrease in speeds at night (Arnold and Lantz 2007). The authors rate this study as having Low robustness.

A study of naturalistic driving data by Oneyear et al. (2016) found that the presence of overhead flashing beacons at 64 rural intersections in New York, North Carolina, Pennsylvania, and Washington increased braking distances in advance of intersections by 67.11 meters (220 feet). The authors rate this study as having Medium robustness.

Alternatives

Other non-electronic enhancements include post-mounted reflectorized strips (discussed in Section 2A.21 of the MUTCD), flags, and/or pennants.

References

Arnold, E. and K. Lantz. 2007. *Evaluation of Best Practices in Traffic Operations and Safety Phase 1: Flashing LED Stop Sign and Optical Speed Bars*. Virginia Transportation Research Council, Charlottesville, VA.

Davis, G., J. Hourdos, and H. Xiong. 2014. *Estimating the Crash Reduction and Vehicle Dynamics Effects of Flashing LED Stop Signs*. Minnesota Department of Transportation, St. Paul, MN.

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

Murphy, B. and J. Hummer. 2007. Development of Crash Reduction Factors for Overhead Flashing Beacons at Rural Intersections in North Carolina. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2030, pp. 15-21.

Oneyear, N., S. Hallmark, and B. Wang. 2016. *Evaluating the Relationship between the Driver and Roadway to Address Rural Intersection Safety using the SHRP 2 Naturalistic Driving Study Data*. Center for Transportation Research and Education, Institute for Transportation, Iowa State University, Ames, IA.

Srinivasan, R., D. Carter, K. Eccles, B. Persaud, N. Lefler, C. Lyon, and R. Amjadi. 2008. *Safety Evaluation of Flashing Beacons at STOP-Controlled Intersections*. FHWA-HRT-08-044, Federal Highway Administration, Research, Development, and Technology, Turner-Fairbank Highway Research Center, McLean, VA.

Stackhouse, S. and P. Cassidy. 1996. *Warning Flashers at Rural Intersections*. MN/RC - 1998/01. Minnesota Department of Transportation, St. Paul, MN.

Enhanced Signs – Warning

Only enhanced warning systems that have been used in Iowa are covered in this guide. The following enhanced conflict warning systems are described in this section:

- Unsignalized intersection
- Signalized intersection

Unsignalized Intersection Conflict Warning Systems

Purpose, Use, and Installation

Unsignalized intersection conflict warning systems (ICWSs) are an experimental intersection treatment meant to enhance driver awareness of an approaching intersection where conflicting traffic may be present. A limited number of these systems (six) have been installed to date in Iowa, and one of these is shown in Figure 10.

David Veneziano, Iowa LTAP

Figure 10. Unsignalized intersection warning sign and flasher

The purpose of these sign and beacon combinations is to warn drivers on the major, minor, or all approaches to an intersection of traffic on the leg(s) that may conflict with their vehicle direction of travel. This warning is done via a word message or symbol signs and beacons that are activated by approaching and/or conflicting traffic (but otherwise turned off).

The system shown in Figure 10, for example, uses in-pavement loop detectors on the major approaches to the two-way, stop-controlled intersection to activate flashing beacons mounted with a warning sign (traffic approaching when flashing) facing the minor approaches. These signs with the beacons alert drivers, in real-time, that a vehicle(s) is present or approaching the intersection and may introduce a potential conflict. The objective of these systems is to increase the attention of drivers and improve their decision-making.

Unsignalized ICWSs are installed at locations where it is believed that drivers would be helped by additional decision-making assistance. These systems are not commonplace and are generally considered at locations where some type of issue has been identified. They are often either after or in combination with other geometric and traffic control improvements.

Higher traffic volumes on the major and minor roadway approaches are also often present when this type of system is considered. The systems that are being used vary in approach and signing. The application is considered experimental and cannot be installed without special approvals by the FHWA.

Safety Effectiveness

A few research projects have examined the safety impacts of unsignalized ICWSs. The robustness of each study is indicated below, and Table A.10 of Appendix A provides additional details.

- One study considered the safety impacts of installing vehicle entering when flashing signs with flashing beacons at or near 74 rural and urban North Carolina intersections. The systems installed were a combination of those that alerted only the major approach vehicle drivers and others that alerted both major and minor approach drivers. The systems that only warned the major approach drivers (23 sites) reduced total crashes by 32 percent and those that warned both major and minor approach drivers (7 sites) reduced total crashes 25 percent (Simpson and Troy 2013). The authors rate this study as having High robustness.

- A simple before-and-after study of crash frequency at 19 sites in Missouri found a 28 percent reduction in total crashes, a 72 percent reduction in severe crashes, and a 37 percent reduction in angle crashes following the installation of vehicle-actuated ICWSs (MoDOT n.d.). These systems warned drivers on the major approach (9 sites) or minor approach (10 sites) of approaching or conflicting traffic. The authors rate this study as having Low robustness.

- An aggregate analysis was conducted of rural sites equipped with vehicle-actuated ICWSs in Minnesota (post-mounted signs and flashers on minor roadway), Missouri (post -mounted signs and flashers on major or minor approaches), and North Carolina (post-mounted or overhead signs and flashers on major roadway). The research found that intersections with single-lane approaches had total crash reductions of 26.7 percent, 29.9 percent in fatal and injury crashes, 19.7 percent in right-angle crashes, and 11.2 percent in nighttime crashes (FHWA. 2016b). Intersections with two-lane approaches on the major roadway and one-lane approaches on the minor roadway had total crash reductions of 17.3 percent, fatal and injury crashes were reduced by 19.8 percent, right-angle crashes were reduced by 15.0 percent, and nighttime crashes decreased by 38.8 percent (FHWA. 2016b). The authors rate this study as having High robustness.

Operational Effectiveness

No documented research was found that evaluated the operational effects of ICWSs. However, a study of a system that used a flashing LED border around a vehicle approaching when flashing sign found a 4.5 mph average decrease in vehicle speed (on all intersection approaches) when the LED flash was activated (Kwon and Weidemann 2010). The authors rate this study as having Low robustness.

Alternatives

Several alternatives should be considered before the installation of ICWSs. Some of these alternatives might include some of the other enhancements described, sight triangle obstruction clearance, additional and/or larger intersection warning signs and plaques (W2-1 through 2-5, etc.), special pavement markings, and/or rumble strips.

References

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

FHWA. 2016b. *Safety Evaluation of Intersection Conflict Warning Systems (ICWS) Tech Brief*. FHWA-HRT-15-076, Federal Highway Administration, Research and Development, Turner-Fairbank Highway Research Center, McLean, VA.

Kwon, T. and R. Weidemann. 2010. *Advanced LED Warning Signs for Rural Intersections Powered by Renewable Energy*. MN/RC 2011-04. Minnesota Department of Transportation, St. Paul, MN.

MoDOT. No date. *Missouri DOT Intersection Warning System Before-After Study Results*. Missouri Department of Transportation, Jefferson City, MO. Available at: www.enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/MOIWSBeforeAfterStudy.pdf.

Simpson, C. and S. Troy. 2013. Safety Effectiveness of "Vehicle Entering When Flashing" Signs: Evaluation of 74 Stop-Controlled Intersections in North Carolina. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2384, pp. 1–9.

Signalized Intersection Advance Warning Systems

Purpose, Use, and Installation

Enhanced signalized intersection warning signs (prepare to stop when flashing) provide an indication to approaching drivers that a downstream signal is in the yellow or red phase and that they should be prepared to stop when the beacons are flashing (see Figure 11). The static sign typically includes the message prepare to stop when flashing (or be prepared to stop) and one or two flashing beacons are mounted in conjunction with the sign.

Theresa Litteral, Iowa LTAP

Figure 11. Signalized intersection advance warning sign and flasher

The MUTCD addresses the installation of the signalized intersection advance warning system components in different chapters and sections. Traditional signal-ahead advance warning sign installation information is included in Section 2C.36 and flashing beacons are discussed in Section 4L.03. The beacons themselves "shall be flashed at a rate of not less than 50 or more than 60 times per minute" as per Section 4L.01 (FHWA 2012).

The signal-ahead advance warning sign systems are used at many locations and MUTCD Section 4L.03 contains language about beacons being used in conjunction with a warning sign that includes the phrase when flashing in its legend. An optional assistance statement is provided that a beacon interconnected with a traffic signal controller assembly may be used for intersection warnings (FHWA 2012). This interconnection is common with signalized intersection advance warning sign systems. These systems, however, need to be designed for a specific intersection on a case-by-case basis.

Safety Effectiveness

Two studies were found that considered the safety impacts of signalized intersection advance warning sign systems. The results of these studies and the ratings of the authors with respect to their confidence in these results are listed below. Table A.11 of Appendix A provides additional details about these studies and the robustness of their results.

- A 34 percent total crash reduction was observed in a before-and-after study at three rural multilane study sites when beacons were activated on prepare to stop signs in advance of the end of the green signal indication (Schultz and Talbot 2009). The authors rate this study as having Medium robustness.

- An 8.2 percent reduction in total crashes was observed in a before-and-after study of 26 sites in Nebraska that had beacons activated on signal ahead advance warning signs in advance of the end of the green cycle (Appiah et al. 2011a and 2011b). The authors rate this study as having High robustness.

Operational Effectiveness

Two additional studies considered the operational impacts of signalized intersection advance warning sign systems. Their results are as follows:

- Approximately 78 percent of the drivers observed in a Nebraska study with beacons at advance signal warning signs activated in advance of the end of the green cycle either maintained or reduced their speeds when the beacons began to flash. The average deceleration was 2.89 ft/s^2 or 1.96 mph (Appiah et al. 2011a and 2013). The authors rate this study as having High robustness.

- An experimental installation included the activation of beacons in advance of the end of the green cycle on a be prepared to stop when flashing sign. The system was found to reduce red-light-running by 40 percent (Sunkari et al. 2005). The authors rate this study as having Low robustness.

Research is currently underway by Iowa State University's Center for Transportation Research and Education (CTRE) at the Institute of Transportation (InTrans), the Minnesota DOT (MnDOT), and the University of Iowa to evaluate driver behavior at mainline and two-way stop-controlled approaches for intersections with and without ICWSs in rural Minnesota.

Alternatives

The implementation of these systems is being considered or completed generally because all alternatives have been implemented and do not appear to be working. Traditional signs to increase awareness include the addition of one or more warning signs, installation of larger signs, and the addition of flags, pennants, or non-actuated flashing beacons (i.e., they flash constantly).

References

Appiah, J., L. Rilett, and Z. Wu. 2011a. *Evaluation of NDOR's Actuated Advance Warning Systems*. NTC Report TSPT1-03, Nebraska Transportation Center, Lincoln, NE.

Appiah, J., B. Naik, R. Wojtal, and L. Rilett. 2011b. Safety Effectiveness of Actuated Advance Warning Systems. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2250, pp. 19-24.

Appiah, J., L. Rilett, B. Naik, and R. Wojtal. 2013. Driver Response to an Actuated Advance Warning System. *Journal of Transportation Engineering*, Vol. 139, No. 5, pp. 433-440.

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

Schultz, G. and E. Talbot. 2009. Advance Warning Signals Long-Term Monitoring Results. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2122, pp. 27-35.

Sunkari, S., C. Messer, and H. Charara. 2005. Performance of Advance Warning for End of Green System for High-Speed Signalized Intersections. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1925, pp. 176-184.

Sign Removal

Souleyrette et al. developed guidelines for the removal of stop signs at ultra-low-volume roadway intersections (i.e., intersections with volumes less than 150 vpd from all directions) in rural areas (2005). The guidance provided for this process included the following four steps:

1. Develop and adopt a formal [removal] policy
2. Undertake a thorough engineering study
3. Provide appropriate public notice
4. Perform follow-up assessment

Aside from this guidance, sign removal is a topic that has not been discussed in past research or guidance documents. In general, the steps outlined above for stop sign removal, or similar steps, may be applicable to other sign removal situations. However, these steps, along with others applicable to the situation, should be considered on a case-by-case basis.

The MUTCD indicates where some signs, such as speed limit signs, shall be used. In other cases, the installation of signs is typically done for a specific reason (e.g., icing occurrences). Removal of signs in these cases should be an indication the problem is no longer occurring or is being addressed through some other means. When warning signs are removed, a warning no longer exists and it could impact whether people slow/stop or make an appropriate decisions.

If removal of a particular sign is considered, the potential human behavioral (e.g., speed choice) impact(s) of this action needs to be evaluated or investigated on a case-by-case basis and the appropriate actions taken to minimize any negative impacts that a sign change may cause. Additionally, it is important to realize that just because a sign has not been studied for safety or operational impacts, it does not mean the sign hasn't raised the attention value of drivers. The removal of signing should be considered carefully and with a significant amount of caution for each case. The authors strongly recommend that the decision-making process be documented.

References

Souleyrette, R., R. Tenges, T. McDonald, and T. Maze. 2005. *Guidelines for Removal of Traffic Control Devices in Rural Areas*. Center for Transportation Research and Education, Iowa State University, Ames, IA.

