Static Warning Signs for Occasional Hazards: A Synthesis of Research and Practice

Final Report

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EXECUTIVE SUMMARY

Static warning signs for occasional hazards (SWSOH) are used to warn drivers of such hazards that may occur unexpectedly on the highway or the adjacent roadside. Examples of those hazards include warning signs for animal crossing, icy roads, falling rocks, etc. The fact that these signs are posted all the time while hazards occur occasionally or rarely raises questions about their effectiveness in improving safety. Specifically, over time drivers may become desensitized to the warning provided by these signs.

The current project includes an investigation into the effectiveness of static warning signs for occasional hazards. The information provided by this investigation is very important as highway agencies need to be assured about the feasibility of investing significant resources on installing and maintaining those traffic control devices. The project conducted a review of the current state-of-the-art and practice. Specifically, a literature search was conducted and included the most important studies on warning signs and devices including those that are not consistent with the Manual on Uniform Traffic Control Devices (MUTCD). Also, a questionnaire survey was sent to all 50 state Departments of Transportation (DOTs) and two Canadian provinces to review their practice concerning warning drivers of occasional hazards. The survey also included information on standard static warning signs as well as other unconventional warning devices. Twenty eight out of fifty two agencies participated in the survey representing a response rate of 54%.

Study results suggest that most survey participating states are not assured about the effectiveness of static warning signs for occasional hazards and that around 57% of those states have some sort of unconventional warning signs or devices in place. The survey also demonstrated a dire need in practice for further guidance on warning the traveling public of occasional hazards.

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INTRODUCTION

The use of warning signs is an option that is made available to traffic engineers by the Manual on Uniform Traffic Control Devices (MUTCD) at many locations where unexpected situations may exist or occur. Examples of those situations are presence of railroad crossings, icy bridges, unexpected alignment and / or geometry, falling rocks, wildlife crossing, etc. The effectiveness of the MUTCD static warning signs is a concern to highway agencies as 1) those unexpected hazardous situations are blamed for higher frequency of accidents at those locations, and 2) knowing the effectiveness is essential in developing alternative measures that will help to improve safety at those locations. This issue becomes more a concern when the specific unexpected condition exists occasionally or rarely such as the falling rocks and wildlife crossings. The use of wildlife crossing signs is extensive particularly in rural states where animal-vehicle collisions become a serious safety concern. It is estimated that 1.5 million vehicle-deer collisions take place across the United States each year. These alarming numbers of accidents kill more than 150 motorists each year and result in more than $1.1 billion in vehicle damage (State Farm 2005). reported that a Also, mountainous terrain in many parts of the country and cold winters require the use of ice and falling rocks warning signs.

The research presented in this paper is mainly concerned with those warning signs that are used for occasional hazards on the highway system. Those are hazards that may exist occasionally on the highway system such as a crossing animal, falling rock, etc. The research aims at examining the literature and current state of practice for the effectiveness of these signs in increasing the attentiveness of drivers to those occasional hazards thus improving safety. The research also aims at identifying the current state of practice in using other unconventional warning devices for occasional hazards.

RESEARCH MOTIVE

Highway agencies expend significant resources on the installation, upgrading, and maintenance of traffic control devices. To ascertain those resources are well invested, it is always important to know whether those traffic control devices serve the intended purpose. While the answer may be an easy one for some traffic control devices such as most traffic signals, regulatory signs, and

guide signs, it may be more difficult for other devices such as warning signs in general and those intended for occasional hazards in particular. The effectiveness of the static warning signs for occasional hazards is questionable at best as those signs are posted almost all the time without real hazard being perceived by drivers. Subsequently, highway agencies have begun to question the feasibility of expending significant resources on the installation and maintenance of those signs when little proof exists of their effectiveness in improving highway safety. With the advanced technologies including the ITS being more affordable and widely used in practice, it is important to investigate the effectiveness of the conventional static warning signs in order to make informed decisions on the use of public funds and better manage safety on the highway system.

LITERATURE REVIEW

The MUTCD is the national reference for the use, design, and placement of traffic control devices. According to the MUTCD (FHWA 2003), warning signs "call attention to unexpected conditions on or adjacent to a highway or street and to situations that might not be readily apparent to road users" usually with the intention of raising driver awareness and lowering speeds. However, several studies suggest that drivers may become complacent to the importance or meaning of traditional static warning signs (Pojar et al. 1975, Putman 1997, Sullivan et al. 2003 and 2004, Vest and Stamatiadis 2005, Al-Ghamdi and Al-Gadhi 2004, Stanley et al. 2006).

