EFFECTIVENESS OF CRASH FACT/SAFETY MESSAGE SIGNS ON DYNAMIC MESSAGE SIGNS

Authors

Peter T. Savolainen, Timothy J. Gates, Eva Kassens-Noor, Megat-Usamah Megat-Johari, Nusayba Megat-Johari, Travis Decaminada, and Meng Cai

Sponsoring Organization

Michigan Department of Transportation

Performing Organization

Michigan State University
Department of Civil and Environmental Engineering
428 South Shaw Lane
East Lansing, MI 48824

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16. Abstract
From 2010 to 2020, transportation agencies have increasingly used roadside dynamic message signs (DMS) to display safety messages. Despite their widespread use, evaluations as to potential impacts on driver behavior, and the resultant impacts on traffic crashes has been very limited. This study evaluated the use of DMS to display safety messages leveraging data from public commentary, opinion surveys, crash statistics, and field studies of driver behavior. Public opinion was largely split as it relates to the appropriateness of using DMS for safety messages. A statewide survey showed that the majority of respondents had seen a DMS, but only 25 percent indicated that such messages improved their driving behavior. A series of crash analyses were conducted to assess relationships between various types of crashes and the frequency with which safety messages were displayed. The results did not show significant differences with respect to total or nighttime crashes based upon the frequency of pertinent safety messages. Speeding-related crashes were significantly lower downstream of DMS that showed higher numbers of messages related to speeding or tailgating. The crash data analysis was complemented by a series of field studies that sought to determine the immediate impacts of safety messages on fundamental aspects of driving behavior. Separate field evaluations were conducted to assess driver compliance with messaging related to the state's move-over law for emergency and service vehicles, as well as compliance with the posted speed limit. In general, the type of message displayed had minimal impact on driver behavior. However, an exception was that drivers were likely to drive at or below the speed limit when targeted move over messages were shown as compared to standard travel time messages. Both speed and lane compliance were improved for all message types if the roadside vehicle was a police car. The findings and conclusions from this research provide MDOT with insights to inform future policies as to the use of DMS for safety messaging.

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Effectiveness of Crash Fact/Safety Message Signs on Dynamic Message Signs

FINAL REPORT

August 11, 2021

Principal Investigator
Peter T. Savolainen, PhD., P.E.
MSU Foundation Professor

Co-Principal Investigator
Timothy J. Gates, PhD., P.E., P.T.O.E.
Associate Professor

Eva Kassens-Noor, PhD.
Associate Professor

Authors
Peter T. Savolainen, Timothy J. Gates, Eva Kassens-Noor, Megat-Usamah Megat-Johari, Nusayba Megat-Johari, Travis Decaminada, and Meng Cai

Sponsored by
Michigan Department of Transportation

A report from
Michigan State University
Department of Civil and Environmental Engineering
428 South Shaw Lane
East Lansing, MI 48824

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EXECUTIVE SUMMARY

Between 2010 and 2020, many transportation agencies have begun displaying safety messages and crash facts to the traveling public using roadside dynamic message signs (DMS). The content of these messages varies from quantitative information, such as safety facts, to more creative messages. The Michigan Department of Transportation (MDOT) launched a messaging campaign in July 2013 as a part of its 'Toward Zero Deaths' campaign, where up-to-date fatality statistics are displayed on DMS throughout the state during periods when the signs are not being used for other purposes. Despite the widespread use of DMS for safety messages, evaluations as to potential impacts on driver behavior, as well as downstream impacts on traffic safety, has been very limited. This study involved a series of investigations aimed at determining the degree to which the use of DMS for safety messages impacts crashes and other surrogate measures of safety. The research also obtained feedback from the public as to the appropriateness of DMS use for such purposes.

An analysis of media content was conducted, which included information from emails to MDOT, social media posts, and public commentary from news and information sites. Comments by individual users tended to center around potential concerns, such as a DMS presenting inaccurate information. User comments also included examples that promoted, expressed appreciation for, or raised awareness of safety message content. The media content analysis was complemented through a statewide survey, which included a series of questions aimed at obtaining insights from Michigan residents as to the use of DMS. The survey results were weighted to account for population, geographic and demographic representation. A section devoted to DMS messages was included, which contained 23 questions. The results of the survey showed that the public was very supportive of using DMS for messages related to travel conditions. Both travel advisories and weather-related messages showed that more than 90 percent of respondents were in favor of use for such purposes. In contrast, respondents were nearly evenly split regarding their support for use of DMS to display safety messages and crash facts.

Beyond public feedback, this study also assessed the relationship between traffic crashes and the frequency with which specific safety messages were displayed. Data were obtained from 202 freeway DMS in Michigan. This message information was integrated with roadway geometry, traffic volume, and crash data for segments downstream of each DMS.

Over the five-year study period, safety messages were displayed approximately 61 days per year, on average, across all DMS in the state. In examining the relationship between crash frequency and type of safety messages displayed, results did not show any meaningful differences in terms of total crashes. This high-level analysis considered all types of safety messages. Subsequent analyses focused on messages that were targeted towards specific types of high-risk behaviors, such as speeding or impaired driving. Nighttime crashes were marginally lower as the frequency of alcohol and impaired driving messages increased, though this result was not statistically significant. Significant reductions were shown when comparing speeding-related crashes to the frequency of messages that were pertinent to speeding and aggressive driving.

The crash data analysis was complemented by a series of field studies that sought to determine the immediate impacts of safety messages on fundamental aspects of driving behavior. Driver behavior was examined in response to different types of DMS messages while considering critical contextual factors, such as the type of vehicle on the shoulder, traffic volumes, and geometric characteristics.

The first set of field evaluations examined driver behavior in response to a series of targeted messages that were displayed on DMS while vehicles approached in-service emergency and MDOT service vehicles parked on the roadway shoulder in consideration of the state's move-over law. This law now requires drivers to move over if possible, and reduce their speeds, for both emergency and service vehicles. Overall compliance with the law, both in terms of speed reduction and lane selection, was markedly higher for police vehicles as compared to transportation service vehicles. Beyond the type of vehicle that is present on the roadside, the findings also show that traffic volume, and the percentage of heavy vehicles in the traffic stream had a significant influence on compliance. Turning to safety messages, there were minimal differences in compliance rates when comparing targeted move-over/slow-down messages to default travel time messages. The one exception was when considering vehicle speeds with respect to the posted limit (i.e., whether the driver was speeding). In this specific case, each of the targeted messages provided improved behavior as compared to the travel time messages.

Additional field studies focused on speeding were also conducted, but these findings showed virtually no change in driver speeds upstream and downstream of the DMS when the targeted safety messages were displayed. The same was true for the default travel time messages.

Consequently, it is recommended that speeding messages be coupled with targeted enforcement where possible as the use of DMS only did not show promising results.

Ultimately, the findings from this study largely reinforce a Federal Highway Administration Memorandum on the use of DMS with nonstandard syntax, which included safety messages. The memo suggests that DMS safety messages should be used as a part of active safety campaigns with limited duration as compared to the continuous display of safety messages such as in the case of crash facts and fatality statistics.

In this study, the evaluation of the move-over laws reinforce this result as driver behavior was predominantly influenced by the type of vehicle present on the roadside. When the vehicle was a police car, as compared to an MDOT service vehicle, compliance rates were significantly higher. Targeted safety messages showed some incremental effects, specifically as it related to speeding, but there were limited impacts observed overall. Other campaigns with heavy enforcement components, such as those focused on distracted driving or impaired driving, would be good candidates for continuing use of safety messages as such messages can be displayed in conjunction with national targeted road safety campaigns.

While the results of this study are consistent with the recommendations of the FHWA, the public feedback suggests that a substantive portion of drivers find value in safety messages. While travel and weather advisory information should take precedence, there is a reasonable argument for displaying safety messages, particularly at locations where these higher priority messages are very infrequent. Ultimately, MDOT’s policy should consider the final language that is approved for the next edition of the MUTCD.

CHAPTER 1 - INTRODUCTION AND OVERVIEW

Each year, more than 35,000 fatalities occur as a result of traffic crashes throughout the United States (NHTSA, 2021). In the state of Michigan, more than 1,000 road users are fatally injured on an annual basis (MSP OHSP, 2021). Starting in 2005, both U.S. and Michigan traffic fatality statistics showed a persistent decrease until 2009, as is shown in Figure 1. A subsequent plateau was experienced through approximately 2014, and recent increases have pushed fatalities to their highest level in roughly a decade. Various factors, including investments in crash countermeasures, improvements in vehicle safety systems, and economic factors have helped to reduce the frequency of traffic crashes, injuries, and fatalities. However, a variety of emerging issues have counteracted these improvements, such as the ubiquity of cell phone use by drivers, weakening of the motorcycle helmet use laws, and additional travel as a consequence of improved economic conditions. Other issues, such as the legalization of marijuana, may also result in adverse impacts on traffic safety.

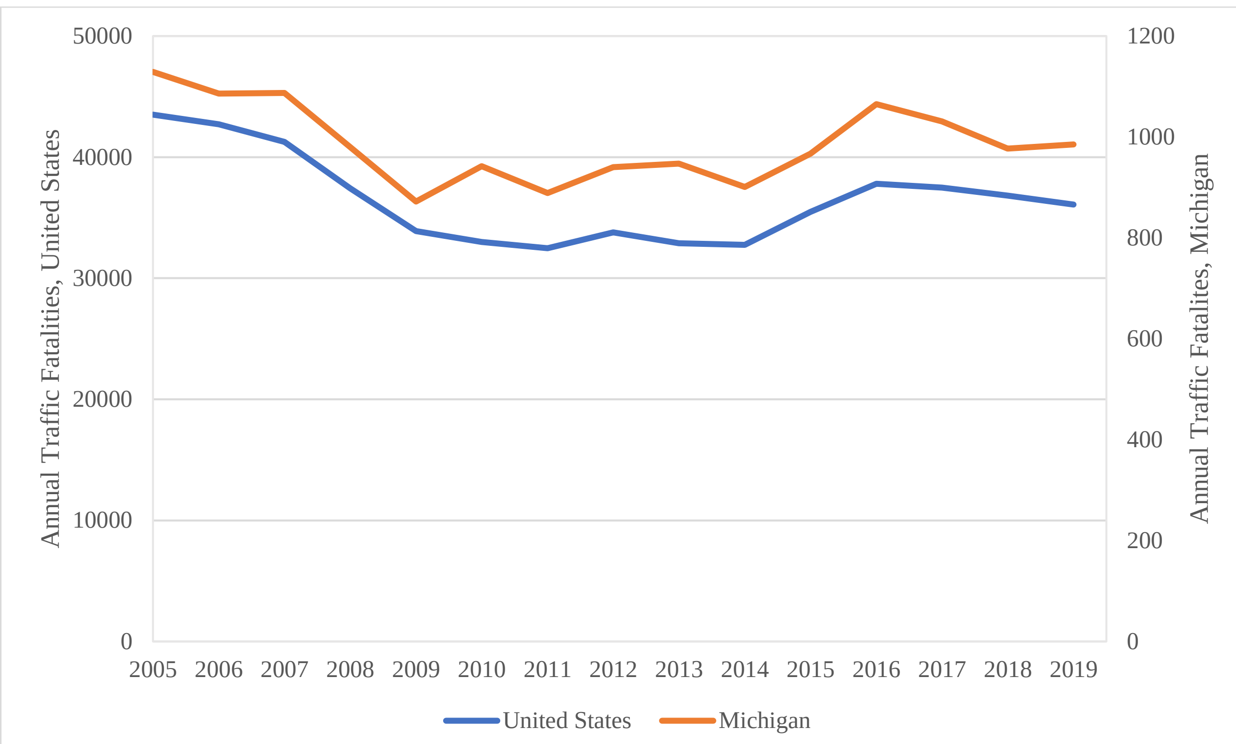


Figure 1. Annual Traffic Fatalities in United States vs. Michigan, 2005-2019

As a consequence, transportation agencies face challenges in developing innovative strategies to combat this public health dilemma. Research suggests that more than 95% of traffic crashes are due, in some part, to driver error (Treat et al., 1979; Hendricks, Freedman and Fell, 2001; NHTSA, 2008). Consequently, facilitating fundamental changes in driver behavior is critical in order to achieve substantive progress towards overarching goals such as Towards Zero Deaths (TZD). To this end, state departments of transportation (DOTs) have used public awareness campaigns in order to spur changes in driver behavior, as well as to raise awareness as to the magnitude of the impacts of traffic crashes on road users and society overall.