Chapter Summary

This chapter included an overview and summary of several static and enhanced regulatory and warning signs that have been studied or evaluated for safety and/or operational effectiveness. The authors focused the information provided on signs that are typically used by local agencies. Very few signs that are commonly used by local jurisdictions have been studied and documented, particularly traditional static signs, to any great extent with an approach that would meet the current state of the practice for highly robust results.

A table that lists commonly used signs, along with whether they are required by the MUTCD or had been studied, was presented at the beginning of this chapter. A lack of research about the effectiveness of a sign, however, does not mean that the sign being considered for installation is not effective in the accomplishment of its objective(s). In many cases, one of the objectives is simply to provide notification and increase awareness of regulations or hazards to an attentive driver. These types of notifications and warnings are essential to the safety and operations of the transportation system. Enhancements are also often introduced when there is concern about a static sign and its ability to gain the awareness or attention of the driver.

Several points should be considered in the application of the information provided in this chapter. Some of the questions that might be asked include the following:

- Is the sign installation accomplishing its objective whether supported by research or not?
- Is the use of the sign consistent with the content of the MUTCD?
- Is the sign consistently applied across the roadway system or is the installation unique to each situation?
- What are the risks and potential consequences due to driver error if the sign was not there?
- Do I have a proper review and documentation process in place to evaluate its installation or removal?

The authors rated the research results with a Low, Medium, or High level of confidence. The definition of these ratings and the process used to develop them is described in the Confidence Rating of Existing Research Results section. Of the research reviewed, we classified the results of 10 documents as having a low rating, 20 as having a medium rating, and 8 having a high rating. These are our opinions based on the definition provided in the text. The ratings are provided to assist users in their decision-making process. It is also important to recognize that research results generally only apply to the situations that were studied (e.g., implementation of a sign in rural situations may be different than urban situations). Tables with additional details about each of the studies are included in Appendix A.

Overall, the safety and/or operational effectiveness of many signs has not been studied. Therefore, the installation or removal of many signs will continue to be based on engineering judgment or studies and consideration of the characteristics of the site on a case-by-case basis. It is recommended that these actions be documented for future reference.

In many cases, it is also known that the installation of a low-cost sign will not improve safety, but the risk and/or consequences of the sign's absence could be significant. In these cases, it is important that these signs remain in place. In fact, in most cases, signs are implemented for valid reasons and the default decision should be that they remain.

Chapter 3. Sign Program Guidance

The installation and maintenance of signs is a significant investment for any local agency. The development of a well-designed signing program is essential to the efficient and effective accomplishment of these activities. This chapter describes what the authors considered to be some of the more important characteristics and elements of a signing program. This chapter describes the following sign program components:

- Iowa county traffic sign program policies
- Approaches to sign inventories
- Retroreflectivity requirements
- Additional signing considerations such as maintenance

Iowa Sign Program Policies

Many agencies have developed and adopted sign program policies. The establishment of a formal signing policy can aid in the overall management of signs. The policy can establish procedures to identify whether there is a need for a sign and also define the processes that should be followed in making such a determination. The policy can provide direction to local agency staff with regard to the prioritization of sign installation, and the allocation of resources to accomplish this activity.

A formal signing policy can also often provide support when legal action related to signing occurs—by documenting the approach used. In fact, these types of policies should generally be developed with the input of the local agency attorney to ensure that they are comfortable with its content.

A signing policy does not need to be complex. Signing policies often include, but are not limited to, the following:

- The objective of the policy
- A summary of the sign maintenance method selected
- The roads to which the policy applies
- The signs the policy applies to
- How the policy will be implemented

The objective of a sign policy should indicate its intent, and summarize the policy content and activities needed for implementation (e.g., discuss the approach used to comply with the MUTCD retroreflectivity requirements). The maintenance method summary identifies and describes the approach selected to manage sign retroreflectivity (e.g., blanket replacement or another approach), and the discussion of road types covered by the policy explicitly states the metric used to identify the roadways to which the policy is applicable (e.g., all roads, roadways below a certain traffic volume, or other measures). Similarly, the discussion of the types of signs covered by the policy indicates whether all signs are covered or if the policy only applies to regulatory, warning, guide, or some combinations of these three. Finally, the actions required to implement the policy should be described. The procedures in this section of the policy might focus on sign inventory, installation, replacement or removals, signing materials used, when engineering studies may be required, budgetary discussions, and inspector training.

General Content

A sample of Iowa county sign program policies were collected as part of this project. Examples of these sign program policies are provided in Appendix B and Appendix C. These policies generally address the management of signs and the approach followed to meet MUTCD retroreflectivity requirements.

Sign program policies were collected from Blackhawk, Buchanan, Clinton, Dallas, Jones, Lee, Madison, Ringgold, Story, Washington, Webster, Winnebago, Winneshiek, and Woodbury counties. A summary of the typical content of these policies follows, along with some specific points of interest. A sample sign policy from the National Association of County Engineers (NACE) that is also posted on the Iowa County Engineers Association (ICEA) Service Bureau website is included in Appendix D.

The signing policies reviewed as part of this project generally had two formats. The first format was a short (e.g., one- to two-page) document that describes the sign assessment or management policy being used to meet minimum retroreflectivity requirements. The second format was a longer document that is more comprehensive and includes the retroreflectivity assessment or management approach used, but also has additional details about sign installation, inspection, and maintenance procedures. These more comprehensive policies were likely in place to address sign inventory, maintenance, etc., prior to the MUTCD requirement to maintain minimum retroreflectivity. The retroreflectivity content was added to those existing policies to meet the MUTCD requirement more recently.

The typical content of the more comprehensive signing policies that were reviewed was fairly standard. These policies typically included the following information:

- Introduction
- Purpose/need
- Assessment or management plan being used
- Details of the selected approach
    - When and how inspections occur (assessment)
    - Who inspectors are, training, vehicle(s) used, and speeds (assessment)
    - Sign replacement intervals (management)
    - How inspections will be conducted
- How the sign inventory would be managed

Field Inspection and Replacement Content

The details of the field inspection and replacement approaches are also provided in the sample policies. The retroreflectivity field inspection intervals for most policies were annual or biannual. But, the time period for the blanket replacement approach typically ranged from 10 to 15 years, based on manufacturer guidance of retroreflectivity degradation for a particular sheeting type. It is common knowledge, however, that the retroreflectivity of some signs in the field may degrade faster than manufacturer guidance, while others may last longer.

If the calibration sign approach was indicated as the chosen retroreflectivity sign assessment or management approach in the policy, a description of the approach was included. In general, as required by the MUTCD, the field inspections with this method are performed at night, typically with two-person teams, and the inspectors were usually rating signs as having good, fair, or poor retroreflectivity. Most of the policies that included this rating system also noted that signs rated as fair should be inspected further (i.e., their retroreflectivity should be measured using a retroreflectometer) or be more closely monitored.

A sample of signs that had their retroreflectivity measured are used by inspectors with this approach to familiarize themselves with the appearance of acceptable sign retroreflectivity. The timeline for the replacement of signs rated as poor or below retroreflectivity minimums varied, but generally it was specified in the policy as either a specific time period (e.g., within one month) or when time and/or budget permitted.

Additional information about the requirements and allowances for retroreflectivity assessment and management in the MUTCD are described in the Retroreflectivity Requirements section of this chapter.

Inventory and Use Content

A majority of the policies also referenced an existing sign inventory system or specifically called for one to be created after the policy was adopted. In most cases, for existing systems, an electronic inventory was employed. In some cases, electronic inventories were also used to track the age of signs and identify those that were approaching the potential end of their retroreflectivity service lives. Additional information about inventory systems are provided in the Sign Inventory Options section of this chapter.

Sign Inventory Options

In order to properly manage sign assets, it is necessary to document those that are present in the field along with their basic characteristics (e.g., location, orientation, installation date, retroreflectivity). The use of an inventory is also generally an important component to meeting the minimum retroreflectivity requirements of the MUTCD. These requirements are described in the Retroreflectivity Requirements section of this chapter. The approaches used to complete and maintain a sign inventory vary by agency and often depend on factors such as available budget, size of the asset inventory, and available technology. Both simple and more complex sign inventory approaches are briefly described in the following paragraphs.

A sign inventory approach does not need to be highly technical. In its simplest format, it can consist of a field visit to each sign installation and the recording of pertinent information using paper and a pencil. In this case, the data collector would record the information of interest for each sign installation. That information typically includes the date the data is collected, roadway, milepost location (and/or possibly global positioning system/GPS coordinates), sign direction, sign type, MUTCD identification number, sign size, retroreflectivity condition, post type, general sign condition, and other notes. The information collected for each sign could then be organized by roadway folder and kept as paper files, entered into spreadsheets, or linked (or entered as individual records) with a geographic information system (GIS) street file if GPS data were collected.

The advantages of this approach are that it is straightforward to implement and generally low cost. It also requires a minimum of technical expertise to apply. The disadvantages to the approach are the potential lack of electronic files to facilitate review and analysis (particularly searches for specific characteristics of signs), as well as the potential for records to be lost if they are not electronically recorded.

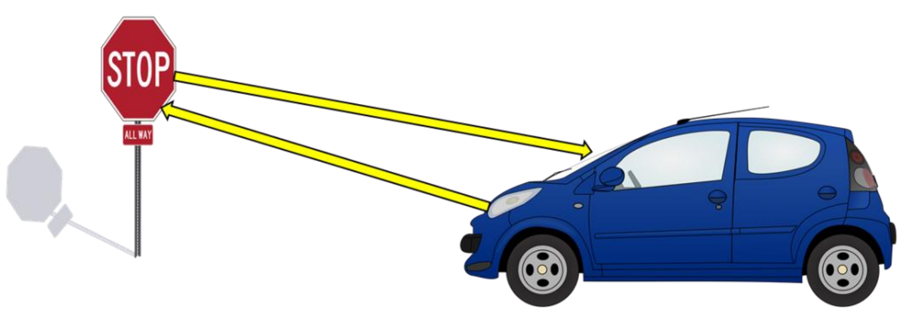
At the other end of the spectrum, sign inventories can be completed and maintained using commercial or custom-developed software. Many sign management programs are available, both for sale and as freeware. Some examples include SimpleSigns, SignWorks, which are software packages. Sign inventory applications (apps) have also been or are being developed, including one by the ICEA Service Bureau. An agency can also develop their own program using existing software packages (e.g., Excel), although this may be a more costly approach.

Sign inventory software installed on a laptop, tablet, or as a smartphone app can be used in the field to record different sign characteristics (e.g., date, roadway, milepost, condition) through electronic means (e.g., the device camera). Information recorded in the field can then be automatically aggregated into a database and updated when new inventory activities are completed.

The advantages of this approach are that it has a straightforward data recording approach (e.g., typing, dropdown boxes for certain data fields), it is easy to link the data collected to other platforms (e.g., visualization mapping) and data, and it provides the ability to conduct data analysis and review in an expedient manner (e.g., data summaries, record searches, retroreflectivity tracking). The primary drawback to the software approach is financial, if software or devices are purchased, or the time it may take to develop an in-house program.

Retroreflectivity Requirements

Retroreflectivity is a critical component of roadway signage and the approach used to manage it must be documented (see MUTCD Section 2A.08). This characteristic of sign sheeting allows drivers to properly see regulation, warning, and other signs at night by directed reflection of light from a vehicle's headlights back to the driver (i.e., sign retroreflectivity). Figure 12 shows how sign retroreflectivity works. The process of directly measuring retroreflectivity is described in the Retroreflectometer Guide in Appendix E.



Rendering by David Veneziano, Iowa LTAP

Figure 12. How retroreflectivity works

The MUTCD has requirements for minimum levels of regulatory and warning sign retroreflectivity. These requirements are specified in Table 2A-3 of the MUTCD as shown in Table 3.

Table 3. Retroreflectivity levels based on color scheme

<table>
<tr><th rowspan="3">Sign Color</th><th colspan="4">Sheeting Type (ASTM D4956-04)</th><th rowspan="3">Additional Criteria</th></tr>
<tr><th colspan="3">Beaded Sheeting</th><th>Prismatic Sheeting</th></tr>
<tr><th>I</th><th>II</th><th>III</th><th>III, IV, VI, VII, VIII, IX, X</th></tr>
<tr><td rowspan="2">White on Green</td><td>W*; G ≥ 7</td><td>W*; G ≥ 15</td><td>W*; G ≥ 25</td><td>W ≥ 250; G ≥ 25</td><td>Overhead</td></tr>
<tr><td>W*; G ≥ 7</td><td colspan="3">W ≥ 120; G ≥ 15</td><td>Post-mounted</td></tr>
<tr><td rowspan="2">Black on Yellow or Black on Orange</td><td>Y*; O*</td><td colspan="3">Y ≥ 50; O ≥ 50</td><td>2</td></tr>
<tr><td>Y*; O*</td><td colspan="3">Y ≥ 75; O ≥ 75</td><td>3</td></tr>
<tr><td>White on Red</td><td colspan="4">W ≥ 35; R ≥ 7</td><td>4</td></tr>
<tr><td>Black on White</td><td colspan="4">W ≥ 50</td><td>–</td></tr>
</table>

1 The minimum maintained retroreflectivity levels shown in this table are in units of $cd/lx/m^2$ measured at an observation angle of 0.2° and an entrance angle of -4.0°
2 For text and fine symbol signs measuring at least 48 in. and for all sizes of bold symbol signs
3 For text and fine symbol signs measuring less than 48 in.
4 Minimum sign contrast ratio ≥ 3:1 (white retroreflectivity ÷ red retroreflectivity)
* This sheeting type shall not be used for this color for this application

Source: MUTCD Table 2A-3 (FHWA 2012)

Table 3 provides information to help guide agencies in the determination of what minimum retroreflectivity levels are needed for different signs based on their color scheme. The MUTCD also required the development and implementation of a sign assessment or management plan or approach to track retroreflectivity by June 2014 (FHWA 2013). There are four methods of sign assessment and three methods of management suggested in the MUTCD, and these seven approaches are summarized in the followings sections of this chapter. The MUTCD also indicates that future engineering methods may also be used when they are available.