Despite the extensive use of the MUTCD static warning signs in the highway system, the effectiveness of those signs in improving traffic safety has hardly been investigated. Most studies that investigated the effectiveness of warning signs involved non-traditional warning devices such as the Dynamic Message Signs (Hardy et al. 2006) (9), flashing lights / beacons (Hammond and Wade 2004, Lyles 1981, Hanscome 1976, Hopkins et al. 1997, Zegeer 1975), retro-reflective fluorescent signs (Al-Ghamdi and Al-Gadhi 2004, Krull and Hummer 2000), or the use of advanced ITS technologies such as dynamic warning signs activated upon sensing and processing hazard or vehicle information (Baker et al. 2000). Most of those studies have looked at the effectiveness of non-traditional warning devices in comparison with the traditional MUTCD warning signs using surrogate safety measures such as average travel speed. One study (Carson and Mannering 2001) used crash data in investigating the effectiveness of static ice

warning signs in reducing accident frequencies and severity in the state of Washington. The study utilized ice-related accident data for a three year period (1993-1995) as well as traffic and geometric site-specific information in the investigation. Statistical analyses were conducted to determine the effect if any, that ice warning signs have on crash frequency and severity. Study findings showed that the presence of ice warning signs was not a significant factor in reducing ice accident frequency or severity.

Another important issue in the literature is the danger of overuse of warning signs. The excessive use of warning signs causes drivers to pay less attention to the warning sign and therefore the effectiveness of the sign is lost (Vest and Stamatiadis 2005). This idea of not overusing signs is also presented in the MUTCD (FHWA 2003), which states that "the unnecessary use of warning signs tends to breed disrespect for all signs."

In the course of literature search, the following observations were made:

1. One important observation that is revealed in the literature search the lack of distinction in the literature between warning signs that are used for permanent hazards (such as sharp curves, winding roads, etc.) and those used for occasional hazards. The fact that the latter group of signs is posted all the time while hazards may become real only rarely or occasionally may make most drivers complacent, thus affecting their effectiveness in warning drivers of impending hazards. Knowing the effectiveness of those signs in improving safety is very important for highway agencies to assess the feasibility of using conventional signs and whether alternative warning devices are required for safer highway environment.

2. In regards to warning signs for occasional hazards, there is more focus in the literature on wildlife crossing than on any other occasional hazard on the highway system (e.g. falling rock, icy bridges, etc.). One possible explanation is that the frequency of occurrence of wildlife crossing is more often than any other occasional hazard.

3. The lack of research on the effectiveness of the conventional static warning signs by highway agencies may be attributed in part to the perceived "legal obligation" of using those signs to minimize tort liability in case of crashes (though there might be other plausible explanations). Therefore, safety effectiveness of those signs may become less of an issue for their use by highway agencies.

STUDY DESIGN

This study aims at examining the state of practice for all aspects of use of static warning signs for occasional hazards. For this purpose, an online questionnaire survey was prepared and sent to all 50 state DOTs and two Canadian provinces requesting their participation in the survey. Out of the 50 states included in the survey and the two Canadian provinces, 28 agencies responded representing around 54% response rate. Figure 1 shows the states that participated in the study besides the Canadian province of Manitoba and Nova Scotia. A list of all respondent states is provided in Appendix B.