In recent years, state DOTs have begun displaying roadside safety messages and crash facts to the traveling public using dynamic message signs (DMS) as shown in the example from **Error! Reference source not found.**. The Michigan Department of Transportation (MDOT) launched a messaging campaign in July 2013 as a part of its 'Toward Zero Deaths' campaign, where up-to-date fatality statistics are displayed on DMS throughout the state during periods when the signs are not being used for other purposes.

Figure 2. Sample DMS Use for Safety Message: Informative-type Message (left), and Creative-type Message (right)

A review of published research and media content (ATSSA, 2017) shows all states have used various forms of safety messages in attempts to raise awareness of traffic safety issues and address problematic driving behaviors that contribute to crashes. The content of these messages varies from quantitative information, such as safety facts (e.g., "440 TRAFFIC DEATHS IN MICHIGAN THIS YEAR"), to more creative message (e.g., "GET YOUR HEADS OUT OF YOUR APPS. DRIVE SAFELY").

Figure 3 illustrates those states that were found to use DMS to display safety-related messages by message type; creative or informational. In total, 21 states (42%) were found to use creative messages, which included pop-culture references and humor. More than half of the states used informational messages (i.e., safety facts), such as the annual number of road fatalities that had occurred up to the date the sign was in operation. More than 15% of the states displayed safety messages on a consistent, periodic basis. For example, some states (Iowa, Utah, and Minnesota) implemented a “Message Monday” while other states, including Michigan, displayed these messages on Wednesdays. Formulation of messages displayed was mostly based on think-tank groups within these respective DOTs, in addition to some DOTs that crowdsourced information from the general public. For example, Maine, Arizona, and Nebraska implemented competitions for the best road safety message. Winning entries, such as "Be protected-not projected-Buckle up" and "Road rage gives you wrinkles," were displayed on those respective DOT’s DMS. Details as to state-specific data are provided in Appendix A.

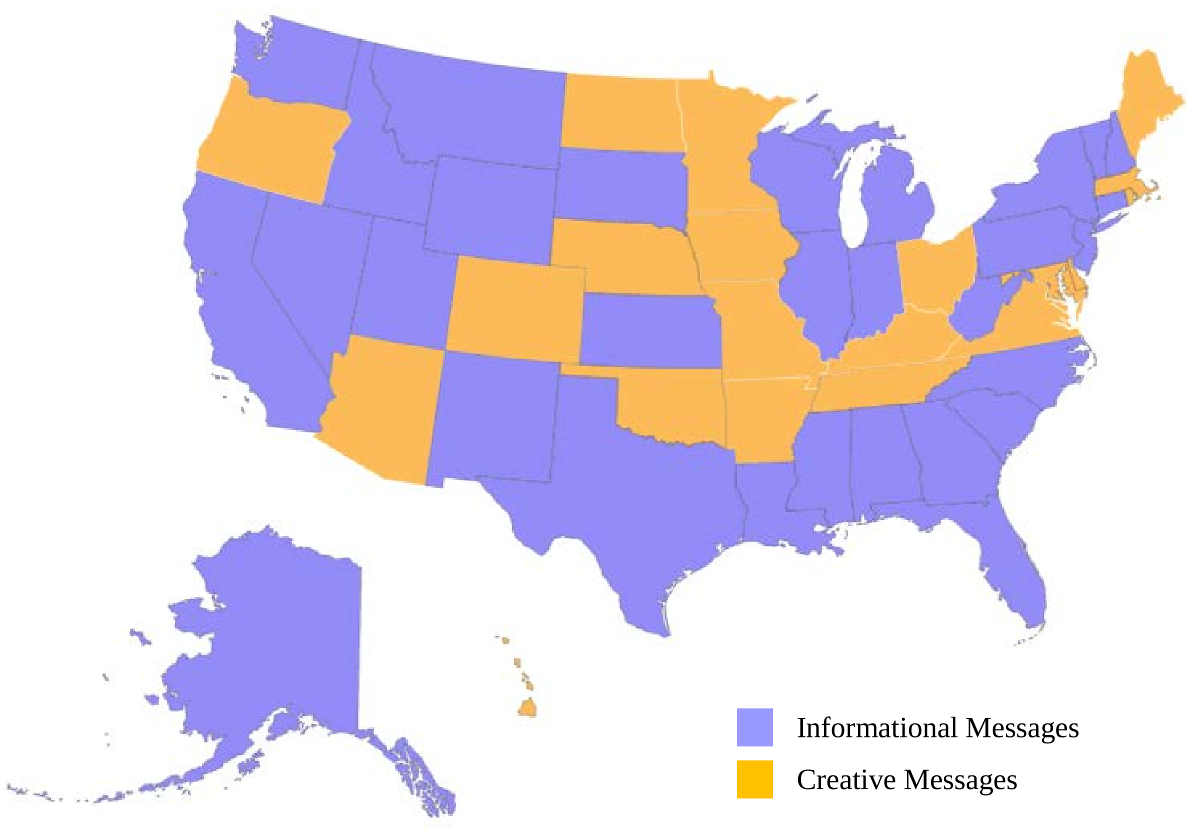


Figure 3. Safety Message Types Displayed on DMS by State (ATSSA, 2017)

While evaluations of the efficacy of intervention programs are evidence-based, reports on road safety campaigns such as safety message advertisements and community awareness campaigns are often bridled by unclear campaign objectives. This uncertainty translates into unclear success criteria, varying campaign objectives and measurement variables, lack of sound data analysis, and limited information regarding any evaluation costs (Boulanger et al., 2009).

The utilization of DMS to display road safety-related messages is a potential strategy to improve safety, particularly during periods when such devices are not being used for other purposes. However, the functionality, as well as the impacts on road users, requires further study. Thus, research is needed to determine the effectiveness of the crash facts/safety message, as well as potential impacts on crashes and other surrogate measures of safety. The findings and conclusions from this research provide MDOT with critical insights to help inform as to the use of DMS for safety messaging.

CHAPTER 2 – LITERATURE REVIEW

For several decades, transportation agencies have incorporated the use of intelligent transport system infrastructure to provide timely feedback as to network performance and to facilitate more informed travel decisions by road users. Dynamic message signs (DMS), which are also referred to as changeable message signs (CMS) or variable message signs (VMS) and by other terms, are programmable electronic signs that are located along highways and provide real-time information to drivers. Historically, dynamic message signs have been used to provide pertinent traffic information, such as speeds, travel times, or the presence of downstream crashes or incidents, to upstream road users. DMS are primarily used to communicate messages regarding these types of operational issues in order to more effectively manage traffic through the provision of advance warning, advisory, and alternative route messages. While DMS have been used for nearly 70 years, it has only been within the past couple of decades that agencies have begun using the signs to communicate safety messages and crash facts. While broad research work has been conducted in the US and worldwide as to the effect of DMS on traffic operations, limited studies have been conducted on the use of alternative messaging on DMS.

2.1 Public Perceptions of Safety Messages

In order to facilitate meaningful impacts on travelers, it is essential for transportation agencies to oversee an effective message development process, which includes careful consideration of the type of language used in the message, particularly in consideration of the intended audience.

Research in Australia has utilized protection motivation theory (PMT) in the development of safety messages. A human factors study was conducted that considered how road users would respond to messages related to speed selection in consideration of issues such as severity, vulnerability, rewards, self-efficacy, response efficacy, and response cost (Glendon and Walker, 2013). PMT suggests that attitude changes are impacted by their concept of both maladaptive responses (e.g., speeding) and alternative adaptive responses (e.g., driving within speed limits) (Floyd, Prentice-Dunn, and Rogers, 2000). The Australian study evaluated the effectiveness of 36 different messages, with the results showing that the PMT model was found to be more effective than jurisdiction-based messages and that threat-judged messages in the PMT model were reported to have a larger impact as compared to coping-judged messages (Glendon and Walker, 2013).

Supporting study shows that in addition to threat type messages, assertive language was found to affect driver behavior (Boyle et al., 2014).

Shealy et al. (2020) conducted a study on the impact of non-traditional safety messages (e.g., “Who Ya Gonna Call? Nobody, You’re Driving”) displayed across the nation. A total of 300 respondents were shown 80 different messages by varying safety behavior (e.g. seat belt wearing, impaired driving), emotion (e.g., humorous type), and theme (e.g., safety statistics, sports, holidays). Participants were questioned regarding their perception of the messages to change driver behavior, identify the intent of the message, as well as recall the message they read. Participants also wore a neuroimaging instrument that records cognitive activity during the experiment. The results indicate that participants perceive all non-traditional safety messages to be effective. It was also observed that general safety messages were more misunderstood compared to targeted safety messages such as distracted driving, impaired driving, and wearing a seat belt, and higher cognitive action, were detected for messages with humor and word play.

Focus group discussion (FGD) studies have been utilized in determining response from a larger population. A study was conducted to determine the comparative effectiveness of formulation of anti-speeding messages based on PMT (Glendon et al., 2018). Messages were ranked and reasoned by drivers of varying experience and resulted in diverse results for the same anti-speeding messages; ranging from positive to the negative. Third-person effect towards messages was prevalent, where drivers believed that messages were meant for other drivers and not themselves. In another study, FGD was used to develop questionnaires on road safety messages on DMS. Survey respondents were found to have a higher recollection of safety messages on DMS compared to weather information, traffic information, and other messages (Tay and De Barros, 2008). Both FGDs and survey questionnaires have provided some input into the types of messages that resonate with drivers, based on locality.

The use of DMS to display safety messages means greater reach for the intended audience, the drivers. A Californian study examined the effect of DMSs in displaying safety campaign messages through expert and industry interviews, driver focus group, telephone and public surveys, as well as analysis of speed data from highway loop detectors. The survey findings indicate that a majority of the respondents who were exposed daily to DMS displays, indicated reading DMS messages more than 75% of the time. Respondents indicated familiarity with message were able to reinforce positive safety effects, i.e. messages that were widely recognizable from safety message campaigns such as ‘Report Drunk Drivers, Call 911’ had higher comprehension rate as opposed to the catchier tagline of ‘Click It or Ticket’. Response indicated that only a third of the survey that were not wearing their safety belts, buckled up upon seeing the ‘Click It or Ticket’ message, and more than half of those that did not, did not understand the message (Rodier et al., 2010).

Similar to the Californian study, a survey in Minnesota indicated that the majority of the respondents (almost 80 percent) were aware of safety message displayed on DMS and reported seeing the state’s Message Monday creative safety messages. Most respondents reported seeing the message on a weekly basis while conducting their routine trips to work, school, run errands, as well as recreational travel. Findings show that 60 percent of respondents found safety messages displayed on DMS were more effective ininfluencing their driving behavior compared to other form of delivery such as television, websites, and social media platforms (Rolland and Kline, 2019).

However, in the case of self-reported behavior, studies have also shown that there was a low correlation between reported behavior and actual behavior (AAA, 2014; Araujo et al., 2017; Prince et al., 2008), requiring the incorporation of a scientific approach to a road safety campaign to understand the effect and usability of the intended message (Adamos and Nathanail, 2008).

2.2 Effects of DMS Safety Messages on Driver Behavior

Among the limited research that has been conducted in this area, studies have generally focused on the effects of safety signs on drivers’ responses as measured by changes in speed selection. For example, a study in Montana investigated the effectiveness of seasonal animal movement advisory messages on a series of DMS as a speed reduction tool on interstate highways. Vehicle speed was found to be reduced when the animal advisory treatment message was displayed, especially during dark lighting conditions. The study also found that speeds increased when generic transportation message were displayed instead of safety messages. It was hypothesized that the general message was assumed as a default message when no condition of concern was present (Hardy, Lee, and Al-Kaisy, 2006).

Contrasting results were observed in other studies. In Canada, an investigation on the effect of anti-speeding messages displayed on DMS revealed little change in mean speed during the message display phase (Tay and De Barros, 2010). Similar results was also shown in other studies which indicated that there was no significant reduction in drivers' speed, or changes in driver behavior upon the display of speed related safety message on DMS (Rodier et al., 2010; Jamson, 2007). Interestingly however, the Canadian study showed a significant reduction in the standard deviation in speeds, which could potentially lead to more stable flow and reduced potential for rear-end crashes. The study concluded that although a fraction of change in speed behavior may be observed through the display of safety messages on information-purposed DMS, the presence of a facility that can be adapted for a multitude of purpose should be taken into consideration (Tay and De Barros, 2010).