Sign assessment methods directly evaluate or assist in the measurement of sign retroreflectivity by assessing their condition through various means. Regardless of the method used, the retroreflectivity of signs should be examined at least annually, although the timing of inspections is not discussed in the MUTCD. The sign management methods suggested in the MUTCD are different than assessment methods. The management methods do not require a specific in-field evaluation or measurement to track retroreflectivity and guide sign replacement decisions. Instead, replacement is based on factors such as expected sign age or date of installation, blanket replacement, or the deterioration of a sample series of representative control signs.

Calibration Signs Assessment Method

The calibration signs procedure uses a set of representative signs, typically set up in a maintenance yard, which a sign inspector views to “calibrate” their eyes to proper retroreflectivity levels prior to conducting nighttime field inspections. The calibration signs should also be viewed at different distances (from 100 to 600 feet) in order to gain a perspective on how signs in the field should appear at comparable distances. These representative signs have been measured with a retroreflectometer to ensure they exceed minimum retroreflectivity values. The calibration signs should be stored when not in use to preserve their retroreflectivity.

During the field inspection, the inspector uses their "calibrated" eyes to characterize a sign as above or below minimum retroreflectivity levels. Signs are viewed at varying distances (see above) for comparison purposes. Any vehicle and inspectors of any age can be used with this procedure, but the signs need to be viewed with the headlights on low beam. Signs that are characterized as below minimum retroreflectivity should then be replaced. The advantages of this sign assessment approach are that is generally simple to implement and conduct for agencies with limited manpower and/or budget, and there are no special requirements for inspectors (e.g., a certain age). The disadvantages of this approach are that it is not necessarily precise (e.g., the views of a "calibrated" eye are likely to change as a nighttime inspection progresses) and it is subjective in the sense that even with training, the characterization of a sign as being at or below retroreflectivity minimums is likely to vary from inspector to inspector.

Comparison Panels Assessment Method

The comparison panel procedure that is described in the MUTCD uses a series of small sign panels of various colors and sheeting types that can be purchased and have known retroreflectivity levels. These panels are then compared to current colors and sheeting in the field. First, signs in the field are inspected at 100 to 600 foot distances at night from an inspection vehicle of any type with an inspector of any age. Signs that are identified by the inspector as having marginal retroreflectivity are then examined more closely with the comparison panels. The inspector clamps the comparison panel(s) to the sign and further inspects the sign with a flashlight at a distance of 25 feet. If the comparison panel is brighter than the sign the inspector will determine that the sign needs to be replaced. This method is more rigorous than the previously described calibration signs procedure, but it also requires an inspector to be on the roadside at night, and he or she may be using a ladder on uneven ground (ditches, etc.) to complete an inspection, and this can be hazardous.

Consistent Parameters Assessment Method

The consistent parameters procedure described in the MUTCD also involves a field inspection of signs from a vehicle at night. This approach, however, requires an older driver (with an age of 60 or more years) as an inspector and the use of a sport utility vehicle (SUV) or pick-up truck (2000 model year or newer). These vehicle types are used because the size of the vehicle is a key factor in how the sign, and its brightness, appear to the driver at night. In addition, this approach and its requirements simulate the conditions of the research used as a foundation for the minimum retroreflectivity levels in the MUTCD (Preston and Barry 2010).

As the inspection vehicle travels the roadway, the inspector notes whether a sign is good, marginal, or bad in terms of retroreflectivity. Marginal signs are then further evaluated using another procedure or they are replaced. Signs that are characterized as bad are automatically replaced. The advantages of this approach are that it does not require the use of specially maintained signs or panels (e.g., comparison panels or calibration signs) and, in using an older driver and a worst-case scenario vehicle, signs with poor retroreflectivity are more likely to be identified by a member of a driver group that would be most impacted by poor retroreflectivity. The disadvantage of this approach is that it is subjective, with retroreflectivity decisions based on an inspector's judgment of a sign's condition. (Note that training needs to be provided before field review.)

Retroreflectivity Measurement Assessment Method

Measuring the retroreflectivity of signs using a retroreflectometer is the most accurate sign management and assessment procedure available. This approach requires that a retroreflectometer device (typically about the size of a cordless drill and currently costs at least $9,000) is placed against the sign and used to collect readings across the sign face. The number of readings collected can vary, but generally multiple readings should be collected for each color on a sign. ASTM International suggests a minimum of four readings for each color on the sign as part of its standard test method for measuring sign retroreflectivity using a portable retroreflectometer (ASTM International 2010).

In practice, eight to 12 readings are typically collected for each color, depending on sign size. The retroreflectometer then computes an average of the reflectivity values measured for each color individually. If this value is above the minimum required values in the MUTCD for each particular color (see Table 2A-3 in the MUTCD and Table 3 in this guide) the sign is acceptable. If the retroreflectivity is below the minimum value for a particular color, the sign will need to be replaced.

Most retroreflectometers are also capable of recording other specific information (e.g., latitude and longitude, text entered by inspector) for inventory systems, use in geographic information systems, etc. This approach does require inspectors to be on the roadside, but it can be completed during daylight. This increases the margin of safety for the data collection effort compared to methods that must be performed at night. Additional information on how a retroreflectometer works and its use is provided in Appendix E.

Expected Sign Life Management Method

The expected sign life approach uses the installation dates of signs in the field to track their ages. The age of the sign in the field is compared to an expected sign life value (the age a sign is expected to degrade below minimum retroreflectivity values) and, once it has exceeded that age, the sign is replaced. The expected life of a particular sign is based on "…weathering deck results, measurements of field signs, sign sheeting warranties, or other criteria" (FHWA 2013).

The advantages of this method are that it is simple to implement and manage, and it does not require time-consuming field inspections (at night). Its disadvantage is that signs that still have remaining retroreflectivity life may be replaced, using financial resources unnecessarily.

Blanket Replacement Management Method

The blanket replacement approach to sign management requires the replacement of all signs on a particular roadway, in a geographic area, etc., at some specified interval (e.g., every seven years). In this case, the age of individual signs does not need to be tracked, but signs that still meet minimum retroreflectivity may be removed. The replacement along the roadway or within the area is based on expected sign life values and the shortest-life sign sheeting material dictates the replacement interval. For example, if the shortest-lived sign sheeting used for a particular group of signs is seven years based on a manufacturer's guidance, all signs are replaced after a seven year period.

The advantages of this method are that it is simple to implement and manage, and it does not require time-consuming field inspections. Its disadvantages are that replacing an entire group of signs means that even signs that were recently replaced for other reasons (e.g., vandalism or damage) are replaced again, expending financial resources in the process.

Control Signs Management Method

The control signs approach to sign management relies on the retroreflectivity performance of a sample of signs either in the field or in a maintenance yard. These signs are selected as representative of those that have been installed throughout a jurisdiction and they are monitored to determine when the minimum retroreflectivity of that set of signs is reached. Once the minimum retroreflectivity of each control sign is reached, the set of signs in the field that it represents is replaced.

Combination of Methods

The MUTCD allows agencies to use a combination of the assessment or management methods described above to address sign retroreflectivity (FHWA 2012). For example, the blanket replacement and expected sign life approaches can be used together to identify when sign replacements may be needed based on the expected life for a particular type of sign/material (such as all stop signs using prismatic sheeting). All of the signs of that type would then be replaced once sign life is exceeded.

Another combination approach might use the visual nighttime inspection (calibration signs) and control signs methods. Control signs would be monitored to determine the rate of retroreflectivity deterioration, and the signs in the field would be visually inspected at night for comparison purposes. If the control signs had deteriorated past the retroreflectivity minimums, the comparable signs in the field would be replaced as well.

Various combinations of methods can be applied if desired. Finally, an agency can also develop their own assessment or management method based on engineering studies, provided that the approach is designed to meet the minimum retroreflectivity levels described in Table 2A-3 of the MUTCD and the standard set in Section 2A.08 (FHWA 2012).

Additional Signing Considerations

In addition to a focus on MUTCD retroreflectivity requirements, a number of other activities are done to properly maintain a sign. These are discussed in this section.

Cleaning

Signs may need to undergo cleaning (depending on conditions) to maintain their visibility during all times of day. A dirty sign may be legible during the day, but nearly invisible at night (i.e., no legibility or retroreflectivity). One example of this occurrence is shown in Figure 13.

David Veneziano, Iowa LTAP

Figure 13. Dirty speed limit sign during the day (left) and at night (right)

Signs located under trees, along truck routes, and in other locations where airborne materials are present may require more frequent sign cleaning.

Vegetation

Sign visibility must also be maintained through vegetation control. Brush control to remove small vegetation that may grow and cover a sign helps to avoid this occurring. The FHWA *Vegetation Control for Safety: A Guide for Local Highway and Street Maintenance Personnel* recommends this activity be performed as part of routine maintenance patrols, with trees, brush, weeds or grass trimmed or cut to provide a clear sight to signs (ISU Technology Transfer Center 2008). A partial sign obstruction due to vegetation is shown in Figure 14.

Paul Albritton, Iowa LTAP

Figure 14. Chevron obstructed by tree branches

Knock Downs and Vandalism

Signs that have been knocked down should be addressed as soon as possible, particularly regulatory and warning signs, to ensure that drivers are presented with the information necessary to accomplish their task. Signs that are repeatedly hit by vehicles running off the road may also be indicative of a potential safety problem at a site. Intentional sign damage, vandalism, and theft for example, are also issues that need to be monitored and addressed. Signs that are marked with bullet holes or paintballs should be replaced or cleaned. Bent signs do not appear as the proper shape nor have the proper retroreflectivity and should be repaired or replaced. Sign theft should also be addressed through replacement as soon as possible. Theft can be minimized or prevented by using specialized fasteners or hammering bolt threads down (see Figure 15).

David Veneziano, Iowa LTAP

Figure 15. Sign theft prevention fastener

Any signs with damage to their retroreflective sheeting can experience degradation. It is also important to remember that signs may not meet MUTCD requirements for many reasons other than retroreflectivity.

Chapter Summary

This chapter discussed different signing program aspects, including Iowa county policy content, aspects of signing inventory, retroreflectivity requirements, and additional singing considerations, such as maintenance. The sign assessment or management approaches used by Iowa counties that had their policies reviewed as part of this project included calibration signs assessment and the expected sign life management method. Other methods are also used in Iowa.

Additional county policy content discussed sign inspection and replacement, and inventory. Sign inventories often include retroreflectivity information, which is the result of MUTCD requirements to maintain minimum retroreflectivity levels for signs. Local agencies are required to have a sign assessment or management method in place and implemented to track retroreflectivity to meet those minimums. Minimum retroreflectivity is maintained through sign assessment and management approaches. Those approaches were described in this chapter and included the following: calibrated signs, comparison panels, consistent parameters, retroreflectivity measurement, expected sign life, blanket replacement, and control signs. Table 4 provides a summary of the characteristics of these seven retroreflectivity assessment and management methods.

Finally, the additional signing considerations that were discussed included general maintenance for signs, including cleaning, repair, and knock downs and vandalism.

References

ASTM International. 2010. *Standard Test Method for Measurement of Retroreflective Signs Using a Portable Retroreflectometer at a 0.2 Degree Observation Angle (E1709).* ASTM International, West Conshohocken, PA.

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

FHWA. 2013. *Maintaining Traffic Sign Retroreflectivity*. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

ISU Technology Transfer Center. 2008. *Vegetation Control for Safety: A Guide for Local Highway and Street Maintenance Personnel*. Federal Highway Administration, Office of Highway Safety, Washington, DC.

Preston, H. and M. Barry. 2010. *Minnesota's Best Practices for Traffic Sign Maintenance/Management Handbook*. 2010RIC10. Minnesota Department of Transportation, St. Paul, MN.

Simpson, C. L. and J. E. Hummer. 2010. Evaluation of the Conversion from Two-Way Stop Sign Control to All-Way Stop Sign Control at 53 Locations in North Carolina. *Journal of Transportation Safety and Security*, Vol 2, No. 3, pp. 239-260.