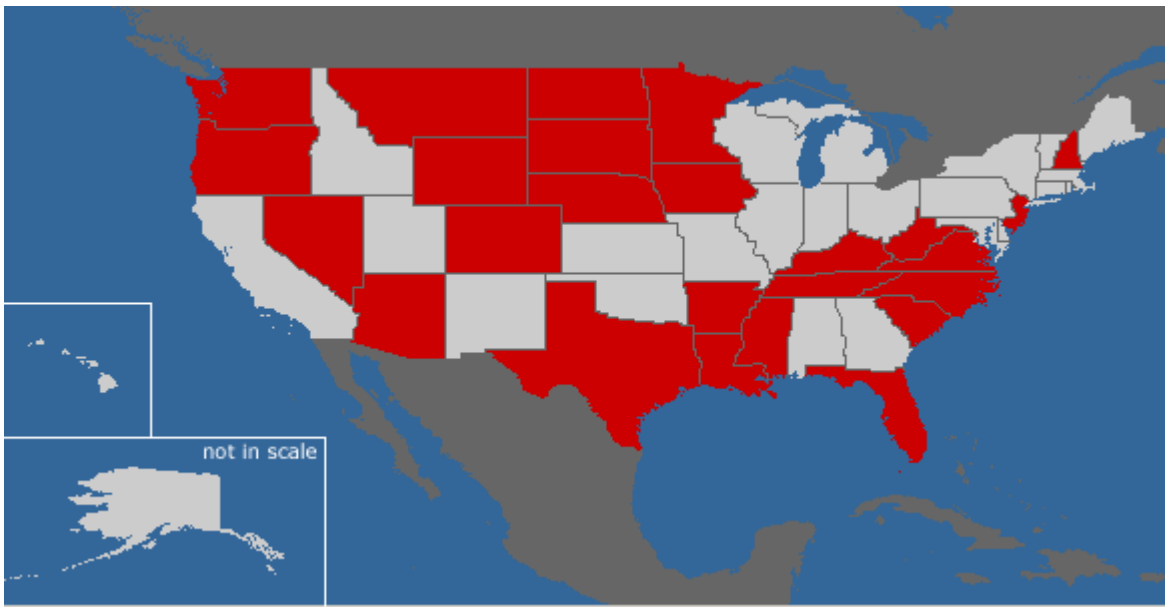

Figure 1 Map Showing Respondent States to Study Survey Marked in Red (Map Does not Include Canadian Provinces)

State DOT Survey

Besides the name and contact information of respondents which was included in the first question, the questionnaire survey consisted of nine questions addressing the following related research aspects:

1. The effectiveness of static warning signs as perceived by state DOTs
2. The effectiveness of static warning signs as evaluated by state DOTs
3. Criteria for the use of static warning signs and the frequency of placement
4. Use of enhanced or unconventional warning devices and their effectiveness

The questions included in the study survey are shown in Table 1.

Table 1 State DOT Survey Questions

1. *Name and contact info*

2. *Do you perceive the use of static warning signs for occasional hazards as*
    a. *Effective*
    b. *Somewhat Effective*
    c. *Ineffective*
    d. *Don't Know*

3. *Does your agency evaluate the effectiveness of static warning signs for occasional hazards?*
    a. *Yes*
    b. *No*

4. *If yes to the previous question, please comment on any relevant studies or current practices.*

5. *What criteria does your agency use to determine if static warning signs for occasional hazards are required?*
    a. *National Guidelines*
    b. *State Practices*
    c. *Best practices*
    d. *Tort Liability*
    e. *Engineering Judgment*
    f. *Other*

6. *If the occasional hazard exists over an extended length of highway (e.g. wildlife crossing), what factors are used to determine the frequency of sign installation?*
    g. *Engineering Judgment*
    h. *Formal Guidelines*
    i. *Costs*
    j. *Crash Experience*
    k. *Other – Please specify*

7. *If National or State guidelines are checked in questions 4 or 5, please specify the source of in formation.*

8. *If unconventional warning signs for occasional hazards are in use, what types of signage are in place?*
    a. *Static-Unconventional Design (size, color, symbol)*
    b. *Static-Flashing Lights*
    c. *Dynamic Message Signs*
    d. *None*
    e. *Other*

9. *If unconventional or enhanced signage is being used, has the practice been effective?*
    a. *Yes*
    b. *No*

10. *Please feel free to comment on any of the previous questions in the space provided.*

SURVEY RESULTS

Surveys were analyzed and the results are discussed in the following sections.

Effectiveness of Static Warning signs for Occasional Hazards

When asked about their perception of the effectiveness of SWSOH, only 18 % of the state DOT respondents thought it is effective. The majority of respondents have less certainty in the effectiveness of the SWSOH as they thought it is somewhat effective. 7% of respondents thought it is ineffective and only 4% were not sure about the answer. Those results are shown in Figure 1.