In another study, the type of messages displayed were found to affect drivers' response time and in turn impact traffic operation. In controlling for speed variation between drivers, the simulator based study showed drivers to have higher response time to graphic-aided DMS message with partial text than a text only message (Song et al., 2016).

A more recent study was conducted by The University of Kansas on the effect of entertaining, non-traffic related messages displayed on DMSs using a combination of surveys and data obtained from a fixed-based driving simulator. One hundred respondents, screened using an online questionnaire, provided feedback on perceieved effectiveness of messages displayed on DMS. Sixty simulator participants then drove by simulated DMSs displaying variety of messages and completed a survey at the end of the simulated drive. In comparing the survey results before and after the simulated driving, it was found that there were significant positive reaction towards various messages displayed. Speed-related, tail-gating, and move-over messages saw significant positive response towards the DMS messages where participants were found to drive significantly lower average speed, increased gap, and increased move-over maneuvers respectively. Distracted driving messages however showed mixed results where only five of the ten anti-texting-related messages were found to positively influence driver behavior (Kondyli, Schrock, and Khan, 2021).

2.3 Guidance on DMS Use for Safety Messages

Several agencies have developed guidelines and policies as to the use of DMS as it relates to the display of safety messages. For example, the Road Traffic Authority of the New South Wales Government in Australia have outlined a policy on the implementation of DMS that includes message protocol and development, as well as recommendations for DMS positioning (Road and

Traffic Authority of New South Wales, 2010). The guideline provides a priority list for urgency in message display, and general safety messages (also identified as ‘stand-by’ messages) are classed as least priority within the list. A tabulated protocol for a number of stand-by messages were included in the guideline, stating suitability or otherwise, of each message to type of traffic, time-of-day, day-of-week, and type of road.

In 2004, the Federal Highway Administration published the *Changeable Message Sign Operation and Messaging Handbook*, which provides guidance for transportation agencies as to the operation and message design of large permanent DMS and portable DMS. This includes details of pertinent Policy Memoranda from the FHWA. The guidance notes that “…use of a CMS for the display of general public information or other nonessential messages is discouraged…However, operational, road condition, and driver safety focused messages are acceptable to be displayed on a CMS. If driver safety focused messages are to be displayed on a CMS, they should be kept current and relate to a safety campaign. The period of time that a specific message is displayed for a safety campaign should be limited to a few weeks.” (Dudek, 2004). There was limited guidance specific to safety messaging campaigns, however.

This is consistent with the general language that is incorporated in the 2009 edition of the MUTCD (FHWA, 2009). The use of DMS is detailed under Section 2L.02 Applications of Changeable Message Signs. As an option in this section, it is noted that “Changeable message signs may be used by State and local highway agencies to display safety messages…” Subsequent guidance notes, “When a CMS is used to display a safety or transportation related message, the message should be simple, brief, legible, and clear. A CMS should not be used to display a safety or transportation-related message if doing so would adversely affect respect for the sign.” This is followed by a standard indicating that “When a CMS is used to display a safety, transportation-related, emergency homeland security, or AMBER alert message, the display format shall not be of a type that could be considered similar to advertising displays.” This comprises the extent of content that is specifically focused on safety messaging in the current version of the MUTCD.

Given the increasing use of DMS for safety messaging, this has been a high-interest area nationally, which has led to extensive discussions regarding the use of DMS for such purposes. To this end, on January 4, 2021, the FHWA issued a Memorandum clarifying the use of DMS through Official Ruling No. 2(09)-174 (I) – Uses of and Nonstandard Syntax on Changeable Message

Signs. As per this memo, the two principal uses of CMS are for real-time traffic control messages (e.g., non-recurring congestion, incidents, work zones, or similar conditions) and travel time messages. It is noted that any other uses, to the extent allowable, are considered secondary in nature. This includes traffic safety campaign messages in addition to several other use. In such cases, it is suggested that when displaying safety messages, the messages should be of limited duration (not continuous and frequent), plan message display in tandem with national safety initiatives, and display messages relevant to the roadway type (Kehrli, 2021).

Of particular relevance to this study, the memorandum states "The use of CMS to help promote traffic safety is becoming increasingly popular among States and transportation agencies. It is recognized that CMS can be an effective means of further propagating traffic safety campaign messages directly to the motoring public in a cost-effective manner. However, to ensure safety and effectiveness as a traffic control device, it is expected that CMS will be used judiciously for the display of safety messages, and that those messages will be derived from larger safety campaigns that rely on other media as their principal means of communicating the campaign message. These other media generally include, but might not be limited to, such outlets as television, radio, and Internet advertisements; 511 travel information system and Highway Advisory Radio messages; displays in rest areas; and mailings with motor vehicle registrations. The CMS display, if used as part of a traffic safety campaign, should be a supplement to the broader national or State-level campaign. In addition, a safety campaign, such as seat-belt use or prevention of impaired driving, should include active enforcement as a primary element of the campaign."

Ultimately, this research will supplement this guidance from the FHWA with empirical data as to the efficacy of using DMS for safety messages. This includes feedback from the public as to the utility of various types of safety messages, as well as data detailing the degree to which these messages show a tangible impact on driver behavior and traffic safety.

CHAPTER 3 – MEDIA CONTENT ANALYSIS

This chapter presents details of a media content analysis that was conducted to discern public feedback, opinions, and commentary regarding the use of DMS and the efficacy and appropriateness of various messaging strategies.

3.1 Data Collection

Data were obtained from three primary sources for the purposes of this analysis: (1) Emails; (2) Social Media; and (3) MLive.

3.1.1 Emails

Emails – MDOT received a total of 16 public comments via email. These details were forwarded on to the research team by MDOT's communications staff.

3.1.2 Social Media

Twitter updates were collected using a Python script incorporating the package TwitterAPI (Geduldig, 2013), enabled by Twitter's Application Program Interface (full archive/sandbox). The queries sent were "DMS -DM" ("-DM" to exclude common usage of DMs as indicating direct messages on social media), "safety message," "(dynamic OR electronic OR mobile OR message OR digital) (sign OR board)," "(freeway OR fwy OR lane OR road) (close OR closure OR closed OR blocked)," "travel time," "(moving work crew) OR (road work)," "(wind OR fog OR flood OR storm OR tornado OR winter OR snow OR rain OR weather) (advisory OR warning OR watch)," "traffic death," "move over," "share the road," "crashes likely," "wrong way driver," "(drink OR drunk OR sober OR buzzed) drive," "in ice and snow," "winter is (here OR coming)," "work zone," "(distract OR phone OR call OR text) drive," "click it," "drive (wicked OR wild)," "veer for deer," "headlights on," "turn signal," "school is open," "road rage," "be safe drivers," "stay (awake OR alert)," "stay belted inside," "buckle up," "beware of heat," "left lane passing," and "seat belt" with mentioning one of the 13 official accounts owned by MDOT (MichiganDOT, MDOT_MetroDet, MDOT_West, MDOT_Southwest, MDOT_Bay, MDOT_LanJxn, MDOT_A2, MDOT_UP, MDOT_Traverse, MDOT_Rail, MDOT_BlueWaterBridge, MDOT_MediaClips, MackinacBridge). The filtering process included removal of tweets that were not in reference to safety messages (e.g. "@MichiganDOT A left turn signal light at Fulton and Forest Hill Dr. in Grand Rapids is needed! For safety, put it back quickly!"), from MDOT accounts, or duplicated due to multiple search queries. A total of 117 tweets generated were captured from July 2013 to June 24, 2019.

Two rounds of searches were conducted on Facebook. First, by a combination of keywords: MDOT ("MDOT," "Michigan DOT" or "Michigan Department of Transportation") and DMS ("DMS -DM," "safety message," "dynamic sign," "electronic sign," "mobile sign," "message sign," "digital sign," "dynamic board," "electronic board," "mobile board," "message board," or "digital board"). The second search was based on specific messages using MDOT ("MDOT," "Michigan DOT" or "Michigan Department of Transportation") and each of the phases in DMS messages, including "(freeway OR fwy OR lane OR road) (close OR closure OR closed OR blocked)," "travel time," "(moving work crew) OR (road work)," "(wind OR fog OR flood OR storm OR tornado OR winter OR snow OR rain OR weather) (advisory OR warning OR watch)," "traffic death," "move over," "share the road," "crashes likely," "wrong way driver," "(drink OR drunk OR sober OR buzzed) drive," "in ice and snow," "winter is here OR coming," "work zone," "(distract OR phone OR call OR text) drive," "click it," "drive (wicked OR wild)," "veer for deer," "headlights on," "turn signal," "school is open," "road rage," "be safe drivers," "stay awake OR alert," "stay belted inside," "buckle up," "beware of heat," "left lane passing," and "seat belt". Through these queries, 10 posts to MDOT were obtained along with 30 comments, including replies from MDOT. In addition, MDOT published two posts regarding DMS on Facebook garnering 24 comments. In sum, 41 public comments were extracted from Facebook.

On Instagram, all posts published by MDOT (mdotpicoftheday) were read and one comment on one MDOT post was collected.

All the items in each playlist of MDOT's YouTube channel (MichiganDOT) were examined. There is no video regarding DMS safety messages with public commentary within the data search time frame.

3.1.3 MLive

MLive.com is the largest news and information website in Michigan. News coverage related to DMS and road safety messages were queried using MLive.com's site search (https://www.mlive.com/search/). The search terms used were "DMS," "safety message," "(dynamic OR electronic OR mobile OR message OR digital) sign," and "(dynamic OR electronic OR mobile OR message OR digital) board."

In addition, message specific searches were conducted in order to cross-check the inclusiveness of the data collection. Included in the search were the five most frequently displayed types of DMS: road closure (69%), travel time (31%), safety messages (8%), weather advisory (8%), and road work notice (6%). The keywords used were a combination of "MDOT OR (Michigan Department of Transportation) OR (Michigan DOT)" and each of the following in separate queries: "(freeway OR fwy OR lane OR road) (close OR closure OR closed OR blocked)," "travel time," "(moving work crew) OR (road work)," "(wind OR fog OR flood OR storm OR tornado OR winter OR snow OR rain OR weather) (advisory OR warning OR watch)," "traffic death," "move over," "share the road," "crashes likely," "wrong way driver," "drink OR drunk OR sober OR buzzed drive," "in ice and snow," "winter is here OR coming," "work zone," "(distract OR phone OR call OR text) drive," "click it," "drive (wicked OR wild)," "veer for deer," "headlights on," "turn signal," "school is open," "road rage," "be safe drivers," "stay (awake OR alert)," "stay belted inside," "buckle up," "beware of heat," "left lane passing," and "seat belt."

Two articles were found to provide public comments. Additionally, one article "Question of the Day: Do signs showing the crash death toll help or hinder safe driving?" listed three complaints MLive received from its readers. The three complaints in were included in the database created; however, this article did not trigger any conversations in its comment section. A total of 158 comments were obtained from MLive.

3.1.4 Local Newspapers

Data were also collected from NewsBank (https://www.newsbank.com), a news database that covers current and archived content from more than 12,000 titles worldwide was utilized to access Michigan local newspapers. Up until June 24, 2019, NewsBank records 165 Michigan sources, including *Detroit News*, *Flint Journal*, *Grand Rapids Press*, *Kalamazoo Gazette* etc. A search on Michigan sources was made using keywords 'MDOT OR "Michigan DOT" OR "Michigan Department of Transportation"' and each of the following terms in separate queries: "(highway OR freeway OR road) (dynamic OR electronic OR mobile OR message OR digital) (sign OR board OR billboard)," "dynamic message sign," "(freeway OR fwy OR lane OR road) (close OR closure OR closed OR blocked)," "travel time," "(moving work crew) OR (road work)," "(wind OR fog OR flood OR storm OR tornado OR winter OR snow OR rain OR weather) (advisory OR warning OR watch)," "traffic death," "move over," "share the road," "crashes likely," "wrong way driver," “(drink OR drunk OR sober OR buzzed) drive,” “in ice and snow,” “winter is here OR coming,” “work zone,” “(distract OR phone OR call OR text) drive,” “click it,” “drive (wicked OR wild),” “veer for deer,” “headlights on,” “turn signal,” “school is open,” “road rage,” “be safe drivers,” “stay awake OR alert,” “stay belted inside,” “buckle up,” “beware of heat,” “left lane passing,” and “seat belt.” We set “source type” to “newspaper” and “year” to “2013-2019”. Each query returned from zero to 5119 articles published in Michigan newspapers since 2013.