Table 4. Retroreflectivity assessment and management methods

Method Selected and Implemented by June 2014		Equipment Used			Inspector Requirements		Time	
		Inspection Vehicle	Retro-reflectometer Use	Known Sign Sheeting Type	Training Required	Age	Day or Night	Visit Sign
Assessment Methods	Calibration Signs	Any vehicle	No	No	Yes	Any	Night	Yes
	Comparison Panels	Any vehicle	No	No	Yes	Any	Night	Yes
	Consistent Parameters	SUV or pick-up	No	No	Yes	60+	Night	Yes
	Measure Retroreflectivity	Any vehicle	Yes	Yes	Yes	Any	Day	Yes
Management Methods	Expected Sign Life	N/A	No	Yes	No	Any	N/A	No
	Blanket Replacement	N/A	No	Yes	No	Any	N/A	No
	Control Signs	Any vehicle*	Yes*	Yes	No	Any	Night*	Yes*

* Control locations only

Chapter 4. Liability and Signs in Iowa

One of the tasks included in this project was to request some legal input about the liability issues connected to traffic control devices, from the perspective of a local municipality in Iowa. This task was accomplished through the Iowa State Association of Counties (ISAC). ISAC obtained an opinion through an attorney used by the Iowa Communities Assurance Pool (ICAP), and this opinion letter is included in Appendix F. The letter provides a discussion of the protections offered to the State and municipalities in Iowa by referring to the Iowa Code that applies, Section 668.10(1)(a) (Iowa Code 2015c), and stating the following:

"In its simplest interpretation, a municipality cannot be held liable for failing to place, erect or install traffic control devices, on any type of road. However, once the traffic control device has been installed, a municipality can be assigned fault if the municipality does not properly and adequately maintain the device." (Madsen 2015)

This statement is also supported by a short discussion related to immunity and traffic control devices. Two specific points made in the letter include the following:

"The immunity granted to municipalities applies to all such placements or installation and thus a claim that the municipality should have done more to warn motorists or should have installed more traffic control devices does not overcome the immunity. McClain v. State, 563 N.W.2d 600 (Iowa 1997).

"It even applies when the state or local government creates a road hazard through its own maintenance or construction and fails to erect warning signs. Foster v. City of Council Bluffs, 456 N.W.2d 1 (Iowa 1990). Section 668.10(1)(a) immunity also applies to state contractors and subcontractors who comply with the State's plans and specifications and who are not negligent in performing the work. McLain v. State, 563 N.W.2d 600 (Iowa 1997)." (Madsen 2015)

The letter provided to us, however, also included a discussion of exceptions to this statutory immunity: "(1) claims for failure to maintain a device; (2) claims for the installation of a misleading sign; and (3) claims that exigencies are such that ordinary care would require the state or municipality to warn of dangerous conditions by other than inanimate devices. Hunt v. State, 538 N.W.2d 659 (Iowa Ct. App. 1995); Estate of Oswald v. Dubuque County, 511 N.W.2d 637 (Iowa Ct. App. 1993)" (Madsen 2015).

Readers are strongly encouraged to read the entirety of the letter in Appendix F and discuss it with their local legal representation. The letter includes additional information and detail not included in the summary above. The conclusion of the research team, based on the content, was that the information provided is generally common knowledge for local agencies in Iowa, but that some of the additional detail may be of value in sign-related decision-making.

References

Iowa Code. 2015c. *State of Iowa Code. 668.10, Governmental Exemptions. Title VIII, Subtitle 2, Chapter 668, Liability in Tort – Comparative Fault*. Des Moines, IA.

Madsen, K. K 2015. Opinion letter received March 2015. Stuart Tinley Law Firm, LLP, Council Bluffs, IA.

Chapter 5. Conclusions and Recommendations

The focus of this project was on compiling and critically reviewing existing information regarding the safety and operational effectiveness and impacts of signs. It provides guidance on the installation, management, maintenance, and removal of signs.

The project included a literature review, which critically evaluated, summarized, and rated existing research related to a variety of regulatory and warning signs, both unenhanced and enhanced (those with LED borders, beacons, etc.), a review of sign removal considerations, and a review of sign installation, management, and maintenance information, as well as the legal considerations connected to traffic control devices.

This guide includes the available information on sign effectiveness and/or impacts, while also considering the value and applicability of research results. It also provides guidance on the installation and removal of signs. The document includes a critical evaluation and summary of the documented safety, operational, and/or behavioral research for a variety of signs used by local public agencies in Iowa. It also presents information on sign installation, maintenance, removal, and alternatives.

The guide may help agencies to better manage their signing budgets. The information provided focuses on the needs of local roadway agencies, but it is also relevant to many other users.

The conclusions and recommendations based on the results of the project tasks are described below.

Conclusions

- A rating system of a Low, Medium, and High was developed to establish a level of confidence in the signing research results that were summarized. Safety research ratings were developed based on the star system used in the CMF Clearinghouse. Operational research ratings were developed by the authors based on factors including the number of sites examined, characteristics of the sites, and whether (and which type of) a statistical analysis was performed. The definition of these ratings and the process used to develop them is described in the Results Rating System section in Chapter 2.

- The safety and operational impacts of very few signs that are commonly used by local jurisdictions have been studied—to any great extent—with a research approach that would meet the current state-of-the-practice for highly robust results.

- A review of 48 research documents that focused on the potential safety and/or operational impacts of the 11 signs listed below resulted in a rating of Low, Medium, and High for 6, 14, and 7 of the safety studies, respectively, and 4, 11, and 1 of the operational studies, respectively. (Some of the 48 documents that were reviewed either were not referenced in this guide or did not get rated). The sign sections in Chapter 2 show the wide range and robustness of the research for each of the signs.

For example, safety research on the use of speed limit signs were of Low and Medium robustness, with one study finding crash rates increased as speed variability increased, another finding crash rates rose following increases or decreases in posted speed limits, and a third finding no evidence that crash experience changed with increases or decreases in posted speed limits. Operationally, only one study of Medium robustness was identified, and it found little to no evidence that driver speeds changed when speed limits were increased or decreased.

- The lack of a documented research study focused on the safety or operational effectiveness of a sign, however, does not mean that it is not effective in the accomplishment of its objective(s). A number of static and enhanced signs are currently being studied, and it is expected that many more will be in the future (particularly with the relatively new driver behavior databases being created).

- In addition to the safety and/or operational impacts a sign may be expected to induce, signs may or do produce other driver behavioral changes and impacts that are not as easy to measure. These changes and impacts could be changes in decision-making, acknowledgment of the additional and expected notification of a hazard, and general increase or heightened awareness of a specific regulation or hazard that is essential to the safety and operations of the transportation system.

- Sign removal is a topic that has not been discussed to any great extent in past research or guidance documents. However, some suggestions found for removal of stop signs and the MUTCD's summary of components related to signal removal included the following general components: implement a policy, conduct engineering studies, provide notice of an upcoming change and conduct a post-removal evaluation.

- Retroreflectivity is a critical component of roadway signage and the assessment and management approaches available to agencies to meet MUTCD requirements include the following: comparison panels, consistent parameters, retroreflectometer measurement, expected sign life, blanket replacement, and control signs. The selection of a particular approach will vary depending on agency needs, resources, etc.

- The sign assessment or management approaches used by Iowa counties that had their policies reviewed included the calibration signs assessment method and the expected sign life management method; however, other methods are also used by counties in the state (e.g., direct measurement using a retroreflectometer).

- General sign maintenance, including cleaning, repair, etc., is an important component of a sign program to extend the useful life of a sign in the accomplishment of its intended purpose.

- The legal consideration or input provided to the project team about traffic control devices appears to be generally common knowledge to local agency personnel in Iowa. The information provided focused on jurisdictional immunity and the maintenance of traffic control devices once they are installed.

Recommendations

The following recommendations were developed based on the results of the tasks completed as part of this project.

- The research team recommends that this guide, along with the MUTCD and field evaluation, be used by transportation professionals during their determination of whether a particular sign can be expected to produce an impact on safety and/or operations. They recommend that he information related to the results of the research completed on sign impacts, along with new research results as they are published, be used as part of sign-related installation and removal decision-making.

  The results are generally applicable to situations similar to those that were studied (e.g., high speed rural settings, lower speed urban settings), and should be useful to those making sign-related decisions (e.g., installation, removal) on a case-by-case basis, as long as the robustness ratings of the research results are also considered. The settings for each of the research studies are summarized in each section of Chapter 2 and in the quick-reference tables (A.1 through A.11) in Appendix A.

- The researchers recommend that an investigation be completed to gather and summarize sign removal policies from throughout the US. An evaluation of the steps included and a study of the potential or actual operational and safety impacts of applying those steps may be of interest also. The research should be done in a robust manner and follow currently accepted state-of-the-practice approaches for safety analysis. The team also recommends that an investigation be completed that considers the need for different removal policies for different types of signs and/or pavement markings (e.g., stop signs, stop-ahead warning signs).

- The research team recommends that the results of the sign removal policy investigation be used by a local agency steering committee to develop sample sign removal procedure policies. This information would need to be reviewed by legal counsel, but should be of value to local agencies.

- The MUTCD has required agencies to use a minimum retroreflectivity assessment or management method since June 1, 2014. The researchers recommend that the advantages and disadvantages experienced in the field by local agencies be explored for the various approaches in use. The information developed could be useful to local agencies in their future decision-making about this requirement.

- Based on a cursory review of *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties* (Iowa DOT n.d.), a number of updates and revisions are required (see Appendix G). An update of this document was beyond the scope of work for this project, and the project team recommends that a more comprehensive review and update be completed in the near future.

References

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

Iowa DOT. No date. *Speed Limit Questions? Here's Your Answer*. Iowa Department of Transportation Office of Traffic and Safety, Ames, IA.

Souleyrette, R., R. Tenges, T. McDonald, and T. Maze. 2005. *Guidelines for Removal of Traffic Control Devices in Rural Areas*. Center for Transportation Research and Education, Iowa State University, Ames, IA.

Master References List

AASHTO. 2010. *Highway Safety Manual (HSM).* 1st Edition. American Association of State Highway Officials, Washington, DC.

Allen, R. E. and D. R. McCullough. 1976. Deer-Car Accidents in Southern Michigan. *Journal of Wildlife Management*, Vol. 40, No. 2, pp. 317-325.

Appiah, J., L. Rilett, and Z. Wu. 2011a. *Evaluation of NDOR's Actuated Advance Warning Systems*. NTC Report TSPT1-03, Nebraska Transportation Center, Lincoln, NE.

Appiah, J., B. Naik, R. Wojtal, and L. Rilett. 2011b. Safety Effectiveness of Actuated Advance Warning Systems. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2250, pp. 19-24.

Appiah, J., L. Rilett, B. Naik, and R. Wojtal. 2013. Driver Response to an Actuated Advance Warning System. *Journal of Transportation Engineering*, Vol. 139, No. 5, pp. 433-440.

Arnold, E. and K. Lantz. 2007. *Evaluation of Best Practices in Traffic Operations and Safety Phase 1: Flashing LED Stop Sign and Optical Speed Bars*. Virginia Transportation Research Council, Charlottesville, VA.

ASTM International. 2010. *Standard Test Method for Measurement of Retroreflective Signs Using a Portable Retroreflectometer at a 0.2 Degree Observation Angle (E1709).* ASTM International, West Conshohocken, PA.

Balke, K., L. Higgins, S. Chrysler, G. Pesti, N. Chaudhary, and R. Brydia. 2011. *Signing Strategies for Low-Water and Flood-Prone Highway Crossings*. Report FHWA/TX-12/0-6262-1, Texas Transportation Institute, College Station, TX.

Beaubien, R. 1976. Stop Signs for Speed Control? *Traffic Engineering*, Vol. 46, No. 11, pp. 26-28.

Beaubien, R. 1989. Controlling Speeds on Residential Streets. *ITE Journal*, Vol. 59, No. 4, pp. 37-39.

Bullough, J., N. Skinner, J. Brons, and M. Rea. 2012. *Using Lighting and Visual Information to Alter Driver Behavior.* Rensselaer Polytechnic Institute, Rensselaer, NY.

Carson, J. and F. Mannering. 2001. The Effect of Ice Warning Signs on Ice-Accident Frequencies and Severities. *Accident Analysis and Prevention*, Vol. 33, pp. 99-109.

Chrysler, S., J. Re, K. Knapp, D. Funkhouser, and B. Kuhn. 2009. *Driver Response to Delineation Treatments on Horizontal Curves on Two-Lane Roads*. Report FHWA/TX-09/0-5772-1, Texas Transportation Institute, College Station, TX.

CTC & Associates. 2007. *Effectiveness of "Children at Play" Warning Signs*. Wisconsin Department of Transportation, Madison, WI.

Davis, G.. K. Knapp, and J. Hourdos. 2012. *Vehicle Speed Impacts of Occasional Hazard (Playground) Warning Signs*. Minnesota Department of Transportation, St. Paul, MN.

Davis, G., J. Hourdos, and H. Xiong. 2014. *Estimating the Crash Reduction and Vehicle Dynamics Effects of Flashing LED Stop Signs*. Minnesota Department of Transportation, St. Paul, MN.

Dixon, K and R. Avelar. 2011. *Safety Evaluation of Curve Warning Speed Signs*. Oregon State University, Corvallis, OR.