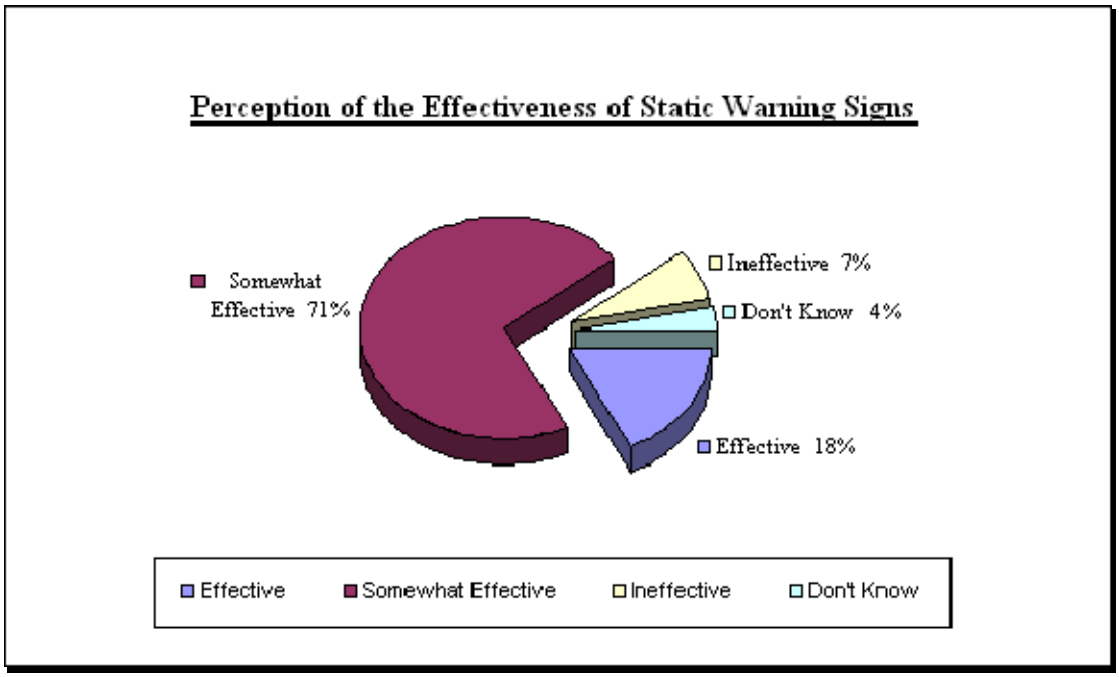

Figure 2 Effectiveness of SWSOH as Perceived by State DOTs

This figure shows that around 70% of people in practice are not assured of the effectiveness of SWSOH as they did not provide a definite answer about the signs being effective or ineffective.

On the other hand, a few respondents (7%) thought the signs have no safety benefits (7%) versus a higher percentage (18%) who believe in the existence of those benefits. The uncertainty of most respondents in answering this question is largely due to lack of information on the safety benefits of those signs. This fact is demonstrated clearly in the results of another survey question that asked state DOTs about any evaluation studies they have done to assess the safety benefits of SWSOH. Figure 2 show that the vast majority of states (93%) have not done any formal or informal study to investigate the effectiveness of those signs and that only 7% (two states) of state DOTs have conducted an investigation into the issue. One state conducted before-and-after crash investigation while the other state conducted an investigation "early 1990's describing the ineffectiveness of Animal Warning Signs" without describing the nature of the study. This is an

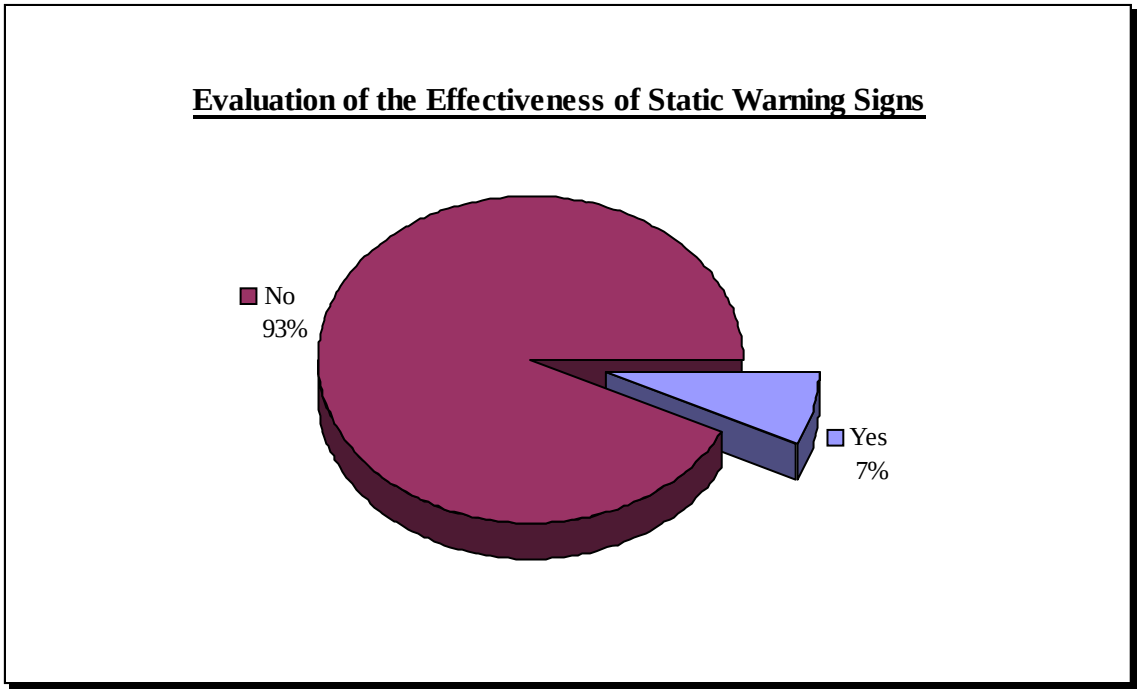

Figure 3. State DOTs evaluation of SWSOH

important piece of information as the standard, the MUTCD, states that "the effectiveness of the placement of warning signs should be periodically evaluated under both day and night conditions" (FHWA 2003).