Each article was skimmed though to filter out irrelevant topics such as commercial billboards along local streets. Using Google, remaining articles was searched by the title, author, and source provided by NewsBank to see if there were presence of correspondence to the articles. Upon identification of correspondence to article, further checks were conducted to identify any public comments made to the articles.

Furthermore, news coverage in *Lansing State Journal* and *Macomb Daily* were searched using the same NewsBank keywords as these two newspapers were not covered by NewsBank despite ranked the top Michigan daily newspapers by circulation, according to Kantar SRDS Media Planning Platform (Kantar SRDS Media Planning Platform, 2019). Unfortunately, no public commentary regarding DMS safety messages were found from the source of local newspapers.

3.2 Data Summary

Collectively, a total of 333 raw entries of public comments were obtained. This included 16 emails that were sent to MDOT, 159 posts on social media, and 158 posts on MLive. The time frame of the data collection was from July 2013, when MDOT first began utilizing DMS to display safety messages, to June 24, 2019.

Manual coding was done for all 333 public comments gathered from MDOT emails, Twitter, Facebook, Instagram, and MLive. A comment was labeled as whether it discussed DMS messages, and, if so, whether it mentioned road safety messages.

Of comments discussing DMS messages, thematic labeling was exercised by means of emergent coding, a process of identifying themes without predetermined categories. Similarly, if a comment involved suggestions regarding DMS and/or safety messages, the suggestions were recorded by an emergent approach. The authors of comments were classified into two types:

individual users, and non-individual users. Non-individual users included accounts of government agencies, companies, media, etc.

Approximately 45% (151 out of 333) of comments discussed DMS messages (including road safety messages) (Table 1). The 151 comments involved in the analysis came from 128 unique users, of which 98 (77%) were individuals and 30 (23%) were non-individual entities. Non-individual users posted 36 comments, contributing 24% of the data.

The remaining 55% (182 out of 333) of comments did not discuss DMS messages and were excluded from the analysis. The majority of MLive data was excluded as data was acquired according to the topic relevancy of a news article; the comments prompted by the news do not necessarily pertain to the identified search terms. As for data from social media platforms, one conversation between a user and a MDOT account usually involves more than one public comment. Comments such as “thank you for answering my question” in a conversation were coded as irrelevant to DMS messages. Of comments discussing DMS, 75% (114 out of 151) mentioned road safety messages.

Table 1. Data Descriptive Statistics – Media Source

Source	Number of Comments	Number of Comments Discussed DMS Messages	Number of Comments Mentioned Road Safety Messages
Email	16	16	10
Twitter	117	109	87
Facebook	41	15	8
Instagram	1	1	1
MLive	158	10	8
Total	333	151	114

3.3 Public Perceptions of DMS Messages

The results from the emergent thematic coding were organized into four parent categories: appreciation, concern, promotion, and suggestion (Table 2). The themes were analyzed by including counts and frequencies to quantify the emergence of each theme. To avoid biased results due to posts from government agencies or safety advocate organizations, both results including and excluding the aforementioned “non-individual users” were evaluated to get a more accurate representation of public perceptions on DMS safety messages.

Table 2. Themes of Public Comments

Theme	# of Comments (All Users)	% of Comments (All Users)	# of Comments (Individual Users Only)	% of Comments (Individual Users Only)
Appreciation	**18**	**11.92**	**17**	**14.78**
Appreciation of DMS device	1	0.66	1	0.87
Appreciation of safety message	6	3.97	5	4.35
Appreciation of traffic information	4	2.65	4	3.48
Safety message awareness	7	4.64	7	6.09
Concern	**53**	**35.10**	**50**	**43.48**
Concerns about hacked DMS	2	1.32	2	1.74
DMS causing distracted driving	4	2.65	4	3.48
DMS inaccurate information	15	9.93	12	10.43
DMS not in operation	8	5.30	8	6.96
DMS wasting money	2	1.32	2	1.74
Missing travel time	12	7.95	12	10.43
Not enough signage for traffic information	3	1.99	3	2.61
Questioning safety message content	7	4.64	7	6.09
Promotion	**68**	**45.03**	**36**	**31.30**
Raise awareness/spread-the-world about safety message	68	45.03	36	31.3
Suggestion	**12**	**7.95**	**12**	**10.43**
Suggestion of DMS message content	12	7.95	12	10.43
Total	**151**	**100.00**	**115**	**100.00**

There were differences in the category ranking and frequency in themes when non-individual users were excluded from the analysis (Table 2, Figure 4). The categories ranking from the highest to the lowest frequencies for comments of all users were: promotion, concern, appreciation, and suggestion. In contrast, when non-individual users were removed, the theme categories ranking from the highest to the lowest frequencies were: concern, promotion, appreciation, and suggestion. In particular, the themes of posts by non-individual users were different from those by individuals (Figure 4). Of those 36 comments posted by non-individual users, 89% (32 out of 36) were in an effort to promote safety messages, while a very small number of comments expressed concerns and appreciations.

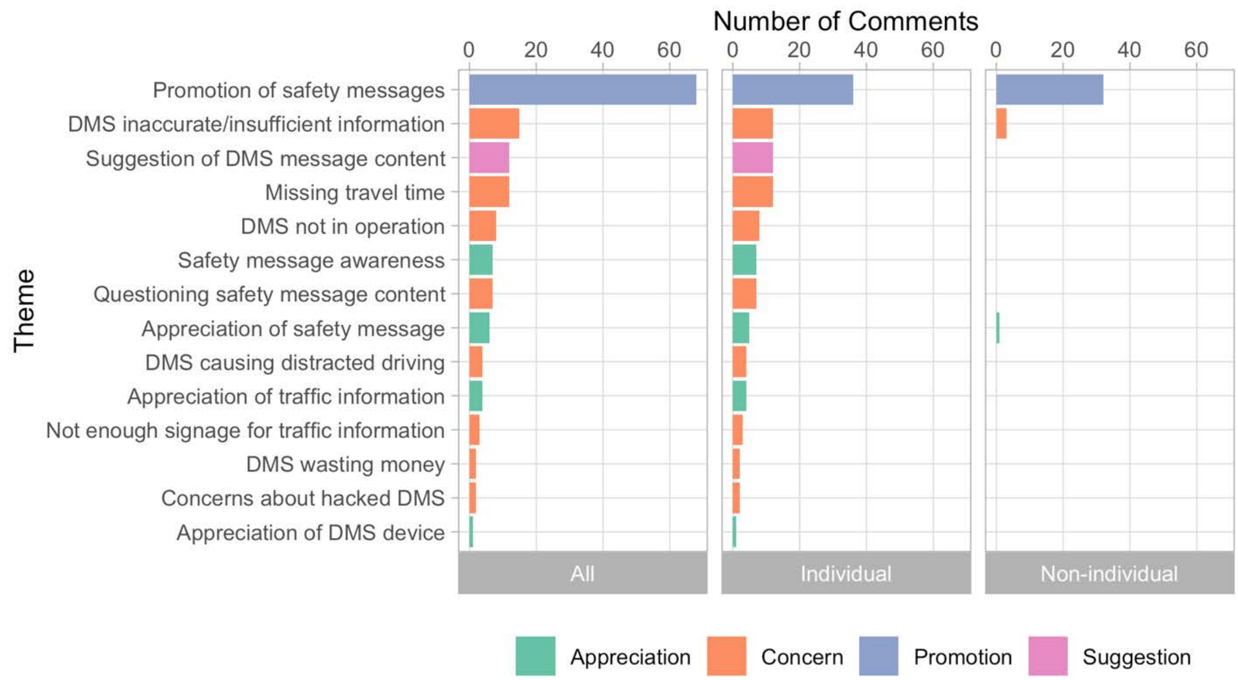


Figure 4. Themes of Public Comments

3.3.1 Promotion

The public paid attention to MDOT's safety campaigns and helped raise awareness of the road safety messages. Almost half (45%) of all comments and one-third (31%) of comments from individual users were promotion of safety messages. It is worth noting that almost half (47%) of comments in this category were from non-individual users (e.g. government agencies, non-profit organizations, media accounts).

The majority (78%, 53 out of 68) of comments in the promotion theme were retweets of MDOT posts. For example, six entries were "RT @MDOT_MetroDet: IN ICE AND SNOW REDUCE SPEED CRASHES 2X AS LIKELY." MDOT used social media as platforms for advertising public safety campaign, and followers of MDOT accounts reposted these messages to their own page, indicating that they agreed with the contents and recognized the significance of those messages. Other data fell into this category included original posts quoted the exact words of safety messages displayed on DMS (e.g., "Hitting the road this #LaborDay? Buckle up, be safe, and watch out for @MichiganDOT #construction crews http://t.co/UFSvAatBbq") and original posts made by media accounts drawing readers to their news articles related to safety messages (e.g., “@MichiganDOT displays traffic death count to encourage safer driving https://t.co/nxointRM6d”).

3.3.2 Concern

Concern was the second most dominant category present in the comments from all users. It was also the most dominant category among individual users. Themes in this category included: perceived inaccuracies or insufficiency as to the level of information displayed on the DMS; missing travel time information; period when the DMS was not in operation; questions as to the safety message contents; concerns as to DMS causing distracted driving; insufficient information regarding traffic conditions; concerns as to the use of public funding for DMS use; and concerns about DMS that were hacked by members of the general public.

28% of all the comments in this category were to inform MDOT about inaccurate or insufficient information, or a spelling error on DMS.

“@MDOT_MetroDet Hey, so it’s actually the left lane that's open? The digital sign on the highway is also wrong and has definitely confused drivers”

“@MichiganDOT What exactly starts March 29 on US-23? Mobile sign trailer yesterday mentioned the date but not sure what is closed”

‘@MDOT_Southwest electronic sign on Napier, W of M-31 says "131" to be closed. Think you mean "31"’

“Will you be putting out a social media update when M5 switches over today? Seeing as your digital signs indicated SB to be open this morning, and it is definitely not. □□□”

A similar proportion (23%) of the comments were about missing travel time information on DMS, and half of them mentioned road safety messages (see examples below). People generally perceived traffic time updates more valuable than safety awareness messages. Several people expressed frustration about the missing time and distance updates on DMS because they relied on this information to determine and adjust their travel routes.

“i would like to know why your electronic message sign facing westbound traffic on m5 near drake rd only shows generics messages instead of travel times which to me is much more important”

"Why are the electronic message signs, mainly on 275, stuck on a worthless message instead of giving useful driving information? They have been like this for almost 2 weeks. I adjust my commute according to these but now all we get is work zone safety and changing lanes with a blinker. Those are useless. Are these broken?"

"@MDOT_MetroDet two days without estimated travel times on southbound I 75 from Troy to 375. When will we be back online?"

Some people wondered why some DMS were not in operation or stated that DMS installation was a waste of money.

"On 96 West between mile markers 11 and 12 in Ottawa County, a large digital traffic sign was put up in the early spring of 2018. It has never been operational. I would like to know why money was spent on putting it up if it is not going to be used. Will it ever work?"

"why doesn't the message board on the Northbound of 131 lanes just before 84th street work? it hasn't worked for months. I believe the same goes for the sign on M6 headed east. They were put there to inform us of situations, and with all the bad weather we've had, have been useless"

A few people questioned the specific contents of safety messages. Two people questioned use of the "don't veer for deer" message and four posts were regarding the meaning of fatalities statistics.

'Traffic message signs on the lodge today saying "Don't veer for deer". Head-on collisions with deer at highway speeds have killed drivers and occupants. Who's bright idea was this?! @MichiganDOT'

"Given the number of vehicles on the road and the number of total miles driven in a year, an increase -or decrease- of 42 fatalities doesn't really mean anything. There's really no way to attribute such a proportionally small variation to anything."

"Need to see if the entire 2016 number is up or down vs. the entire 2015 total (which was up a bit from 2014's total). The best number to look at is fatalities per million miles driven. Then see how that trends (it typically has been trending downward, for decades)."

A small number of people suggested that safety awareness messages displayed on DMS would divert drivers' attention away from driving and cause safety concerns.

'You preach about distracted driving with tv, radio, and billboards. Why must you put up stupid info on the electric "Megan Law" signs? They were supposed to be for emergencies. I almost got run into a ditch by some lady trying to read one of your multi-page "info's"! Shut them off until needed in an emergency!'