FHWA. 2012. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition with Revision Numbers 1 and 2 incorporated, dated May 2012. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

FHWA. 2013. *Maintaining Traffic Sign Retroreflectivity*. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

FHWA. 2016a. Crash Modification Factors Clearinghouse. Federal Highway Administration, U.S. Department of Transportation, Washington, DC. www.cmfclearinghouse.org/sqr.cfm.

FHWA. 2016b. *Safety Evaluation of Intersection Conflict Warning Systems (ICWS) Tech Brief*. FHWA-HRT-15-076, Federal Highway Administration, Research and Development, Turner-Fairbank Highway Research Center, McLean, VA.

Fitzpatrick, K., S. Turner, M. Brewer, P. Carlson, B. Ullman, N. Trout, E. S. Park, J. Whitacre, N. Lalani, and D. Lord. 2007. *Improving Pedestrian Safety at Unsignalized Crossings*. TCRP Report 112/NCHRP Report 562. Transit Cooperative Research Program and National Cooperative Highway Research Program, Washington, DC.

Forbes, G. J., T, Gardner, H. McGee, and R, Srinivasan. 2012. *Methods and Practices for Setting Speed Limits: An Informational Report*. Federal Highway Administration Office of Safety and Institute of Transportation Engineers, Washington, DC.

Hammond, C. and M. Wade. 2004. *Deer Avoidance: The Assessment of Real World Enhanced Deer Signage in a Virtual Environment*. MN/RC-2004-13. Minnesota Department of Transportation, St. Paul, MN.

Iowa Code. 2015a. *State of Iowa Code. 321.252, Department to Adopt Sign Manual. Title VIII, Subtitle 2, Section 321.252, Motor Vehicles and Law of the Road*. Des Moines, IA.

Iowa Code. 2015b. *State of Iowa Code. 321.249, School Zones Title VIII, Subtitle 2, Section 321.249, Motor Vehicles and Law of the Road*. Des Moines, IA.

Iowa Code. 2015c. *State of Iowa Code. 668.10, Governmental Exemptions. Title VIII, Subtitle 2, Chapter 668, Liability in Tort – Comparative Fault*. Des Moines, IA.

Iowa DOT. No date. *Speed Limit Questions? Here's Your Answer*. Iowa Department of Transportation Office of Traffic and Safety, Ames, IA.

ISU Technology Transfer Center. 2008. *Vegetation Control for Safety: A Guide for Local Highway and Street Maintenance Personnel*. Federal Highway Administration, Office of Highway Safety, Washington, DC.

Knapp, K. and X. Yi. 2006. Crash Data and Deer Crossing Sign Installation. ITE Journal on the Web, pp. 69-73, May 2006.

Kwon, T. and R. Weidemann. 2010. *Advanced LED Warning Signs for Rural Intersections Powered by Renewable Energy*. MN/RC 2011-04. Minnesota Department of Transportation, St. Paul, MN.

Lalani, N. 1992. Comprehensive Safety Program Produces Dramatic Results. *ITE Journal*, Vol. 61, No. 10, pp. 31-34.

Lohnes, R., R. Gu, T. McDonald, and M. Jha. 2001. *Low Water Stream Crossings: Design and Construction Recommendations*. Center for Transportation Research and Education, Iowa State University, Ames, IA.

Madsen, K. K 2015. Opinion letter received March 2015. Stuart Tinley Law Firm, LLP, Council Bluffs, IA.

McGee, H. and M. Blankenship. 1989. *NCHRP Report 320: Guidelines for Converting Stop to Yield Control at Intersections*. National Cooperative Highway Research Program, Washington, DC.

Meyer, E. 2006. *Assessing the Effectiveness of Deer Warning* Signs. University of Kansas, Topeka, KS.

MoDOT. No date. *Missouri DOT Intersection Warning System Before-After Study Results*. Missouri Department of Transportation, Jefferson City, MO. Available at: www.enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/MOIWSBeforeAfterStudy.pdf.

Montella, A. 2009. Safety Evaluation of Curve Delineation Improvements. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2103, pp. 69-79.

Murphy, B. and J. Hummer. 2007. Development of Crash Reduction Factors for Overhead Flashing Beacons at Rural Intersections in North Carolina. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2030, pp. 15-21.

Oneyear, N., S. Hallmark, and B. Wang. 2016. *Evaluating the Relationship between the Driver and Roadway to Address Rural Intersection Safety using the SHRP 2 Naturalistic Driving Study Data*. Center for Transportation Research and Education, Institute for Transportation, Iowa State University, Ames, IA.

Parker, M. R., Jr. 1997. *Effects of Raising and Lowering Speed Limits on Selected Roadway Sections*. FHWA-RD-97-084. Federal Highway Administration, Research and Development, Turner-Fairbank Highway Research Center, McLean, VA.

Peaslee, G. 2005. Signs Show the Way to Cost-Effective Rural Safety. *Public Roads*, Vol. 68, No. 4.

Preston, H. and M. Barry. 2010. *Minnesota's Best Practices for Traffic Sign Maintenance/Management Handbook*. 2010RIC10. Minnesota Department of Transportation, St. Paul, MN.

Preston, H., R. Newton, D. Keltner, and C. Albrecht. 1998. *Statistical Relationship Between Vehicular Crashes and Highway Access*. MN/RC-1998-27. Minnesota Department of Transportation, St. Paul, MN.

Re, J., G. Hawkins, and S. Chrysler. 2010. Assessing Benefits of Chevrons with Full Retroreflective Signposts on Rural Horizontal Curves. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2149, pp. 30-36.

Ritchie, M. 1972. Choice of Speed in Driving Through Curves as a Function of Advisory Speed and Curve Signs. *Human Factors*, Vol. 14, No. 6, pp. 533-538.

Schultz, G. and E. Talbot. 2009. Advance Warning Signals Long-Term Monitoring Results. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2122, pp. 27-35.

Simpson, C. L. and J. E. Hummer. 2010. Evaluation of the Conversion from Two-Way Stop Sign Control to All-Way Stop Sign Control at 53 Locations in North Carolina. *Journal of Transportation Safety and Security*, Vol 2, No. 3, pp. 239-260.

Simpson, C. and S. Troy. 2013. Safety Effectiveness of "Vehicle Entering When Flashing" Signs: Evaluation of 74 Stop-Controlled Intersections in North Carolina. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2384, pp. 1-9.

Solomon, D. 1964. *Accidents on Main Rural Highways Related to Speed, Driver, and Vehicle*. Traffic Systems Research Division, Office of Research and Development, U.S. Department of Commerce, Bureau of Public Roads, Washington, DC.

Souleyrette, R., R. Tenges, T. McDonald, and T. Maze. 2005. *Guidelines for Removal of Traffic Control Devices in Rural Areas*. Center for Transportation Research and Education, Iowa State University, Ames, IA.

Srinivasan, R., D. Carter, K. Eccles, B. Persaud, N. Lefler, C. Lyon, and R. Amjadi. 2008. *Safety Evaluation of Flashing Beacons at STOP-Controlled Intersections*. FHWA-HRT-08-044. Federal Highway Administration, Research, Development, and Technology, Turner-Fairbank Highway Research Center, McLean, VA.

Srinivasan, R., J. Baek, D. Carter, B. Persaud, C. Lyon, K. Eccles, F. Gross, and N. Lefler. 2009. *Safety Evaluation of Improved Curve Delineation*. Report No. FHWA-HRT-09-045. Federal Highway Administration, Research, Development, and Technology, Turner-Fairbank Highway Research Center, McLean, VA.

Stanley, L., A. Hardy, and S. Lassacher. 2006. Responses to Enhanced Wildlife Advisories in a Simulated Environment. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1980, pp. 126-133.

Stackhouse, S. and P. Cassidy. 1996. *Warning Flashers at Rural Intersections*. MN/RC - 1998/01. Minnesota Department of Transportation, St. Paul, MN.

Stockton, W., R. Brackett, and J. Mounce. 1981. *Stop, Yield, and No Control at Intersections*. Texas Transportation Institute, College Station, TX.

Sullivan, T. L., A. F. Williams, T. A. Messmer, L. A. Hellinga, and S. Y. Kyrychenko. 2004. Effectiveness of Temporary Warning Signs in Reducing Deer-Vehicle Collisions during Mule Deer Migrations. *Wildlife Society Bulletin*, Vol. 32, No. 3, pp. 907-915.

Sunkari, S., C. Messer, and H. Charara. 2005. Performance of Advance Warning for End of Green System for High-Speed Signalized Intersections. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1925, pp. 176-184.

Wilmot, C. G. and A. S. Jayadevan. 2006. *Effect of Speed Limit Increase on Crash Rate on Rural Two-Lane Highways in Louisiana*. Technical Assistance Report No. 07-1TA. Louisiana Transportation Research Center, Louisiana State University, Baton Rouge, LA.

Yi, X. 2003. Deer-Vehicle Crash Patterns and Deer Crossing Sign Placement. Master's Thesis, University of Wisconsin, Madison, WI.

Zegeer, C. V., J. R. Stewart, H. H. Huang, P. A. Lagerwey, J. Feaganes, and B. J. Campbell. 2005. *Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines*. FHWA-HRT-04-100, Federal Highway Administration, Research, Development, and Technology, Turner-Fairbank Highway Research Center, McLean, VA.

Appendix A. Summary Tables of Sign Studies

Table A.1. Stop sign studies

Study	Location	No. of Sites	Safety Impact(s)	Operational Impact(s)	Study Confidence
Stockton et al. 1981	NY, TX, and FL Urban and Rural	48	Conversion from yield to TWSC did not significantly reduce crashes	Field studies observed 19% voluntary stops at TWSC and AWSC sites	Medium
Souleyrette et al. 2005	IA Rural	500+	Crash rates for ultra-low volume two-way stop control not significantly different from no control Uncontrolled crash rate appears to decline versus AWSC above 150 DEV	N/A	Medium
Simpson and Hummer 2010	NC Urban and Rural	53	Conversion from TWSC to AWSC produced 68.1% crash reduction	N/A	High

TWSC - Two-way stop control, AWSC - All-way stop control, DEV - Daily entering vehicles

Table A.2. Yield sign studies

Study	Location	No. of Sites	Safety Impact(s)	Operational Impact(s)	Study Confidence
McGee and Blankenship 1989	CO, MI, and SD Urban	141	Conversion from stop to yield expected to increase crash frequency by one crash every 2 years	N/A	Low
Stockton et al. 1981	NY, TX, and FL Urban and Rural	48	N/A	Conversion from stop to yield produced 2-4 second time savings	Medium

TWSC - Two-way stop control, AWSC - All-way stop control, DEV - Daily entering vehicles

Table A.3. Speed limit sign studies

Study	Location	No. of Sites	Safety Impact(s)	Operational Impact(s)	Study Confidence
Solomon 1964	11 states	600 miles of rural roads	Crash rates increase as speed variability increases Crash involvement lowest at speeds slightly above average travel speeds	N/A	Low
Parker 1997	22 states Urban and Rural	100 segments 1 to 2 miles long	No evidence of crash frequency changes with raise or lowering of speed limit	Minor changes (~1.5 mph) in driver speeds with raise or lowering of speed limit	Medium
Wilmot and Jaydevan 2006	LA Rural	Statewide two-lane roads	ROTR injury, rear-end injury, ROTR PDO, rear-end PDO, and overturn PDO crash rates increased following speed limit increase	N/A	Medium

ROTR - Run off the road, PDO - Property damage only

Table A.4. Horizontal alignment warning sign studies

Study	Location	No. of Sites	Safety Impact(s)	Operational Impact(s)	Study Confidence
Srinivasan et al. 2009	CT and WA Rural	228	Installing curve warning signs and chevrons produced: 18% reduction in injury and fatal crashes 27.5% reduction in nighttime crashes 25% reduction in lane departure crashes	N/A	High
Lalani 1992	CA Urban	3	Chevrons produced 50% reduction in crashes	N/A	Low
Montella 2009	Italy Rural	15	Chevrons produced 2.6% crash reduction Curve warning signs and chevrons produced 40.8% crash reduction Curve warning signs, chevrons and beacons produced 47.6% crash reduction	N/A	Medium
Dixon and Avelar 2011	OR Rural	16	Curve advisory speed plaque had small positive impact on crash reduction	N/A	Medium
Peaslee 2005	CA Rural	Unknown	Curve warning sign installation produced 42.1% crash reduction	N/A	Low
Re et al. 2010	TX Rural	2	N/A	Chevrons produced 1.28 mph mean speed reduction Chevrons and reflectors produced 2.20 mph mean speed reduction	Medium
Chrysler et al. 2009	TX Rural	5	N/A	Installation of chevrons reduced mean speeds 0.17-4.08 mph	Medium
Bullough et al. 2012	NY Rural	2	N/A	Progressively larger chevrons reduced mean speeds 05.0-1.75 mph during daylight and 3.0 mph at night	Medium
Ritchie 1972	OH Rural	162	N/A	Average horizontal curve speeds exceeded posted advisory speed when advisory was less than 40 mph	Medium

Table A.5. Playground and children at play sign studies

Study	Location	No. of Sites	Safety Impact(s)	Operational Impact(s)	Study Confidence
Davis et al. 2012	MN Urban	3	N/A	No effect on mean speeds (one site) and decreases of 0.9-1.5 mph (two sites)	Medium