Criteria for the Use of SWSOH and the Frequency of Installations

The Manual on Uniform Traffic Control Devices (MUTCD) is the national reference for the use, design, and placement of traffic control devices. This important document provides only limited guidance on the use of warning signs in general and heavily refers to the use of engineering judgment. Specifically, the MUTCD stipulates that "the use of warning signs shall be based on engineering study or engineering judgment" (FHWA 2000). As related to frequency of installation, the manual states that "the use of signs should be kept to a minimum so that the signs do not lose their effectiveness" and that subsequent placements after first location are to be determined by "appropriate intervals" (FHWA 2000). Also, the MUTCD states that "in situations where the conditions or activity are seasonal or temporary, the warning sign should be removed or covered when the condition or activity does not exist" (FHWA 2003).

As for the guidance used by state DOTs in the installation of the SWSOH, the vast majority of states (26 out of 28) reported the use of engineering judgment, a matter that is consistent with the MUTCD guidance. Out of the 28 states surveyed, only 17 reported the use of the national guidelines (MUTCD) versus 14 reported the use of state guidelines (mostly state traffic engineering manuals and supplements). Also, relatively significant number of respondents (11 states) reported the use of best practices. Another interesting finding is that 20% of respondents (6 states) reported that tort liability and litigation play an important role in the decision to use SWSOH. Among other criteria mentioned by respondents is the use of crash data, crash experience, as well as requests from the public in installing SWSOH. Those results are shown in Figure 3.

In regards to the frequency of placement of SWSOH when the hazard exists over an extended segment of highway, 96% of respondents reported the use of engineering Judgment while 72% reported the use of crash experience. Only three states reported the use of formal guidelines (national or state guidelines). Those figures show that: (1) crash history is a key criterion that is used in determining the frequency of sign installation using engineering judgment, and (2) no real standards exist in practice in determining the frequency of placement of SWSOH where hazards exist over extended highway sections. Also, cost of installing and maintaining signs was found to be not much an issue in the frequency of sign placement. Those results are shown in Figure 4.