"So to bring attention to driving fatalities they give drivers something to read and distract them from the road? Seems logical…"

In rare instances, people showed concerns about the absence of traffic information due to hacked DMS or suggested that there was not enough signage to communicate road closure and congestion.

"Actually the signs have an IP address and you have to use a program to change them. So someone hacked in remotely. Not sure if you'd find it funny though if the sign had a important message originally displayed on it and someone was hurt or killed because the sign got hacked."

'@MichiganDOT @MDOT_A2 there is less and less advance notification of closures. No more electronic sign messages or "lane closed 2 miles..."'

3.3.3 Appreciation

Appreciation was a less frequently mentioned domain. It comprised 12% of comments from all users and 15% of those from individual users. However, this is likely a reflection of general use of social media where people appear more likely to share their concerns or report a problem than to talk about positive experience. However, this category did show a non-negligible amount of people were appreciative of traffic information and safety awareness messages on DMS. Themes in this category included: safety message awareness, appreciation of safety messages, appreciation of traffic information, and appreciation of DMS device.

Roughly 40% of comments in this category simply revealed that people noticed road safety messages and they were positive about the messages.

'I guess I am I Michigander now. When someone says "Spring is here!" instead of "Flowers!" I think "Don't veer for deer!" @MDOT_MetroDet'

"Every day should be National work Zone Awareness day!!!!"

One in three (33%) comments in this category showed people's gratitude to MDOT for utilizing DMS to remind and educate drivers on road safety.

"I am a big fan of the work zone safety messaging. When we see @MichiganDOT use the same message and tone to protect people walking and biking, we'll know we've arrived."

"Love the electronic signs reminding people to use blinkers when changing lanes (on the freeways)!!!! …"

In addition, some people expressed appreciation towards traffic alerts displayed on DMS.

"@MDOT_Southwest Thanks for heads up on I-69 message board. I detoured!"

"@MDOT_MetroDet Thank you for heads up on southbound 75. The message board allowed me to avoid the back up and take an alternate route."

One person applauded the cool appearance of DMS device.

"@T_Kratofil I didn't realize @MDOT_A2 was doing active #traffic mgmt on US23 S of Brighton. Cool looking gantries and DMS. https://t.co/IDJim6grtD"

3.3.4 Suggestion

Among all comments, 8% included suggestions for DMS message content, and all such comments were all from individual users. In addition, some comments in other categories also offered suggestions, even though they were not the main topic. All suggestions from the general public are summarized as follows.

Commenters felt it would be helpful if DMS:

- Always display travel time (suggested by 10 people);
- Alternate safety messages with travel time (suggested by 3 people);
- Only use DMS for traffic alerts (suggested by 2 people);
- Display weather warnings (suggested by 2 people);

- Display “use zipper merge” before lane closures (suggested by 1 person);
- Display specific lane closure information to prevent bottlenecks (suggested by 1 person).

Commenters also believed it would be helpful if safety messages on DMS:

- Focus more on lane discipline (suggested by 3 people); distracted driving (suggested by 2 people); tailgating (suggested by 1 person);
- Were used less frequently (suggested by 1 person);
- Include location information, such as “no incidents reported from place A to place B” (suggested by 1 person);
- Display basic rules of the roadway and fewer fatality statistics (suggested by 1 person);
- Show changes in fatality statistics (suggested by 1 person);
- Display more positive contents (suggested by 1 person).

3.4 Perception Timeline

The total number of comments regarding DMS messages fluctuated over the time period from July 2013 to 2017, and have gone up considerably since 2018 (Figure 5). The number of comments that promoted safety awareness and expressed concerns shared the same trend, except that there was a sharp decline in the number of concerns since 2018. The number of comments showing appreciation and offering suggestions have remained relatively constant over the six year period.

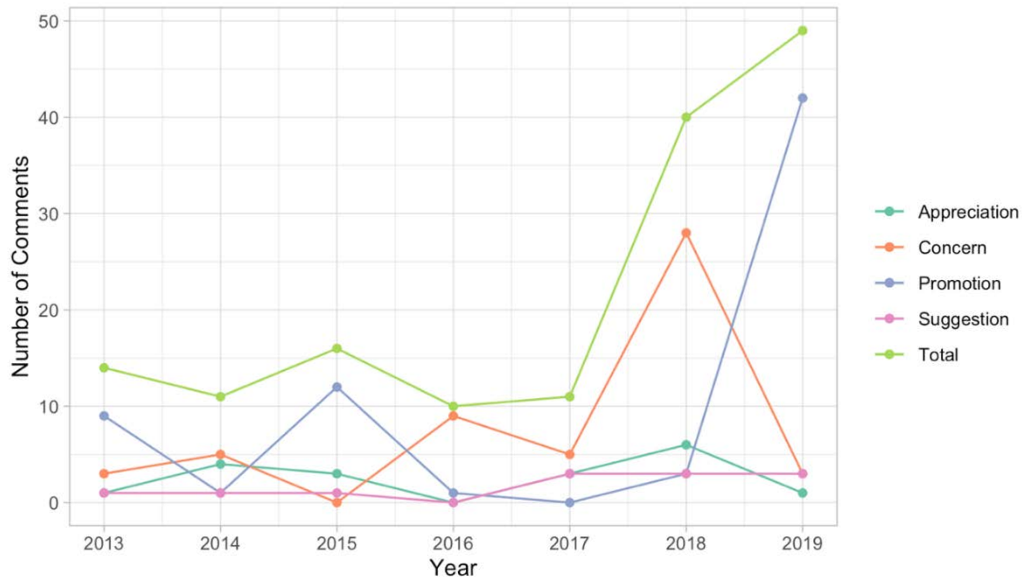


Figure 5. Public Comments by Year.

3.5 Perception by Source

Overall, public comments on social media were not only more in number, but also covered a wider range of topics than commentary emails to MDOT and comments on MLive (Figure 6). Of all the comments we gathered, 10% were MDOT emails, 83% were posts on social media, and 7% were from MLive.

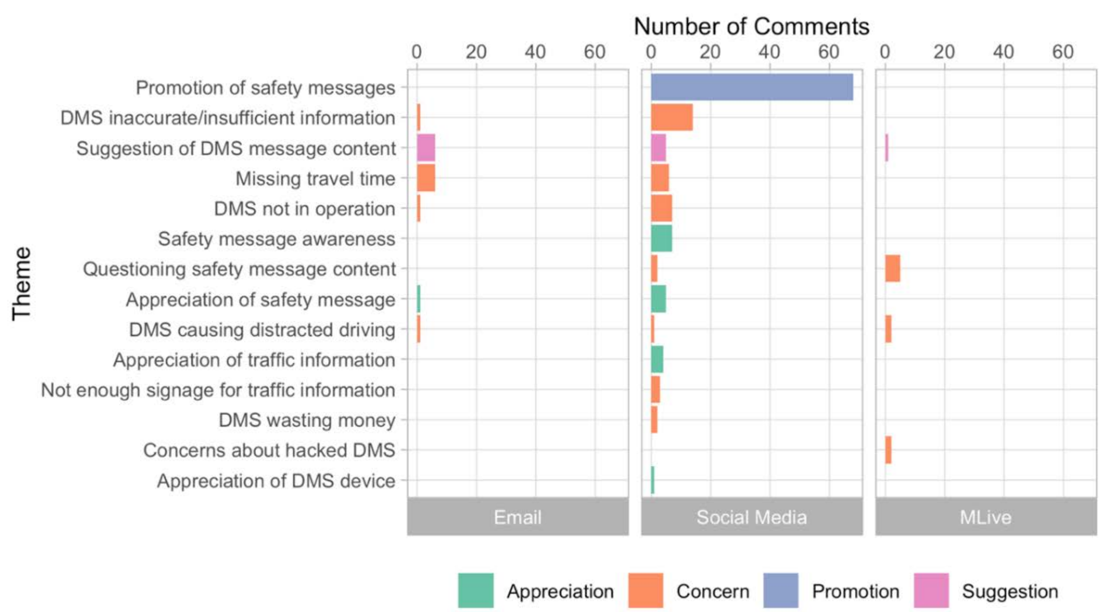


Figure 6. Public Comments by Source

Six themes appeared in commentary emails to MDOT: appreciation of safety messages, DMS inaccurate/ insufficient information, missing travel time, DMS not in operation, DMS causing distracted driving, and suggestion of DMS message content. More people wrote to MDOT to express concerns and offer suggestions than to show appreciation, as was true for all platforms. However, it is noteworthy that on social media, a relatively large number of people helped to promote road safety messages, indicating that they were supportive of MDOT's safety campaign. On MLive, news coverage regarding DMS messages promoted conversations, and thus the contents and tones of the news articles placed influences on public comments. Besides the two MLive articles from which we collected comments, many more news articles related to DMS messages did not trigger any public conversation, suggesting that the topic was of low public interest and not controversial.

Drivers commented on safety messages displayed on DMS along state freeways. While some people appreciated DMS messages and believed DMS for safety awareness were appropriate, some were concerned that it would be less distracting to motorists if MDOT only used DMS for emergency situations. Many people expressed that travel time and distance information on DMS were critical to their travelling.

CHAPTER 4 – PUBLIC OPINION ANALYSIS

The media analysis was complemented through a statewide survey, which included a series of questions aimed at obtaining insights from Michigan residents as to MDOT's use of dynamic message signs (DMS). This chapter details the results of these survey questions and provides insights as to public perceptions of the use of DMS for safety messages.

4.1 Methodology

Several times per year, the Institute for Public Policy and Social Research (IPPSR) at Michigan State University conducts a telephone-based State of the State Survey (SOSS) collecting general information and asking for respondents' opinions about various topics. The survey was specifically targeted towards non-institutionalized, English-speaking adult Michigan residents. The data was collected and then weighted to be representative of Michigan as a whole. Most respondents were selected via randomized telephone numbers, though roughly a third (20-40%) of respondents were those that have previously participated, and agreed to be re-surveyed. The survey was then weighted and adjusted to account for population, geographic and demographic representation, and homes with multiple phones or individuals. The survey analyzed within this report was conducted between June thirteenth and November third, 2019. Nine hundred thirty-seven people responded to the survey, and 886 completed it in full. Respondents were not asked every question included in the SOSS; instead, skip-logic was used to guide respondents through the survey based upon their previous responses.

A section devoted to dynamic message signs (DMS) was included within the SOSS; this section contained 23 questions (see Appendix B). Respondents were first asked if they had seen DMS; if they answered "yes" they were then asked how often/if DMS reminded them of good driving behavior that they were not using at the time. If they answered "yes" or "sometimes," they were further asked how often DMS improved their driving behavior immediately and in the long term. If respondents answered "never" to both the immediate and long-term improvement questions, they were skipped to the section of reacting to nine messages; if respondents gave answers other than "never," they were then asked to recall a specific message that had the greatest effect on their driving behavior. The messages provided by respondents were then coded into one of ten categories consisting of speeding, seat belt use, cell phone use, lane discipline, aggressive driving, drunk driving, children's safety, tailgating, general safety messages, or other.

Additionally, respondents were asked if their chosen message evoked a positive, negative, or neutral emotion. Respondents were then asked what kind of consequence the messages in question spoke to, be they personal, societal, law-enforcement consequences, or no consequences.

Some respondents could not recall a specific message or theme but reported DMS improved their driving behavior either immediately or in the long term. When this was the case, they were randomly given one of two sample messages, these were: "152 traffic deaths to date, down 34 from April 2018" or "152 traffic deaths to date, up 34 from April 2018", and asked how likely these messages were to change their driving behavior. (Less than ten respondents answered these two questions, and thus were not included in the analysis.) This recall DMS part of the survey concluded by asking when does a message lose its effectiveness, offering the following categories: twice, three to nine times, ten to twenty times, more than twenty times, or never.

The survey continued by asking all respondents how likely specific messages were to affect their driving behavior on a four-point Likert scale, ranging from very likely to very unlikely. The messages were selected from the national registry of DMS or other state surveys or developed to evoke emotions or implied consequences. Each respondent was prompted to react to nine messages, while each message was designed to elicit emotion and consequence as explicit or implicit in the message:

- "Be safe drivers." (Neutral emotion, no consequence).
- "Stay alert. 63% of traffic deaths occur on dry roads" (Negative emotion, no consequence).
- "152 traffic deaths in *Michigan* this year" (Negative emotion, no consequence).
- "152 traffic deaths in *your* area this year." (Negative emotion, personal consequence).
- "Distractions are deadly, just drive." (Negative emotion, no consequence).
- "Drive carefully, 90% of all people are caused by accidents" (Humor, no consequence).
- "Don't drive wicked, avoid a ticket." (Negative emotion, law-enforced consequence).
- "Don't drive wild. Think of your child." (Positive emotion, personal consequence).
- "Goodbye John. Good luck and you'll be missed" (Negative emotion, societal consequence).