Table A.6. Deer crossing sign studies

Study	Location	No. of Sites	Safety Impact(s)	Operational Impact(s)	Study Confidence
Knapp and Yi 2006	WI Rural	22	DVC frequencies and rates between warning signs higher than adjoining segments	N/A	Medium
Meyer 2006	KS Rural	123 segments	Signs did not have any impact or reduce crash rates after installation	N/A	Medium
Sullivan et al. 2004	UT, NV, and ID Rural	5 segments 5 to 13 miles long	Crash reduction of 51% for signs with flashing beacons (mule deer migration areas)	Seasonal signs found to reduce likelihood of high vehicle speeds	Medium
Hammond and Wade 2004	N/A	1 (simulator)	N/A	Speed reduction of 2.32 mph within 500 feet of beacon-enhanced sign	Medium
Stanley et al. 2006	N/A	1 (simulator)	N/A	Speed decreases and braking increased when signs enhanced	Medium

DVC - Deer vehicle crashes

Table A.7. Ice warning sign studies

Study	Location	No. of Sites	Safety Impact(s)	Operational Impact(s)	Study Confidence
Carson and Mannering 2001	WA Urban and Rural	N/A - Evaluated sign presence in conjunction with individual crashes	Installation does not have a statistically significant impact on frequency or severity of ice-related crashes	N/A	Medium

Table A.8. Road may flood warning sign studies

Study	Location	No. of Sites	Safety Impact(s)	Operational Impact(s)	Study Confidence
Balke et al. 2011	TX	74 focus group participants Rural images used	Presence of signs did not significantly impact decisions to continue on roadways covered with water	N/A	Low

Table A.9. Electronically enhanced stop sign studies

Study	Location	No. of Sites	Safety Impact(s)	Operational Impact(s)	Study Confidence
Davis et al. 2014	MN Urban and Rural	15	Flashing LED border - 41.5 % right angle crash reduction	N/A	High
Srinivasan et al. 2008	NC and SC Urban and Rural	5	Sign-mounted beacon - 58.2% reduction in angle crashes	N/A	High
Murphy and Hummer 2007	NC and SC Rural	34	Overhead beacons - 12% total crash reduction, 40% injury crash reduction, 26% reduction in failure to stop crashes	N/A	Medium
Stackhouse and Cassidy 1996	MN	4	Sign-mounted beacon - 40% crash reduction	N/A	Low
Arnold and Lantz 2007	VA	1	N/A	LED borders produced 1 to 3 mph speed reduction in advance of intersection; greater decrease at night	Low
Oneyear, et al. 2016	WA, PA, NC, and NY Rural	64	N/A	Presence of overhead beacons increased braking distance by 220 feet	Medium

Table A.10. Unsignalized intersection conflict warning system studies

Study	Location	No. of Sites	Safety Impact(s)	Operational Impact(s)	Study Confidence
Simpson and Troy 2013	NC Urban and rural sites	23 with flashers on major 7 with flashers on major and minor	Signs alerting major approaches reduced total crashes by 32% Signs alerting major and minor approaches reduced crashes by 25%	N/A	High
MoDOT n.d.	MO Rural sites	19 total 9 with flashers on major 10 with flashers on minor	Signs reduced total crashes by 28%, severe crashes by 72%, and angle crashes by 25%	N/A	Low
FHWA 2016b	MO, MN, and NC Rural sites	88 sites in total spread among the three states	Two-lane by two-lane sites: Total crash reduction 26.7% Fatal and injury crash reduction 29.9% Right-angle crash reduction 19.7% Nighttime crash reduction 11.2% Four-lane by two-lane sites: Total crash reduction 17.3% Fatal and injury crash reduction 19.8% Right-angle crash reduction 15.0% Nighttime crash reduction 38.8%	N/A	High
Kwon and Weidemann 2010	MN Rural site	1	N/A	Similar systems reduce average speeds by 4.5 mph on all approaches	Low

Table A.11. Signalized intersection advance warning system studies

Study	Location	No. of Sites	Safety Impact(s)	Operational Impact(s)	Study Confidence
Schultz and Talbot 2009	UT Urban	3	Total crash reduction of 34%	N/A	Medium
Appiah et al. 2011a, 2011b	NE Urban and Rural	26	Total crash reduction of 8.2%	N/A	High
Appiah et al. 2013	NE Urban and Rural	26	N/A	78% of drivers maintained or reduced speed when signs were active	High
Sunkari et al. 2005	TX Urban	2	N/A	Experimental advance warning for "end of green" reduced red light running by 40%	Low

Appendix B. Clinton County, Iowa Sign Policy

CLINTON COUNTY SECONDARY ROAD DEPARTMENT
POLICY AND PROCEDURES
FOR
TRAFFIC SIGNAGE REPAIR AND REPLACEMENT

SUBJECT: Establish department procedures and policies for traffic sign inspection and replacement in accordance with applicable state and federal requirements.

GENERAL: The Clinton County Board of Supervisors recognizes the fact that traffic signage within the county road right-of-way may be damaged or destroyed outside normal Secondary Road crew working hours and that the sign sheeting will lose retroreflectivity over time. It is the policy of Clinton County to replace or repair within a reasonable period of time traffic signs that are destroyed, damaged or have lost their retroreflectivity. This policy statement will cover the procedures to be followed in accordance with this objective and establish regular inspection and replacement procedures. This policy will be subject to change in order to comply with periodic revisions to the Manual on Uniform Traffic Control Devices (MUTCD) as approved by the Federal Highway Administration (FHWA) and the Iowa Department of Transportation.

PROCEDURES:

A. Replacement of Signs Required Due to Damage or Theft

The Maintenance Superintendent or designated representative will evaluate reports and claims regarding traffic sign damage or theft. The evaluation of all such reports and claims shall be conducted as promptly as possible and a determination made by the Maintenance Superintendent or designated representative as to the validity and extent of damage. The following types of signs should be replaced within 24 hours of verification of damage.

1. Stop Signs and Stop Ahead Signs

2. Horizontal Alignment Warning Signs

3. No Shoulder Signs

4. Speed Limit Signs

5. Two-Direction Large Arrow Signs

6. Yield Signs

The replacement or repair of these signs may be completed under an overtime call-in situation as required to facilitate repair or replacement within 24 hours of verification of damage. If the Maintenance Superintendent determines that the missing sign is an immediate hazard to the traveling public he/she may install temporary signage and make temporary repairs before calling

Secondary Road Department personnel to permanently repair or replace the sign. Repair or replacement within 24 hours is subject to manpower, equipment and material availability. If conditions exist where these signs cannot be replaced or repaired within 24 hours temporary signage should be installed until permanent repairs can be completed.

Other types of signs damaged that will not normally be replaced or repaired until normal Secondary Road Department working hours include: 911 address signs, no passing signs, crossing signs, street and avenue signs, warning signs not previously listed, and various other traffic signs used throughout the county not previously listed in items 1-6. The Maintenance Superintendent or designated representative may call Secondary Road Department personnel in under an overtime situation to repair or replace a sign not listed in items 1 through 6 at his/her discretion.

B. Replacement of Signs in Accordance with Minimum Retroreflectivity Requirements

In order to comply with the FHWA minimum retroreflectivity levels as adopted by the MUTCD 2009 edition and subsequent revisions, Clinton County will implement a combination of the Expected Sign Life Management Method and the Measured Sign Retroreflectivity Assessment Method for maintaining sign retroreflectivity. These methods are approved by the FHWA for maintaining sign retroreflectivity. The Expected Sign Life Management Method requires monitoring the age and condition of signs and replacing signs before they reach their expected sign life. The expected sign life is based on the experience of sign retroreflectivity degradation in a geographic area compared to minimum levels. Based on field measurement of sign retroreflectivity in Clinton County the sign life expectancy for High Intensity Prismatic Sheeting is 15.04 years.

1. Each year applicable signs with a service life greater than 14 years will have their retroreflectivity measured in the field. Those signs not meeting the minimum retroreflectivity requirements will be scheduled for replacement within the fiscal year they were measured.

2. Visual inspections will also be conducted to evaluate sign positioning, cleanliness, legibility and overall general condition.

3. The following signs are excluded from minimum retroreflectivity requirements: parking, standing and stopping signs (R7-R8 series), walking/hitchhiking/crossing signs (R9 series and R10-1 thru R10-4b), Adopt-A-Highway signs and all signs with blue or brown backgrounds.

4. Signs will normally be replaced with "Diamond Grade" DG3 reflective sheeting and/or DG3 (VIP-fluorescent) signs. Warranty period specified by the manufacturer is 12-years.

5. Installation and location of signs shall be in accordance with the current version of the "Manual on Uniform Traffic Control Devices" (Chapter 2A) as approved by the Iowa Department of Transportation.

Appendix C. Woodbury County, Iowa Sign Policy

WOODBURY COUNTY SECONDARY ROAD DEPARTMENT
POLICY AND PROCEDURE MEMORANDUM

Sign Installation, Inspection, and Maintenance Program and Policy

Background: The 2009 Manual on Uniform Traffic Control Devices (MUTCD) is the official sign manual for the State of Iowa as defined in Section 321.252. Woodbury County adopts and follows the appropriate provisions of the MUTCD as required in Section 321.255.

Sign Facing: The County will use only high intensity or higher grade prismatic sheeting for all traffic signs on county highways. This shall not preclude the County Engineer from utilizing current stock of engineer grade signs that were purchased or installed prior to the adoption of this policy until their usefulness is exhausted. The County Engineer, in his professional judgment, will determine locations where higher grade sheeting is required for additional warning or visibility.

Street Signs: Street signs shall conform to the Manual on Uniform Traffic Control Devices. Existing signs not in compliance with the current MUTCD standards will be replaced with compliant signs at the end of the current sign's useful life.

Retroreflectivity and nighttime visibility: Woodbury County will comply with standards for maintaining nighttime sign visibility as required in section 2A.08 of the MUTCD by a program of nighttime visual inspection of county road signs. The retroreflectivity of existing signs will be assessed by a trained sign inspector conducting a visual inspection from a moving vehicle during nighttime conditions. Complete system inspection will be done in compliance with MUTCD recommendations on a bi-annual basis beginning in 2014. Signs that are visually identified by the inspector to have retroreflectivity below the minimum levels will be replaced as soon as budget and staff time allow after being identified by the inspection.

Secondary Road employees will also be encourage to note and turn in reports of damaged signs or signs screened by vegetation as part of their normal duties while performing work on county roads to supplement this inspection program.

Sign Repair and Replacement: Damaged signs will be repaired or replaced based on the following guidelines:

Stop and Yield Signs: Stop and yield signs will be repaired on a 24 hour per day, 7 day per week basis. Upon receiving a report of the loss or damage to a stop or yield sign from emergency responders, county emergency dispatchers, secondary road department staff or other reports, county secondary road staff will respond as soon as an employee can be called in to work and travel to the location with a replacement sign. Emergency replacement will normally be accomplished by installing a temporary sign on a support, stand or barricade until a permanent replacement can be installed to replace the damaged sign. If time, conditions at the site, and equipment allow, the damaged sign may be replaced on a permanent post immediately at the discretion of the employee or his immediate supervisor. If not placed on a permanent support as part of the emergency repair, the sign will be permanently replaced after a utility locate is performed, usually within two business days.

Warning and other regulatory signs: Warning and other regulatory signs will be repaired the next business day after being reported to the road department if the sign can be replaced within its existing mounting or post hole. Signs which cannot be replaced in their existing mounting or posthole will be replaced as soon as utility locates can be completed.

Rural intersection signs: Rural intersection signs will be replaced as soon as new signs are available during the sign technician's normal working day. Since rural intersection signs are not always kept in stock, a period of days or weeks may pass before replacement signs can be ordered and manufactured.

Supplemental signs: This policy serves direction for the placement of certain signs either not contained in the manual or not required by the manual. Examples of signs in this category include: Children at Play, Farm Machinery, Trucks Entering Highway, and historic and park signs as requested by other departments, public agencies, and members of the public. This document outlines Woodbury County's policy for placement of the signs as well as defines who will pay for the signs, posts, and installation of each type of sign.

School related signs: There are two types of school signs, school bus related signs and school warning signs. The installation of both types of signs is not required by the MUTCD and it is not the policy of the Secondary Road Department to place these signs in every location requested by the public. Signs of these types are placed only at the request of the schools under the terms of this policy.

Two types of signs fall into the category of school bus signs, the school bus stop ahead sign and the school bus turnaround sign. Both are designed as warning signs as designated by the MUTCD, but warn of conditions that are not present throughout the day or the year.

These signs may be placed at the request of the school district. Any requests for the placement of these signs must come through the school bus superintendent or the superintendent of the school district. Requests from county residents will be directed to the school district.