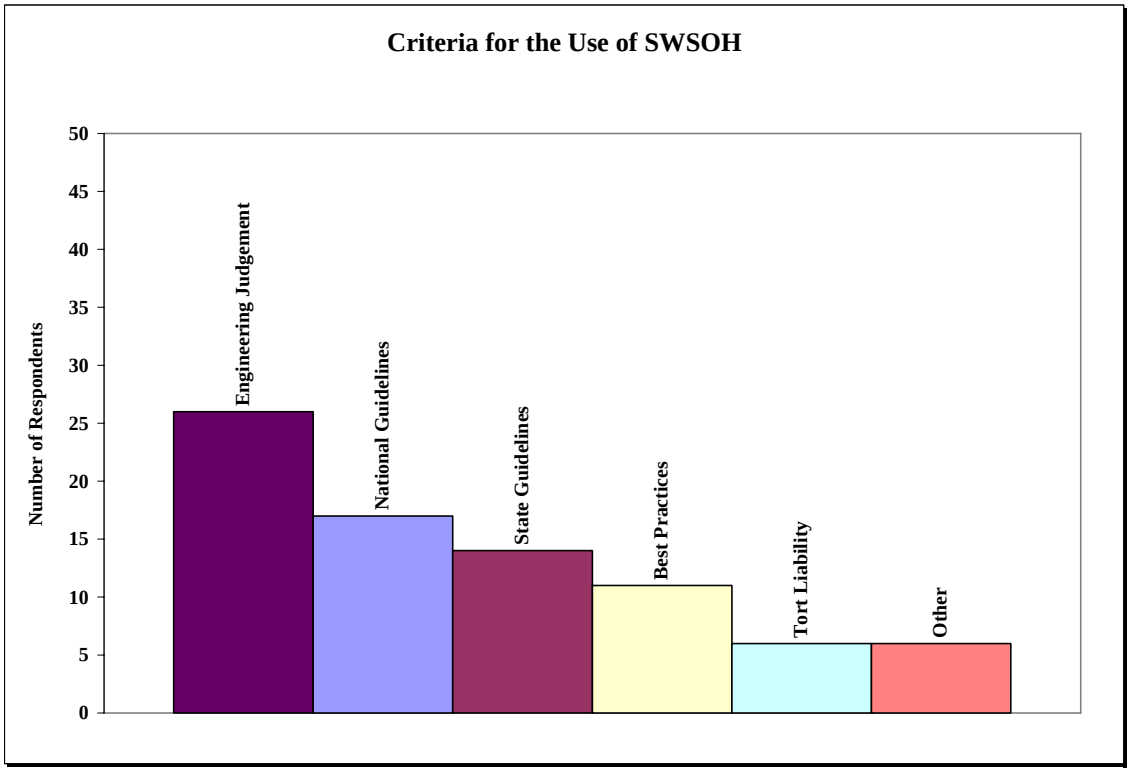

Figure 4 Criteria Used in determining the Need for SWSOH

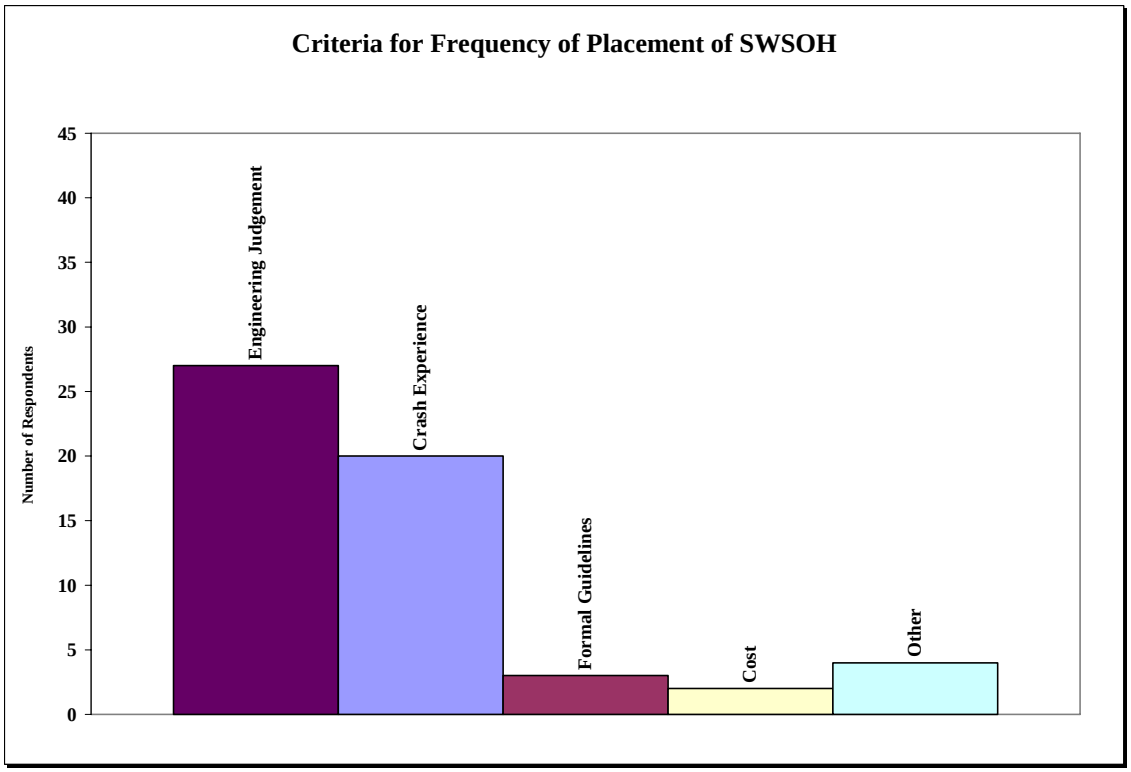

Figure 5. Criteria Used by State DOTs for Frequent Placement of SWSOH

Use of Unconventional Warning Devices

The state DOTs were asked whether they use enhanced warning signs / devices other than the traditional SWSOH. Results are shown in Table 1. More than half the respondents (57%) reported the use of enhanced devices. This seems an indication of the implicit dissatisfaction with, or lack of assurance concerning, the effectiveness of the SWSOH. Around 20% of respondents reported the use of static signs with unconventional design, which involve signs that are of a different size, color, or enhanced with reflectors or any other altered feature from the standard MUTCD warning signs. Similar percentage of respondents reported the use of dynamic message signs. However, a higher percentage of respondents (43%) reported the use of static signs with flashing lights. Those signs flash when the occasional hazard is in effect, for instance, when a deer crossing movement is detected at the location of interest.