Finally, the DMS section of the SOSS survey concluded by asking respondents about their preferences for messages displayed on DMS. Respondents were asked about DMS displaying fatality statistics, weather advisories, travel advisories, and whetherthey prefer messages with humor. Respondents were asked to reply to these questions with either "yes" or "no."

In order to analyze the SOSS data, logistic regression models were estimated for all questions where answers were dichotomous in nature (i.e., yes/no). For questions with more than two response categories, and when there was a natural order to dependent variables, ordinal logistic regression was employed. For questions with more than two answer groups without a natural order, multinomial logit models were estimated. All statistical analysis was performed in R Studio, using packages "survey" (Lumley, 2020), "modelr" (Wickham and RStudio, 2019), and "srvyr" (Ellis et al., 2020).

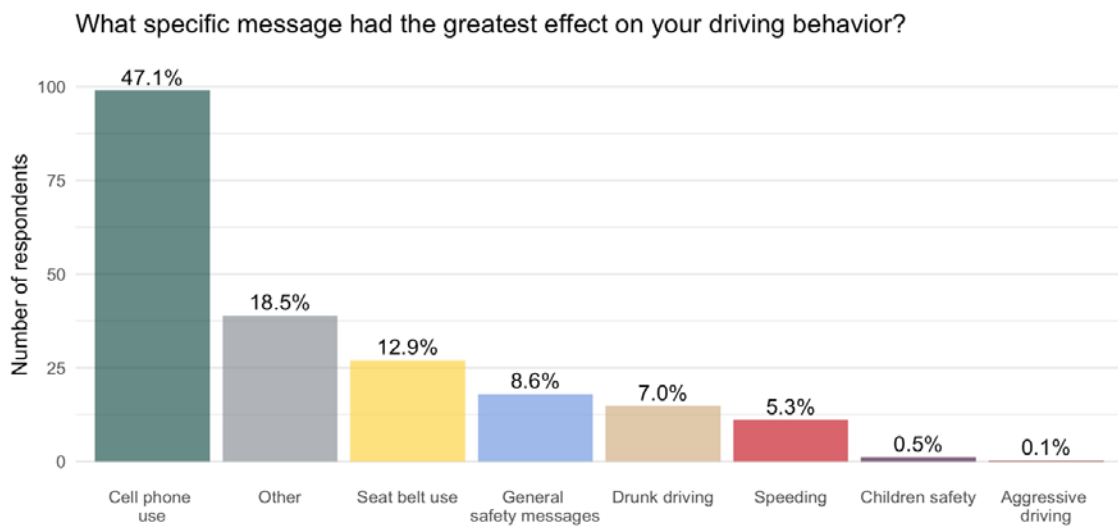
4.2 Driving Behavior in Response to DMS

The majority (84.4%) of drivers have seen DMS. Younger, more educated, and people with a higher income were more likely to be aware of DMS than were older ($p < 0.001$), less educated ($p < 0.05$), and people with a lower income ($p < 0.001$). Though not all respondents saw DMS messages, 61.2% of those who did, reported that they were *not* reminded of good driving behaviors by DMS messages, whereas only 36.1% of them were. Younger people and people in the labor force were more likely to report being reminded of good driving behavior than older people ($p < 0.001$), or people not in the workforce ($p < 0.01$).

Statewide, DMS is likely to have self-reported behavioral effects on one-quarter of the population. Specifically, 26.7% of respondents reported that DMS messages improved their driving behavior immediately, with 13.0% of respondents reporting that their driving was either always improved after viewing them, or improved most of the time; and 13.7% reported that their driving behavior was improved either some of the time or rarely. Respondents with a lower income and those who identify as Democrats were more likely to report an immediate change in their driving behavior compared to a higher income people ($p < 0.05$), or Republicans ($p < 0.05$).

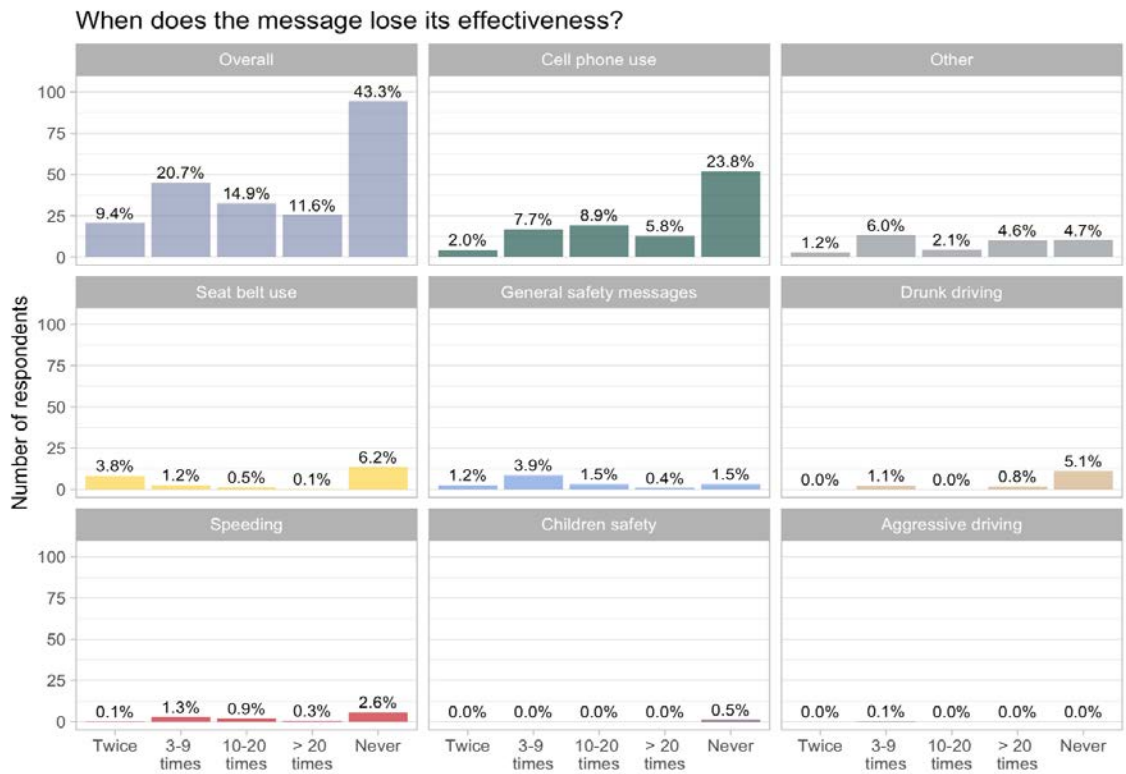
In the long-term, reading DMS messages is likely to improve driving behavior of 26.9% of Michigan residents. 14.2% of respondents said, after reading the messages, their driving behavior had always been improved or most of the time and 13.7% reported some of the time or rarely. Respondents with a lower income, Democrats, and African Americans were more likely to report that DMS messages impacted their long-term driving behavior than respondents with higher incomes ($p < 0.01$), Republicans ($p < 0.05$), or Caucasians ($p<0.001$).

Respondents who self-reported recalling seen different DMSs were greatly impacted in terms of their driving behavior. 47.1% of respondents who self-reported were affected by DMS recalled messages mentioning cell phone use; 12.9% recalled messages regarding seat belt use; 8.6% recalled general safety messages; 7% recalled messages regarding drunk driving; and 5.3% recalled messages regarding speeding (Figure 7). The majority of respondents who self-reported were affected by DMS also felt that DMS messages take a long time to lose their efficacy, 43.3% said that the messages never lose effectiveness; messages mentioning cell phone use were less likely to lose effectiveness than other messages (Figure 8**)**. Respondents who were in the labor force were more likely to report that DMS messages take longer to lose their efficacy than those who were not ($p < 0.05$).



Notes: Percentages may not sum to 100% due to rounding. Number of respondents may not be integers due to sample weighting. No respondents mentioned lane discipline or tailgating

Figure 7. Varying Messages Displayed on DMS, and which Specific Messages had the Greatest Impact on Respondents.

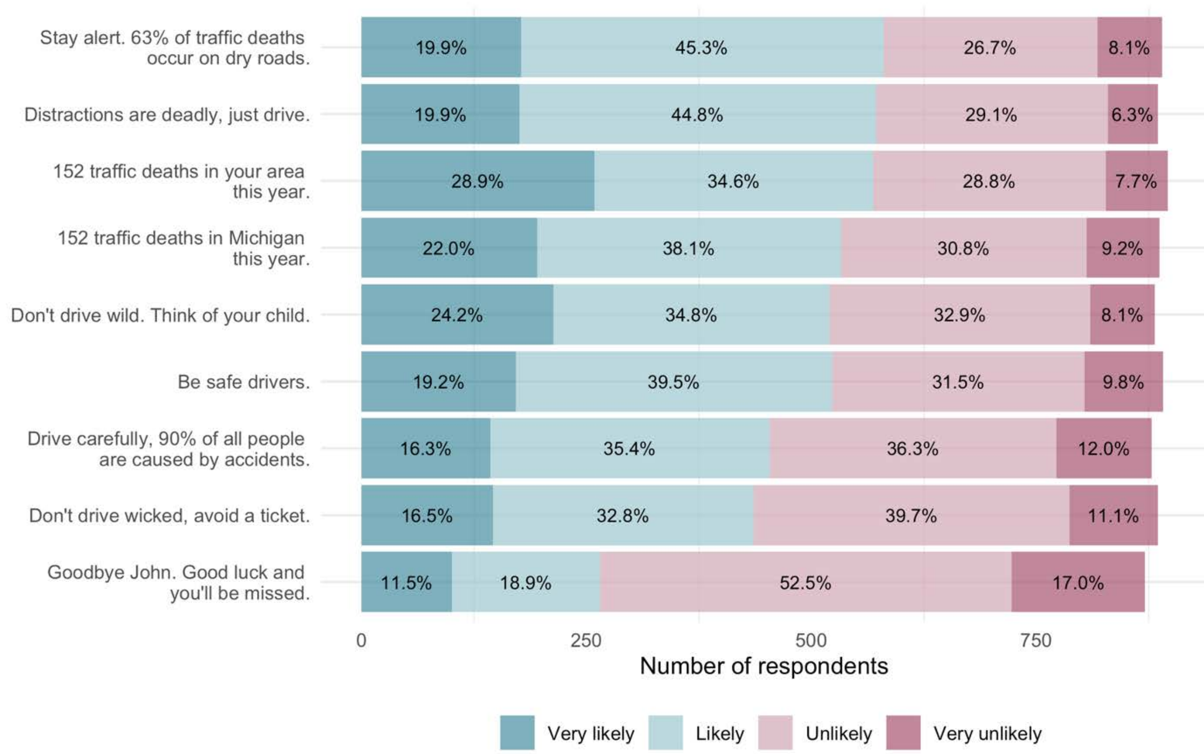


Note: Percentages may not sum to 100% due to rounding. Numbers of respondents may not be integers due to sample weighting

Figure 8. Respondents' View of when DMS Messages Lose Efficacy.

4.3 Testing for Specific Messages

The actual messages displayed on a DMS impact the degree to which drivers are influenced by them and some messages were more likely to cause behavioral changes than others **(**Figure 9**)**. For example, when "Stay Alert. 63% of traffic deaths occur on dry roads" is displayed on a DMS, 65.2% of respondents self-reported being likely or very likely to change their behavior; 34.8% said this message is unlikely or very unlikely to change their behavior. Younger respondents, those with a lower income, African Americans, and suburban respondents were more likely to change their driving behavior because of this message than older generations ($p < 0.01$), people with higher income ($p < 0.05$), Caucasians ($p < 0.001$), or rural respondents ($p < 0.01$).