Upon receipt of a request from the school bus superintendent or the superintendent of schools for a school bus stop ahead or a school bus turnaround sign, the engineer or designated maintenance staff will review the location for the adequacy of available sight distance according to the MUTCD. The determination of adequate sight distance will be based on whether or not sight distance in advance of the location in question exceeds the values shown in Table 2C-4, Guidelines for Advance Placement of Warning Signs, for the Condition A column of the table. The speed will based upon the legal speed limit of the road, unless there are circumstances present that lead the engineer or maintenance staff to believe that the speed is significantly higher or lower than posted. If the location has less than optimum sight distance, the county will install a sign at the appropriate distance ahead of the school bus stop or turnaround. The county will provide the post, labor and equipment to erect the sign at no cost to the school. Signs no longer needed will be removed upon request of the school district and stored in the sign shed for the future use of the district. Each school district will be reminded annually to review the need for these signs.

If the location has adequate sight distance for the speed limit of the road, the engineer will recommend to the school official making the request that a sign not be placed. If the school insists that a sign be placed at the location against the recommendation of the engineer, the school will be responsible for all cost associated with the installation including sign, post, labor, and equipment costs.

Children at Play and Related Signs: Children at play, horses on the highway, and other similar warning signs requested by county residents will be installed by the county sign crew when warranted. Upon receipt of a request from a county resident for a sign in this classification, the engineer or designated maintenance staff will review the location for the adequacy of available sight distance according to the MUTCD. The determination of adequate sight distance will be based on whether or not sight distance in advance of the location in question exceeds the values shown in Table 2C-4, Guidelines for Advance Placement of Warning Signs, for Condition A column of the table. The speed will based upon the legal speed limit of the road, unless there are circumstances present that lead the engineer or maintenance staff to believe that the speed is significantly higher or lower than posted. If the location has less than optimum sight distance, the county will install a sign at the appropriate distance ahead of the condition for which the sign is requested. Where signs exceed the minimum requirements of the Condition A distance, signs shall not be installed.

The county will provide the post, labor and equipment to erect the sign. The cost of the sign, post, and labor, including equipment expense, shall be paid by the resident or other party making the request for the sign. The county will install the sign at its staff's earliest convenience.

Signs may not be installed on county right of ways by private property owners. All sign installations will be done by county crews. Signs installed by others will be removed.

Farm Machinery and Trucks Entering Highway signs: Farm machinery, truck entering highway, and other similar warning signs requested by county residents will be installed by the county sign crew when warranted. Upon receipt of a request from a county resident for a sign in this classification, the engineer or designated maintenance staff will review the location for the adequacy of available sight distance according to the MUTCD. The determination of adequate sight distance will be based on whether or not sight distance in advance of the location in question exceeds the values shown in Table 2C-4, Guidelines for Advance Placement of Warning Signs, for the High Judgment Conditions column of the table. Where signs exceed the minimum requirements of the High Judgment Condition distance, signs shall not be installed.

When signs are installed, the cost of the sign and post shall be paid by the resident or other party making the request for the sign. The county will provide the equipment and labor to install the sign at no cost to the party making the request. The county will install the sign at its earliest convenience. If the resident so requests, an advisory speed plate may also be installed with the warning sign. The appropriate advisory speed will be established based on a survey of the location by engineering staff and a determination of stopping sight distance by the county engineer.

Signs may not be installed on county right of ways by private property owners. All sign installations will be done by county crews. Signs installed by others will be removed.

Historic Markers, Park Signs, and other Recreational/Cultural Interest Signs: When requested by IDOT, county or state conservation and park employees or organizations, or the Woodbury County Historical Society, the County Secondary Road department will install signs of this type on county rights of way. The sponsoring organization will provide funding for purchase and continuing maintenance of signs. The sponsoring organization will also pay for posts and hardware needed to install the signs. The secondary road department will provide equipment and labor for installing the signs, unless a written agreement or other instrument approved and signed by the Board of Supervisors related to such signs provides differently.

If the signs become faded, damaged, lose their reflectivity or are otherwise in poor condition, the secondary road department will contact the sign sponsor and see if they want to replace or repair the sign. If the sponsoring agency is no longer interested in maintaining the sign, the secondary road department will remove the sign at no cost to the sponsoring organization.

Appendix D. Sample National Association of County Engineers Sign Policy

The City of Eagan, Minnesota sign policy was provided by the National Association of County Engineers via the Iowa County Engineers Association Service Bureau.

I. SIGN MAINTENANCE
   Sign Maintenance
   A. Sign Installation: Signs will be installed and maintained to meet federal standards set forth in the most recent Minnesota Manual on Uniform Traffic Control Devices (MnMUTCD) in accordance to City of Eagan guidelines, standard installation plate and practices.

   B. Maintain Signing, Overall Responsibility: Eagan sign maintenance practices are established to meet all requirements and ensure appropriate signing for the traveling public.

   C. Sign Retroreflectivity: The City of Eagan has maintained a field sign inventory database in the form of a sign management system (software) since 1993. The city is currently analyzing the database to determine the best approach to meet <u>Federal Sign Retroreflectivity Standards</u>.
      1. The City of Eagan will use a combination of EXPECTED SIGN LIFE and CONTROL SIGNS as management methods.
         a. CONTROL SIGNS
            i. Evaluation of retroreflectivity of city signs will continue on a 2 year cycle as it has to date (1/2 of city signs each year).
            ii. As per Federal directives, a group of "calibration signs" will be assembled to represent a sample of each color that is known to have retroreflectivity levels at or above minimum levels. The signs will be set up so that the sign technician can view the calibrations signs in a manner similar to nighttime field inspection conditions. The technician will use the visual appearance of the calibration signs to establish the evaluation threshold for that night's inspection activities.
               1. Calibration sign samples are needed for each color of sign in Table 2A-3 (MUTCD Manual)
               2. Calibration signs are viewed at a typical distance using the inspection vehicle. (SUV or standard P/U with low beam head lights).
               3. Calibration signs will be stored appropriately to prevent deterioration.
               4. Calibration signs retroreflectivity will be verified periodically.
            iii. A group of small portable samples known to have retroreflectivity levels at or above minimum levels will be assembled to be used to assess signs that have questionable retroreflectivity. When the visual inspection identifies questionable signs, a comparison sample may be attached to the sign and viewed as a comparison by the technician.

b. EXPECTED SIGN LIFE
   i. Expected sign life processes/practices will be established utilizing a combination of expected sheeting warranty life estimations of manufacturers/suppliers and "on the ground" experience in the field at the city. The city will develop and update as needed general criteria for life cycle replacement of signs in companion with calibration review and nighttime sign examinations.
      1. The city began installing 3M High Intensity Prismatic (HIP) sheeting signs in 2002 and migrated to 3M Diamond Grade 3 (DG3) sheeting in 2006. A system wide evaluation will occur identifying all signs that are not scheduled for replacement between now and Jan 2015. Following review and planning, the city will implement a program to replace all signs having insufficient sheeting properties (engineer grade) incrementally between now and Jan. 2015 to meet the new Fed retroreflectivity standards. Additional planning (and implementation of plan) will occur to assure compliance for the Jan 2018 deadline at the same time.
      2. The city will plan for (budget for) replacement of all signs found via the control section/night sign checking process. The eventual goal will be that the majority of retroreflectivity related sign replacement will be handled through the expected life cycle/sign life process.

D. Sign Maintenance Responsibility: Maintain signs and street identification signs on all City of Eagan roadways (specific agency name) highways, with the exception of:
   a. Signage on approaches to county highways are not installed or maintained by the city. Street name signs and stop signs intersecting with Dakota County Highways are maintained by Dakota county.
   b. Stop signs at Minnesota Department of Transportation (MnDOT) controlled intersections and highway ramps with state/county highways.
   c. Specific signs installed by others (Mn/DOT, transit agencies, and private signs as agreed upon by the City of Eagan.
   d. Signs along county highways, within Mn/DOT right of way, unless specific agreement with Mn/DOT/Dakota County stipulates a city maintenance responsibility for signing.
   e. Bike path and other pedestrian-control signs not pertaining to vehicle traffic installed by government entities other than the city.
   f. Signs on approaches to city streets installed by private business and/or property owners.

E. Response to Incident Report for Sign Repair Needs: Sign maintenance staff will respond after receiving notice of a repair need to determine appropriate action with the following priorities:
   a. Stop sign: as soon as practical, no later than one business day, a temporary stop sign will be placed if required.
   b. Other regulatory signs: no later than three business days.
   c. Warning signs: within one scheduled workday.
   d. Informational/guidance signs: as soon as scheduling/delivery permits

F. Sign replacement resulting from field inspections:
    a. 3 year cycle review (1/3 each year)
    b. Night retroreflectability sign check):
        i. Written documentation of the location, sign type, size and reason for sign replacement will be recorded (into database) for each sign that is not in an acceptable condition and needs replacement.
        ii. Sign replacement will occur as follows:
            1. Stop signs – as soon as scheduling permits
            2. All other signs – concurrent with neighborhood refurbishing replacement schedules or as determined by sign technician.

G. Miscellaneous Sign Practices:
    a. Sign staff is not directly on-call after normal working hours. After hours phone numbers for maintenance managers are available to Public Safety dispatchers so staff can be contacted in case of an emergency.
    b. Training is provided to ensure traffic staff can perform sign maintenance duties in an efficient, effective and responsive manner. Such training shall consist of, at a minimum, appropriate signing and traffic control seminars (when available and funds are available in the city training budget), appropriate available training videos or website trainings, and training as appropriate and available for supervisors.
    c. Unauthorized signs will be removed from city rights of way.
    d. Support staff will be informed and updated regarding sign maintenance operations (e.g., schedules and other priority needs or equipment failures) to ensure accurate information is available to respond to telephone inquiries.
    e. Sign staff may park a sign maintenance vehicle against traffic flow in order to perform necessary emergency and routine maintenance duties.
    f. Sign staff may drive or park maintenance vehicles on the center medians or boulevards in order to perform necessary emergency and routine maintenance duties.

Appendix E. Retroreflectometer Guide

A retroreflectometer works by placing the device against the sign face, with a light pulse emitted from a lens on the front of the unit when a trigger on the device is pulled. That light reflects off the sign face and returns to a light sensor in the unit that provides a measurement of the retroreflectivity level for the particular sign color. General retroreflectometer use involves a series of steps, beginning with calibration, conducting field measurements, and downloading or recording the data.

Prior to initial use, the retroreflectometer is calibrated to ensure it is making accurate measurements. Calibration is performed using a card comprised of a black surface and a white surface for which the retroreflectivity is known. The card is held to the lens of the retroreflectometer for the black surface first in order to calibrate the unit for a non-reflective surface. Then, the white surface is held to the lens. The values collected should be compared to those listed by the manufacturer in the instruction manual. Incorrect readings may be indicative of a problem with the unit or deterioration of the calibration card material, and the retroreflectometer should not be used for field retroreflectivity measurements unless the calibration measurements are accurate.

Following calibration, field data collection (or shop measurement of calibration/control signs) may occur. Field data collection can be difficult, as the height of some signs is such that it requires use of a ladder or an extender arm (specific for the retroreflectometer) to collect measurements. The inspector should park off the roadway and wear high visibility apparel when working in the field. If a particular location presents difficulties or a hazard for an individual collector, then a second person should be present to assist. Temporary traffic control may also be necessary during this process.

While manufacturers do not provide guidance on the number of readings of each sign color that should be made, ASTM International (2010) suggests a minimum of four readings. Most retroreflectometers can collect up to 20 readings for both the sign legend and background colors, so the user is not limited to collecting only four readings. In our experience, eight to 12 readings for both the legend and background taken at various locations across the sign have provided an accurate retroreflectivity measurement. No set measurement pattern is recommended, although working from the top of the sign downward is one approach that can be used.

Damage such as bullet holes, peeling or flaking sheeting and other areas that can lead to incorrect readings should be avoided. (Note that the presence of these other problems is also potentially indicative of other reasons a sign should be replaced.) Any site-specific information (sign location, inventory number, etc.) can also be entered into the retroreflectometer before or after readings are collected.

Once sign readings are completed, they will need to be recorded. If the measurements are being collected for calibration or control signs, the retroreflectivity reading for the legend and background of each sign can be read directly from the retroreflectometer and recorded with a marker on the back of the sign. If sign measurements are being collected in the field, those readings can be downloaded when the inspector returns to the office.

Appendix F. Traffic Control Devices – Understanding Liability From the Perspective of a Municipality

By: Kristopher K. Madsen[1]
Stuart Tinley Law Firm LLP
310 W. Kanesville Blvd., 2nd Floor
Council Bluffs, IA 51503

The State of Iowa, like the majority of states, offers certain protections to the State and municipalities relative to traffic control devices. Specifically, Iowa Code §668.10(1)(a) states:

> 1. In any action brought pursuant to this chapter, the state or a municipality shall not be assigned a percentage of fault for any of the following:
>
> a. The failure to place, erect, or install a stop sign, traffic control device, or other regulatory sign as defined in the uniform manual for traffic control devices adopted pursuant to section 321.252. However, once a regulatory device has been placed, created, or installed, the state or municipality may be assigned a percentage of fault for its failure to maintain the device (23).

Understanding the law surrounding this statute, and its application, is critical to municipalities. In its simplest interpretation, a municipality cannot be held liable for failing to place, erect or install traffic control devices, on any type of road, including low-volume, paved roadways . However, once the traffic control device has been installed, a municipality can be assigned fault if the municipality does not properly and adequately maintain the device.