Table 2 Use of Unconventional Warning Devices by State DOTs

Type of Unconventional Devices	Number of Respondent States	Percentage
Static - Unconventional Design	6	21.4
Static - Flashing Lights	12	42.9
Dynamic Message Signs	5	17.9
None	12	42.9
Other	2	7.1

The survey also asked state DOTs who have implemented enhanced warning devices whether those devices had been effective. 64% of those states using enhanced devices responded that the practice had been effective while 21% stated that the signs had not been effective. The remaining percentage (around 14%) did not know the answer to the question as no evaluation of advanced devices was performed by those agencies. This information show that over half of the States that participated in the survey had unconventional or enhanced signs in place, and of that group of participating states, around two thirds found the unconventional signage to be effective.

SUMMARY OF FINDINGS

Literature Review:

In general, literature review that was conducted in the course of this research revealed the limited research that has been done on the effectiveness of static warning signs for occasional hazards. The review included only one study that investigated the effectiveness of static ice warning signs using crash records (Carson & Mannering 2001). This study, which was conducted in the state of Washington, showed that the presence of ice warning signs was not a significant factor in reducing accident frequency and severity. All other studies utilized surrogate safety measures such as average speed.

The literature review also revealed lack of distinction in the literature between warning signs that are used for permanent potential hazards versus those that are used for occasional hazards. The effectiveness of those signs that are used for occasional hazards is a concern due to the fact that these signs are posted most of the time without real hazard being perceived by users. Local drivers become accustomed to always seeing the sign and thereby becoming complacent. This explains to some extent why the use of flashing lights or similar active devices at specific times or upon the onset of hazard has proven effective, as it is an indication to the drivers that occasional hazards are real during that particular time.

Finally, most of recent studies focused on investigating the effectiveness of using advanced warning devices in alerting drivers of occasional hazards. The conventional static warning signs were used in some of those studies as a reference against which the effectiveness of the advanced devices is evaluated. However, inadequate effort was done to investigate the effectiveness of conventional static signs, which remains a gap in the current state of knowledge. Such information is important for highway agencies to answer the question about the feasibility of expending material and personnel resources to install and maintain those traffic control devices.

Practice Review:

A state DOT questionnaire survey was used to review the current national practice concerning the use of SWSOH. The most important findings of the survey are:

- The majority of participating agencies perceived the effectiveness of SWSOH as only "somewhat effective." This implies that many of those agencies lack assurance about the effectiveness of those signs in warning of occasional hazards and the feasibility of using them.
- Around 93% of the respondents said that they do not evaluate the effectiveness of SWSOH. This means that while state DOTs may perceive the practice to be somewhat effective, there is generally no data to support that notion, and in reality the performance of those signs remains uncertain.
- The criteria used for the installation of SWSOH and placement frequency are vague and arbitrary at best. The practice largely relies on the use of engineering judgment. While this is relatively consistent with the MUTCD, it also indicates that little guidance is available in this regard. Besides engineering judgment, tort liability and litigation, crash experience, and requests from the public were reported as other criteria used in the process.
- More than half of responding states reported the use of unconventional warning devices for occasional hazards. This may be an indicator of agencies being less than satisfied with the effectiveness of SWSOH. The use of static signs with flashing lights was the most frequently reported unconventional device.
- Around two thirds of the respondent states found the use of unconventional warning devices to be effective.

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APPENDIX A

SURVEY RESULTS

1. Name and contact info

2. Do you perceive the use of static warning signs for occasional hazards as:

   Effective – ***(16)***

   Somewhat Effective – ***(20)***

   Ineffective – ***(2)***

   Don't Know – ***(1)***

3. Does your agency evaluate the effectiveness of static warning signs for occasional hazards?

   Yes – ***(2)***

   No – ***(26)***

4. If yes to previous question, please comment on any relevant studies or current practices.

   Only <u>two</u> comments

   - *Before and after crash studies*
   - *We did a study in the early 1990's describing the in effectiveness of animal warning signs*

5. What criteria does your agency use to determine if static warning signs for occasional hazards are required?

   National Guidelines – ***(17)***

   State Practices – ***(14)***

   Best practices – ***(11)***

   Tort Liability – ***(6)***

   Engineering Judgment – ***(26)***

   Other – ***(6)***

   i. *Crash Data*

   ii. *Crash Experience*

   iii. *Reoccurring conditions such as floods.*

   iv. *Requests from the public.*

v. *Engineering principals and practices that are localized.*
vi. *National standards if they exist or state policies are created.*

6. If the occasional hazard exists over an extended length of highway (e.g. wildlife crossing), what factors are used to determine the frequency of sign installation?