Note: Percentages may not sum to 100% due to rounding. Number of respondents may not be integers due to sample weighting

Figure 9. DMS Messages and their Likelihood to Influence Self-Reported Driving Behavior

When "Distractions are deadly, just drive" is displayed on a DMS, again the majority (64.7%) of respondents self-reported being likely or very likely to change their behavior, and 35.4% of respondents were unlikely to do so. This message was more likely to influence behavior for people with lower incomes and African Americans than with a higher income ($p < 0.05$) or Caucasians ($p < 0.001$).

When "152 traffic deaths in your area this year" was displayed on a DMS, 63.5% of respondents self-reported being likely or very likely to change their behavior; 36.5% said this message was unlikely or very unlikely to change their behavior. This message is more likely to cause a change in self-reported behavior of younger respondents than older respondents ($p < 0.01$).

When "152 traffic deaths in Michigan this year" is displayed on a DMS, the majority (60.1%) of respondents self-reported being likely or very likely to change their behavior, and 40% were unlikely or very unlikely to do so. This message is significantly more likely to change the self-reported driving behavior of people with a lower income and African Americans, than it was for people with a higher income ($p < 0.01$) or Caucasians ($p < 0.05$).

When "Do not drive wild. Think of your child" was displayed on a DMS, 59% of respondents reported being likely or very likely to change their behavior; 41% say this message is unlikely or very unlikely to change their behavior. This message was significantly more likely to cause a change in self-reported behavior for people with a lower income, African Americans, and unmarried people than it was for people with a higher income ($p < 0.001$), Caucasians ($p < 0.001$), or married people ($p < 0.05$).

When "Be safe drivers" is displayed on a DMS, the majority (58.7%) of respondents reported that they were likely or very likely to change their behavior, whereas 41.3% were unlikely or very unlikely to change their behavior. Respondents with more education, higher incomes, and Caucasians were significantly less likely to be influenced by this message than were people with less education ($p < 0.05$), lower incomes ($p < 0.001$), or African Americans ($p < 0.001$).

The message "Drive carefully, 90% of all people are caused by accidents" was not likely to be as effective as other messages, 51.7% of respondents reported that this message was likely or very likely to cause a change in their driving behavior, whereas 48.3% said that it would be unlikely or very unlikely to do so. This message was significantly more likely to change the behavior of people with a lower income, African Americans, and unmarried people than it was for people with a higher income ($p < 0.01$), Caucasians ($p < 0.01$), or married people ($p < 0.01$).

The message "Do not drive wicked, avoid a ticket" was even less likely to cause self-reported change, 49.3% of respondents said this message was likely or very likely to do so, whereas the majority (50.8%) said that the message was unlikely or very unlikely to cause a change in behavior. This message was significantly more likely to influence a change in self-reported behavior for people with a lower income and African Americans than it was for people with a higher income ($p < 0.01$), and Caucasians ($p < 0.05$).

Lastly, the message "Goodbye John. Good luck and you will be missed" was the least likely to inspire a self-reported change in behavior, only 30.4% of respondents reported that they were likely or very likely to change their behavior because of this message, whereas the majority (69.5%) were unlikely or very unlikely to do so. This message was significantly more likely to cause a self-reported change in behavior for people who are not of Hispanic origin, than those who were ($p < 0.001$).

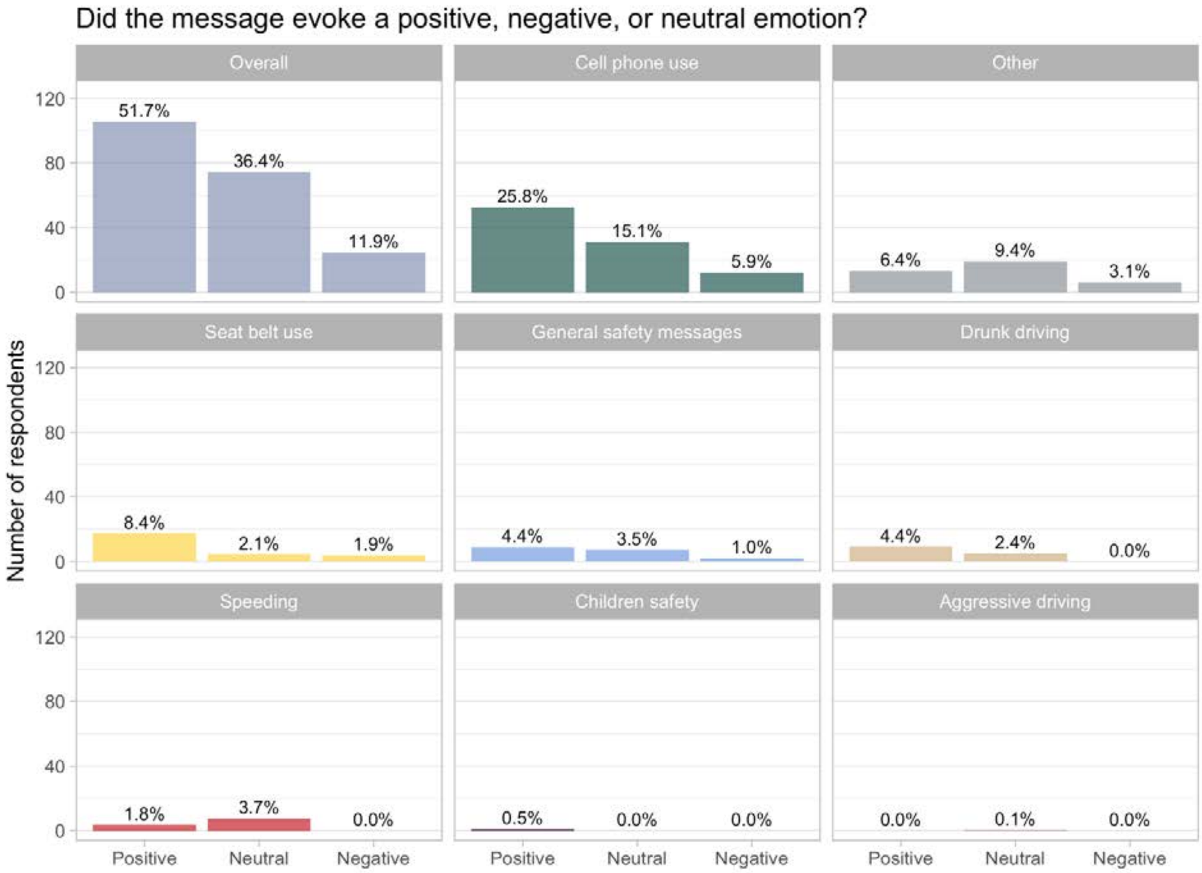
When messages were compared against a neutral message (“Be safe drivers”), the message “152 traffic deaths in your area this year” was significantly more likely to cause a self-reported change in behavior ($p < 0.01$). The messages: “Drive carefully, 90% of all people are caused by accidents”, “Don't drive wicked, avoid a ticket”, and “Goodbye John. Good luck and you'll be missed” were all statistically significantly less likely to cause a self-reported change in driving behavior ($p < 0.05$, $p < 0.05$, and $p < 0.001$ respectively).

Finally, when messages were compared against one that evokes a positive emotion (“Don’t drive wild. Think of your child”), the messages: “Drive carefully, 90% of all people are caused by accidents”, “Don't drive wicked, avoid a ticket”, and “Goodbye John. Good luck and you'll be missed” were all significantly less likely to cause a change in self-reported driving behavior ($p < 0.01$, $p < 0.001$, and $p < 0.001$ respectively).

4.4 DMS Impact on Driving Behavior based on Emotion and Consequence

4.4.1 Emotional Response

Overall, the majority (51.7%) of respondents who self-reported were affected by DMS recalled messages with positive emotions; 34.6% recalled messages with neutral emotions; and 11.9% recalled messages with negative emotions. The emotions identified by respondents varied by the topics of messages they recalled; respondents who recalled messages regarding seat belt use and cellphone use reported more positive emotions than other topics (Figure 10**).** When comparing messages within the same topic, the messages were significantly more likely to evoke positive emotions in older respondents than they did for younger respondents ($p < 0.05$). Respondents who recalled messages mentioning cellphone use with a positive emotion were significantly more likely to report a long-term improvement in their driving behavior than respondents who recalled messages mentioning cellphones in a negative light ($p < 0.05$).



Note: Percentages may not sum to 100% due to rounding. Number of respondents may not be integers due to sample weighting

Figure 10. Varying Messages Displayed on DMS, and Emotions Respondents Felt towards them

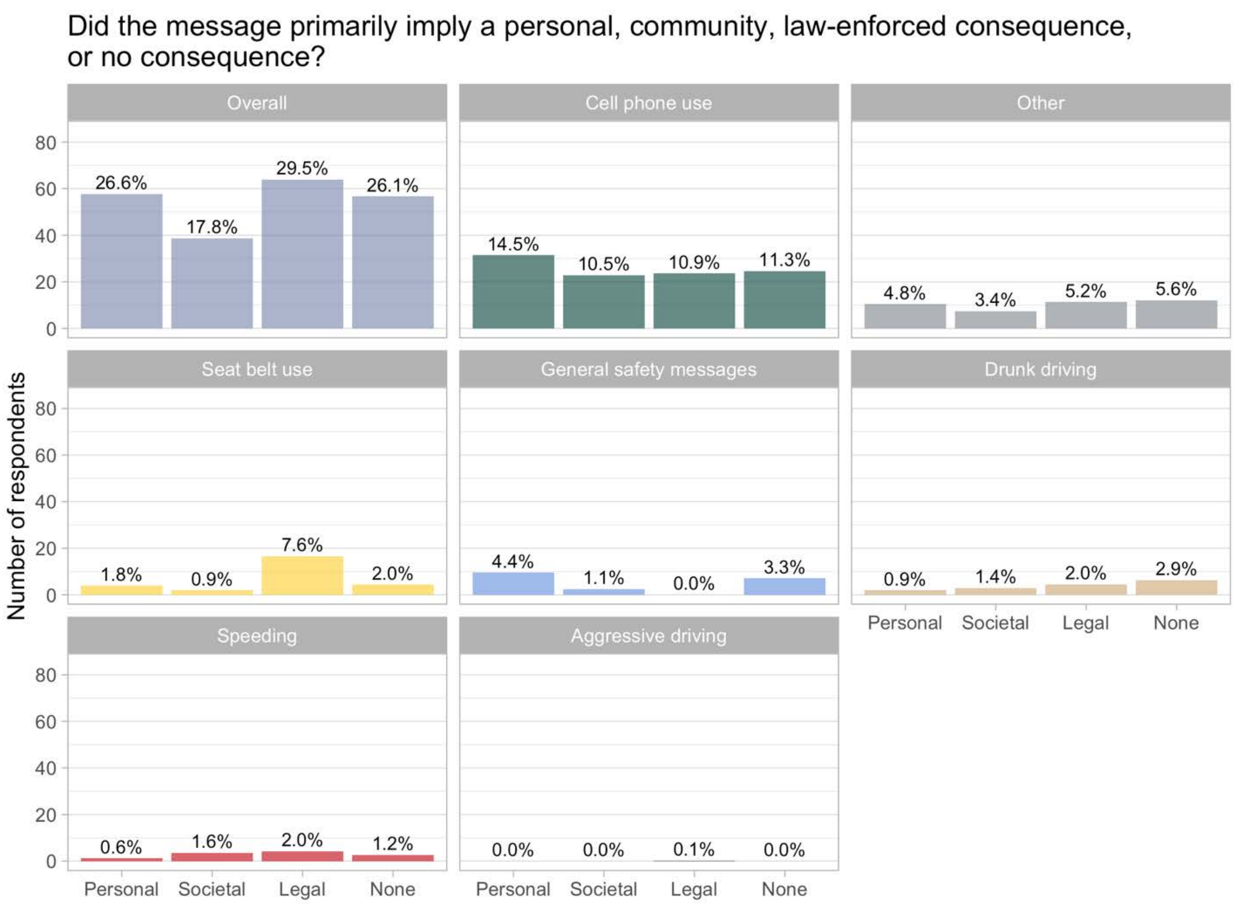
Ultimately, respondents who identified the most effective DMS message as one with a positive emotion were more likely to report both an immediate and a long-term improvement in their driving behavior than those who recalled messages with negative emotions ($p < 0.05$).

This is consistent with our finding that compared to “Don’t drive wild. Think of your child” (positive emotion), “Don't drive wicked, avoid a ticket” (negative emotion/ anger) and “Goodbye John. Good luck and you'll be missed” (negative emotion/ sadness) were less likely to affect driving behavior ($p < 0.001$).