The immunity granted to municipalities applies to all such placements or installation and thus a claim that the municipality should have done more to warn motorists or should have installed more traffic control devices does not overcome the immunity. McClain v. State, 563 N.W.2d 600 (Iowa 1997).

It even applies when the state or local government creates a road hazard through its own maintenance or construction and fails to erect warning signs. Foster v. City of Council Bluffs, 456 N.W.2d 1 (Iowa 1990). Section 668.10(1)(a) immunity also applies to state contractors and subcontractors who comply with the State's plans and specifications and who are not negligent in performing the work. McLain v. State, 563 N.W.2d 600 (Iowa 1997).

However, there are three exceptions to this statutory immunity: (1) claims for failure to maintain a device; (2) claims for the installation of a misleading sign; and (3) claims that exigencies are

[1] Kristopher Madsen is a partner in Stuart Tinley Law Firm LLP in Council Bluffs, Iowa. His practice is devoted to civil litigation. He defends municipalities, including county and city prosecutors, law enforcement officials and elected officials in a diverse array of claims, including civil rights violations. He is a Fellow in the Iowa Academy of Trial Lawyers and a Fellow in the American College of Trial Lawyers.

such that ordinary care would require the state or municipality to warn of dangerous conditions by other than inanimate devices. Hunt v. State, 538 N.W.2d 659 (Iowa Ct. App. 1995); Estate of Oswald v. Dubuque County, 511 N.W.2d 637 (Iowa Ct. App. 1993).

Exception One – Failure to Maintain Device

The Court applied the first exception—failure to maintain a device—in overturning a district court's decision granting a county immunity for failure to have warning signs in place at a bridge repair site. Estate of Oswald v. Dubuque County, 511 N.W.2d 637 (Iowa Ct. App. 1993). In that case, the county road repair crew had originally placed warning signs in front of a bridge they had torn out, but the signs were later removed by unknown parties. Id. The Court held that the removal of the posted signs generated a fact question regarding whether the county had appropriately maintained the devices as required by Section 668.10. Id. Presumably, if no sign had been erected at all, the county would have been immune.

In a case where it was claimed that the state failed to monitor the effectiveness of its warning signs, the court said that such monitoring "relates solely to the State's ultimate decision of whether or not to erect additional warning signs," and therefore the statutory immunity applied. McLain v. State, 563 N.W.2d 600 (Iowa 1997). The court further stated "Failure to monitor only invokes the maintenance exception when the monitoring involves signs that have already been placed, erected, or installed." Id. See also Saunders v. Dallas County, 420 N.W.2d 468, 472 (Iowa 1988) ("No matter how the challenged county activity is defined or labeled, it comes down to a choice of whether or where to place signs. A decision whether to replace this sign, to move it, or to supplant it with one or more other signs, is not a matter of maintenance under the statute. On the contrary such an action is a matter of deciding to place signs, for which the county cannot be held liable."). Also, if the issue boils down to whether the county should have placed or installed different signage to warn motorists, then the county is within the statutory immunity provision of section 668.10(1). Mehlberger v. Johnson County, Iowa, 2015 WL 1063056 (Iowa Ct. App. March 11, 2015).

Exception Two – Installation of a Misleading Sign

This exception has frequently been attacked by plaintiffs, however, the only successful challenge involved a blatant mistake by a county government, placing a right turn sign on a road that turned left. 11 Ia. Prac., Civil & Appellate Procedure Section 15.94 (2014 ed.); See generally Sullivan v. Wickwire, 476 N.W.2d 69 (Iowa 1991); Phillips v. City of Waukee, 467 N.W.2d 218 (Iowa 1991); Saunders v. Dallas County, 420 N.W.2d 468 (Iowa 1988). The government was found immune when a "Be Alert for Fog" sign provided no other instructions to the motorist on what to do in the event of fog. Sullivan, 476 N.W.2d 69. Placement of a "Crossroad Ahead" sign, instead of a "Yield Ahead" sign was also found not to be misleading, therefore, squarely within the government's immunity. Phillips, 467 N.W.2d 218. The rationale the court applied in these cases was that if the sign placement is done as the government intended, the immunity will apply to bar suit. 11 Ia. Prac., Civil & Appellate Procedure Section 15.94 (2014 ed.). However, if a mistake is made in carrying out the government's intention, e.g., placing a right turn sign on a left curve, no immunity will apply. Saunders, 420 N.W.2d 468.

Exception Three – Exigencies Require Warning with Other than Inanimate Devices

A government may be exempt from liability for failure to post signs, but recent decisions have suggested the possibility that courts may look to see if other duties have been violated that might trigger liability. 11 Ia. Prac., Civil & Appellate Procedure Section 15.95 (2014 ed.). In Collister v. City of Council Bluffs, 534 N.W.2d 453 (Iowa 1995) the defendant argued that Iowa Code Ann. § 668.10 immunized the city against a tort claim which resulted when a city employee left a disabled street sweeper in the middle of the road without warning lights or signs. The city claimed that under Iowa Code Ann. § 668.10, the city employee was not required to post signs or provide notice of the street sweeper to motorists. Collister, 534 N.W.2d 453. The Court dismissed the city's argument concluding that the posting of signs or traffic control devices was not a part of the complaint and that operators of city vehicles had the same duty to comply with the rules of the road as other drivers. Id; See also McLain v. State, 563 N.W.2d 600 (Iowa 1997) (no evidence to suggest that construction project was particularly unusual or that anything other than signs, such as a flagger, were needed).

Iowa Code §668.10(1)(a) has also been challenged and upheld on constitutional grounds. The Iowa Supreme Court did find that the application of this statute does not deprive a plaintiff of equal protection, due process or property rights. See Phillips v. City of Waukee, 467 N.W.2d 218 (Iowa 1991).

Appendix G. *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties*

An additional task completed during the course of this project was a cursory review of *Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties* to identify content that has changed between the time it was published and the present. This manual, which was published in 2001, relied on then-current editions of documents such as the MUTCD when referencing specific information. Since the time the manual was produced, two editions of the MUTCD have been published, resulting in outdated or incorrect information.

The work undertaken during the current project reviewed the Iowa manual and identified the outdated information; a rewrite/update of the manual was not part of this project. Incorrect or outdated information was noted by page and content. The work that was completed was not all inclusive but based on a cursory review of the original content and its referencing of the MUTCD. A more comprehensive review of the manual as part of a future project will be necessary to identify all materials that need to be revised or updated.

The following list summarizes the information and references identified during the course of reviewing the existing Iowa manual that will need to be updated in any future revisions.

Pg. A1.1 - References the millennium edition of MUTCD.

Pg. A2.1 - Minnesota video link missing, video is old and may contain incorrect or outdated information.

Pg. B1.1 - Outdated tables.

Pg. B1.2 - Outdated tables.

Pg. B1.3 - MUTCD section reference is incorrect.

Pg. B1.4 - Information is incorrect and questionable directional arrows on cones depicted.

Pg. C1.2 - MUTCD section reference is incorrect, presents outdated information, and color code is out of date.

Pg. C1.3 - Standards and website outdated and incorrect. Sheeting types are discussed that may not meet current retroreflectivity requirements.

Pg. C1.4 - Company information is outdated and incorrect.

Pg. C1.6 - MUTCD section reference is outdated and incorrect.

Pg. C4.1 - MUTCD section reference is incorrect.

Pg. C5.1 - MUTCD section reference is incorrect.

Pg. C5.3 - Outdated and incorrect information presented.

Pg. C5.3-4 - Questionable sign placement discussed, does not reflect current MUTCD information.

Pg. C5.5 - Outdated table.

Pg. C6.2 - MUTCD section reference is incorrect.

Pg. C7.2 - W3.1 sign depicted is outdated.

Pg. C7.3 - Multiple MUTCD section references are incorrect.

Pg. C8.1 - MUTCD section reference is incorrect.

Pg. C9.1 - Text should be reworded to match information contained in the MUTCD.

Pg. C9.2-3 - Text should be reworded to match information contained in the MUTCD.

Pg. C10.2 - The typical presented should be reviewed and revised as appropriate.

Pg. C11.1 - MUTCD section reference is incorrect and text should be reworded to match information contained in the MUTCD.

Pg. C11.4 - Table of minimum taper lengths should match MUTCD information or Iowa DOT practices.

Pg. C13.1 - MUTCD section reference is incorrect and signs presented are outdated.

Pg. C16.1 - MUTCD section references are incorrect.

Pg. C17.1 - Iowa Code reference is incorrect.

Pg. C18.2 - Table is outdated and information is incorrect.

Pg. D1.1 - MUTCD section references are incorrect and information is outdated.

Pg. D1.8 - Double centerline diagram is incorrect.

Pg. D1.11 - Table is outdated.

Pg. D1.13 - MUTCD section references and information are incorrect.

Pg. D1.17 - Information is outdated.

Pg. D1.18 - Terminology is outdated.

Pg. D1.19 - MUTCD section reference and information is incorrect.

Pg. E1.1-1.2 - MUTCD section references and information are incorrect.

Pg. E1.3 - The typical presented should be reviewed and revised as appropriate.

Pg. F1.1 - MUTCD chapter reference is incorrect.

Pg. G1.1 - Text should be reworded to match information contained in the MUTCD.

Pg. G1.2 - Some signs illustrated are outdated, others have incorrect MUTCD sign numbers.

Pg. G1.3 - Some signs illustrated are outdated.

Pg. G1.4 - MUTCD section references and signs presented are incorrect, text should be reworded to match information contained in the MUTCD.

Pg. G1.5 - Dimensions for marking and sign layouts should be checked and verified.

Pg. G1.6 - Pavement marking symbol has changed.

Pg. G2.1 - MUTCD section references and sign number are incorrect, text should be reworded to match information contained in the MUTCD.

Pg. G2.2 - MUTCD section reference incorrect.

Pg. G2.3 - MUTCD section reference incorrect, specifications presented should be checked and verified.

Pg. G3.1 - MUTCD section references and sign presented are incorrect, text should be reworded to match information contained in the MUTCD.

Pg. G4.1 - MUTCD section reference and sign number are incorrect.

Pg. G4.2 - MUTCD section reference is incorrect and sign is outdated.

Pg. G4.3 - Signs are outdated and MUTCD sign numbers are incorrect.

Pg. G4.4 - MUTCD sign number is incorrect and diagrams should be revised.

Pg. G4.5 - Text should be reworded to match information contained in the MUTCD and diagrams should be revised.

Pg. G4.6 - MUTCD section reference is incorrect and terminology used is questionable.

Pg. G5.1 - Incorrect and questionable information presented.

Pg. G5.2 - Information presented should be checked and verified.

Pg. G5.3 - Information presented should be checked and verified.

Pg. G5.4 - Information presented should be checked and verified.

Pg. G6.1 - MUTCD section reference is incorrect and information presented should be checked and verified.

Pg. G6.2 - Information presented should be checked and verified.

Pg. G6.3 - Signs are outdated and text should be reworded to match information contained in the MUTCD.

Pg. G7.2 - Signs are outdated and information presented should be checked and verified.

Pg. G8.1 - Signs are outdated.

Pg. G8.2 - Signs are outdated and in some cases questionable.

Pg. G10.2 - Information presented should be checked and verified.

Pg. G10.3 - Information presented should be checked and verified.

Pg. H2.3 - Text should be reworded to match information contained in the MUTCD and table should be updated.

Pg. H3.3 - MUTCD section reference is incorrect and text should be reworded to match information contained in the MUTCD.

Pg. H4.1 - MUTCD section reference is incorrect and text should be reworded to match information contained in the MUTCD.

Pg. I1.1 - MUTCD section reference is incorrect and text should be reworded to match information contained in the MUTCD.

Pg. I2.1 - Text should be reworded to match information contained in the MUTCD.

Pg. I4.3 - Images are outdated.

Pg. I4.4 - Text should be reworded to match information contained in the MUTCD.

Pg. I4.7 - Images are outdated.

Pg. I4.1-I4.7 - Information presented should be updated.

Pg. J1.1 - Images are outdated and text should be reworded to match information contained in the MUTCD.

Pg. J1.2 - Images are outdated and text should be reworded to match information contained in the MUTCD.

Pg. J1.3 - Information presented should be checked and verified and text should be reworded to match information contained in the MUTCD.

Pg. K1.3 - Text should be reworded to match information contained in the MUTCD.

Pg. K1.4 - Text should be reworded to match information contained in the MUTCD.

Pg. K1.5 - Incorrect measurements presented in table.

Pg. K1.6 - Incorrect measurements presented in table.

Pg. K1.7 - Incorrect measurements presented in table.

Pg. K1.8 - Incorrect MUTCD sign number and incorrect measurements presented in table.

Pg. K1.9 - Incorrect measurements presented in table.

Pg. K1.10 - Incorrect measurements presented in table and text should be reworded to match information contained in the MUTCD.

Pg. K1.11 - Incorrect measurements presented in table and text should be reworded to match information contained in the MUTCD.

Pg. K1.12 - Sign spacing is incorrect.

Pg. K1.13 - Text of pedestrians should be updated.

Pg. L1.4 - Utility located colors are outdated and need to be updated.

Pg. L3.8 - Incorrect table reference.