Engineering Judgment – ***(27)***
Formal Guidelines – ***(3)***
Costs – ***(2)***
Crash Experience – ***(20)***
Other – ***(4)***

i. *After major crashes.*
ii. *We use 5 animal hits per mile per year.*
iii. *Data from the Department of Fish and Wildlife.*
iv. *Consult with the wildlife agencies.*

7. If national or state guidelines are checked in questions 4 or 5, please specify the source of information.

16 Answers:

i. *MUTCD*
ii. *MUTCD & ITE Handbook*
iii. *MUTCD Division of Traffic Guidance Manual Research Report From the Kentucky Transportation Center*
iv. *MUTCD Tennessee Sign Supplement*
v. *MUTCD for Canada*
vi. *Traffic Engineering Guidelines of South Carolina DOT*
vii. *MUTCD*
viii. *MUTCD as well as several animal and ice warning sign policies.*
ix. *MUTCD*
x. *MUTCD and AASHTO Subcommittee on Traffic Engineering*

xi. *Texas MUTCD*

xii. *MUTCD for Canada*

xiii. *MUTCD*

xiv. *MUTCD & Washington State Traffic Manual*

xv. *MUTCD & Montana Traffic Engineering Manual*

xvi. *Crash Data- If crash history is higher than the state average a sign is warranted.*

8. If unconventional warning signs for occasional hazards are in use, what types of signage is in place?

Static-Unconventional Design (size, color, symbol) – ***(6)***

Static-Flashing Lights – ***(12)***

Dynamic Message Signs – ***(5)***

None – ***(12)***

Other – ***(2)***

i. *Wind Socks*

ii. *Standard Design Word Message*

9. If unconventional or enhanced signage is being used, has the practice been effective?

Yes – ***(7)***

No – ***(4)***

10. Please feel free to comment on any of the previous questions in the space provided.

Twelve comments:

i. *I am not sure if I understand correctly what is meant by "occasional" or "unconventional" hazards*

ii. *Relative to question #9, unconventional or innovative signing or devices usually prove effective initially but over time loose their impact.*

iii. *Conducting a research project along a rural section of state highway with numerous deer kills. Installed deer crossing warning signs with flashers that activate by sensing deer entering the state highway right of way.*

iv. *We have one fog warning system, which uses detection equipment to actuate flashers on static signs in times of reduced visibility. It is still being evaluated. Otherwise, we use standard diamond-shaped warning signs for conditions such as fallen rock, deer crossing, etc*

v. *On question #9 -- we haven't performed any evaluations of some of the unconventional signs we have used. Examples: "Landslide Area", "Icy conditions when flashing" (w/ flashing lights), "Slippery When Icy". Sometimes we fall victim to the "political" warrant: We don't believe the signs will have any effect, but it makes local residents feel good to have them installed.*

vi. *I answered "NO" on question 9 because there was no "don't know" option and because the question was rather absolute (as opposed to " Do you think the practice has been effective?).*

vii. *My answer to question 9 would be "Don't know."*

viii. *My answer to question 9 should be more towards a maybe. We haven't done any studies to see how effective unconventional or enhanced signage has been.*

ix. *Many occasional hazards that are signed do not have a high enough associated collision experience to provide study of statistical significance.*

x. *We determine the average number of deer/vehicle crashes per mile of roadway each year and then compare new locations to the statewide average in determining the need for the deer signs. We have also been installing more warning signs to warn of "turning traffic" or "turning trucks" at intersections with higher crash rates. We have not completed any studies on the effectiveness of these signs.*

xi. *Locals tend to disregard signs after extended use.*

xii. *Question 3: I'm not aware that our agency evaluates the effectiveness of static warning signs, as we never receive feedback. Question 9: Don't receive any feedback so not such if the practice is effective.*

APPENDIX B

PARTICIPANT AGENCIES IN STUDY SURVEY

United States

1. **Arizona DOT**
2. **Arkansas State Highway and Transportation Department**
3. **Colorado Department of Transportation**
4. **District of Columbia DOT**
5. **Florida DOT**
6. **Iowa DOT**
7. **Kentucky Transportation Cabinet**
8. **Louisiana Department of Transportation and Development**
9. **Minnesota DOT**
10. **Mississippi DOT**
11. **Montana Department of Transportation**
12. **Nebraska DOT**
13. **Nevada DOT**
14. **New Hampshire DOT**
15. **New Jersey DOT**
16. **North Carolina DOT**
17. **North Dakota DOT**
18. **Oregon DOT**
19. **South Carolina DOT**
20. **South Dakota DOT**
21. **Tennessee DOT**
22. **Texas DOT**
23. **Virginia DOT**
24. **Washington State DOT**
25. **West Virginia DOT**
26. **Wyoming DOT**

Canada

1. **Manitoba Transportation and Government Services**
2. **Nova Scotia Department of Transportation and Public Works**