However, other messages appeal to negative emotions, including “Stay alert. 63% of traffic deaths occur on dry roads”(fear), “152 traffic deaths in Michigan this year”(fear), “152 traffic deaths in your area this year”(fear), and “Distractions are deadly, just drive”(fear) were not statistically significantly different from "Don't drive wild. Think of your child" (positive emotion) in their likelihood of affecting behavior.

4.4.2 Consequences

In regards to what types of consequences respondents felt DMS messages evoke, the plurality (29.5%) of respondents who self-reported were affected by DMS recalled messages with legal consequences, followed by personal (26.6%), no consequence (26.1%), and/or societal consequences (17.8%) (Figure 11). There was no statistically significant relationships between the types of consequences conveyed by DMS, and self-reported behavior change; be it in the short or long-term.



Note: Percentages may not sum to 100% due to rounding. Number of respondents may not be integers due to sample weighting

Figure 11. Implication of Messages Displayed on DMS as Determined by Respondents.

When messages were compared within the same topic and against one with a personal consequence, respondents with a higher income were significantly more likely to report the most effective message as one with a community/societal consequence ($p < 0.05$), than were respondents with a lower income. Respondents not in the labor force, married respondents, and respondents who live in small cities or towns were significantly less likely to recall the most effective message as one with a community/societal consequence than were people in the labor pool ($p < 0.05$), unmarried ($p < 0.05$), or rural respondents ($p < 0.05$).

4.5 Preferences

Drivers reported that they prefer travel and weather advisories over fatality statistics and messages with humor. 50.9% of respondents would like to read DMS messages displaying fatality statistics; 57.1% preferred that messages be humorous. Though advisories are much more preferred than either of the above, 90.3% of respondents preferred travel advisories, and 89.6% preferred weather advisories (Figure 12**)**. Younger people, Democrats, and liberals were significantly more likely to prefer reading DMS messages with humor than older people ($p < 0.001$), Republicans ($p < 0.05$), or conservatives ($p < 0.001$). People of Hispanic origin and those with children under eighteen were significantly more likely to prefer DMS display messages about travel advisories than were Non-Hispanic people ($p < 0.001$) and those without young children ($p < 0.05$). When messages were analyzed collectively, respondents were significantly more likely to prefer reading travel ($p < 0.001$) and weather advisories ($p < 0.001$) than fatality statistics.

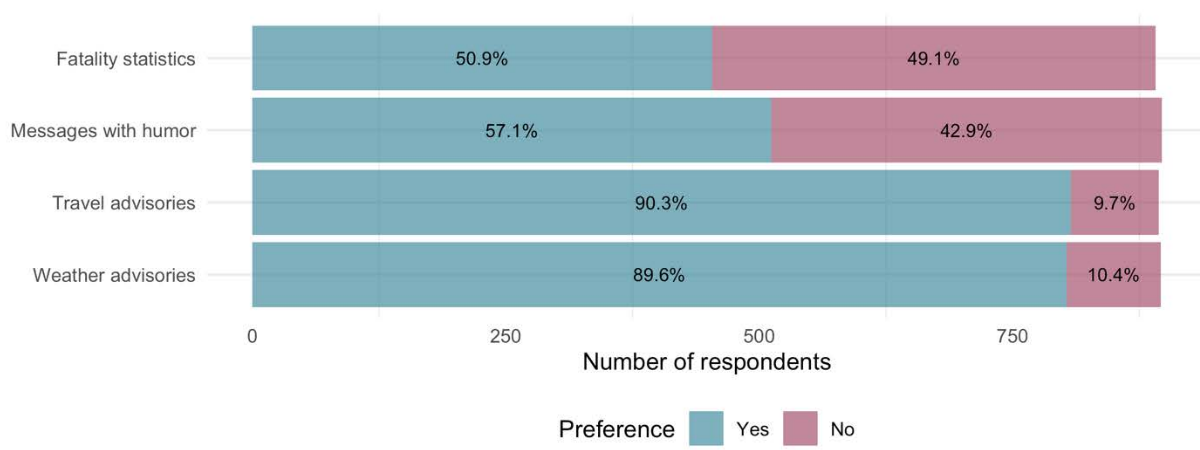


Figure 12. Different Types of Messages Displayed on a DMS, and Respondents' Preference towards them.

4.6 Recommendations

Ultimately, of those who had noticed DMS, approximatly one-third reported they were reminded of good driving behaviors that they were not using at the time. Reading DMS messages was likely to improve driving behavior of one-quarter of Michigan residents. The majority of respondents who self-reported a DMS-effect on their driving stated that the messages retained their efficacy for a long time. Consequence did not, but emotion played a role in changing self-reported driving behavior. The majority of respondents who self-reported were affected by DMS recalled messages with positive emotions. Respondents who identified the most effective DMS message as one with a positive emotion were more likely to report both immediate and long-term improvements in their driving behavior than those who recalled messages with negative emotions. In contrast, those who had neither seen DMS nor were reminded of a good driving behavior reported negative messaging would have an impact on their driving behavior. Thus, the content of a message affected how likely a driver self-reports a change in behavior. In general, respondents preferred travel and weather advisories as compared to safety messages, though there was varying degrees of support for the use of year-to-date fatality statistics and other targeted messages.

CHAPTER 5 – EVALUATION OF RELATIONSHIP BETWEEN CRASHES AND FREQUENCY OF SAFETY MESSAGES

All state transportation agencies have used DMS to display safety messages to varying degrees, although the frequency and nature of the messaging strategy varies from state to state. Safety messages range from showing current traffic fatality statistics to more creative messages, such as "DRINKING AND DRIVING IS PATH TO THE DARK SIDE." Some agency utilize the DMS for safety message as part of a specific awareness campaign such as Delaware and Michigan, while others open up for public input on the type of message to be displayed (e.g., Massachusetts held contest for most humorous safety message submitted) (Mitran, Cummins, and Smithers, 2018).

Since 2012, Michigan has consistently used its DMS to display safety-related messages, including the number of traffic fatalities and other safety messages (e.g., speeding, drunk driving, and distracted driving). Yet, there is limited evidence as to the effectiveness of this initiative. This study addresses this gap in the research literature through an evaluation of the safety impacts of using DMS to display road safety messages. The scientific approach to investigating road safety campaigns can provide evidence-based results on the effect and usability of the intended safety message (Adamos and Nathanail, 2018).

5.1 Data

As a part of this study, a geospatial dataset was developed that involved the integration of data from various sources. This included historical information detailing the messages that have been displayed on DMS across Michigan, as well as crash, roadway, and traffic volume data for the MDOT-maintained highway network. Detailed information regarding each of these data sources, as well as the data integration process is presented in the following sections.

5.1.1 Dynamic Message Sign Data

The Michigan Department of Transportation (MDOT) provided information on all messages displayed on DMS across Michigan. Data were obtained for the period from 2012 through 2018. As of 2018, there are 202 fixed DMS on freeway across Michigan, with the Metro Region (including Detroit) including the highest number, followed by the University, and Grand Regions as shown in Figure 13.

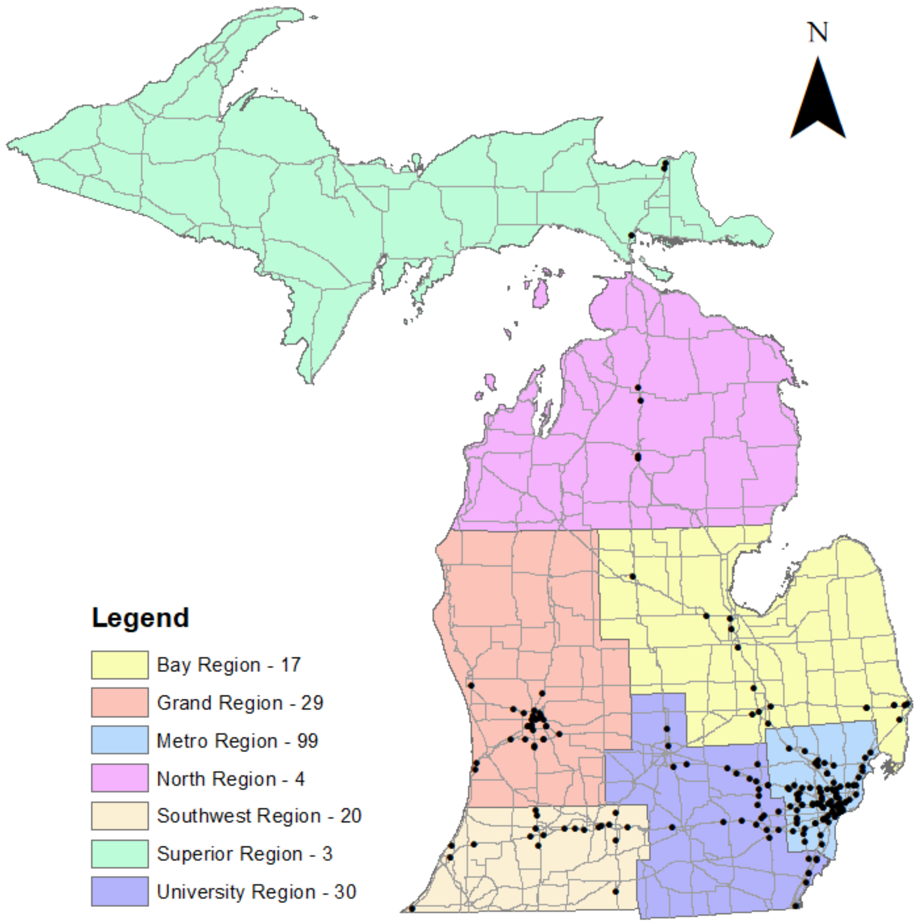


Figure 13. Number of Fixed Dynamic Message Signs by MDOT Region

The messages displayed on these DMS covered a wide range of traffic-related information. The majority of the time, the DMS are used to display current travel times to specific locations (e.g., cities, destinations). Occasionally, other types of messages were also displayed, including those related to incidents (e.g., crashes, vehicle breakdowns), weather (e.g., icy road, snowstorm), amber alerts, and safety messages.

All safety messages displayed on DMS in Michigan were categorized into two types: (1) general safety messages and (2) site-specific safety messages. The general safety messages provide details of important traffic safety issues that do not relate to any specific location or event. These types of messages: (1) aim to increase awareness of traffic safety issues among drivers, (2) refer to safety-related laws and behaviors, or (3) encourage safe driving practices.

In contrast, site-specific safety messages are more targeted and aimed at improving driver awareness of important local conditions. Messages in this category are attributed to events such as a crash occurring at a downstream location, the presence of a work crew, and rare events such as the presence of wrong-way drivers in the area. Segregating site-specific messages is important as they may affect drivers differently than those in the general safety message category. The primary emphasis of this study was to evaluate the potential impacts of the general safety messages.

In identifying messages related to safety, this study employed a keyword-searching method using R Studio and Microsoft Excel. After reviewing hundreds of messages, a series of keywords were selected that were common amongst those messages that were safety-focused. Among the general safety messages, 27 different keywords were utilized, including impaired, drunk, buzz, sober, seat belt, move over, phone, text, ticket, fine, deer, and death, among others. Additional keywords were used to classify the site-specific safety messages.

After identifying all messages containing these keywords, a quality assurance review was conducted. This process was used to eliminate non-safety related messages that may have been inadvertently flagged by the same keywords, as well as to correct errors in the categorization of safety message (i.e., general versus site-specific). For example, the keyword "ice" was chosen to identify messages like "ice and snow take it slow" or "use caution watch for ice on ramps and bridges". However, this keyword will also flag non-safety related messages such as "amber alert 1998 purple Voyager MI license ABC1234" as this message contains the keyword "ice" in the word "license". Consequently, these messages were removed from the data.

In other cases, some of the keywords used may have resulted in the safety messages being classified in the wrong category. For example the keyword "crash" would yield the site-specific safety messages such as "crash ahead on US-23 north after M-59 exit 67". However, this keyword will also filter some general safety messages such as "texting and driving increases crash risk by 23 times". In this case, these messages were manually reclassified into the correct category.

Table 3 provides examples of general safety messages that were displayed on DMS during 2018. For analysis purposes, these messages were classified into seven different groups: impaired driving, distracted driving, seat belt use, fatality statistics, work zone related, aggressive driving, and others.

Table 3. Examples of General Safety Message

Category	Message
Impaired Driving	Impaired driving 42% of traffic deaths in Northern Michigan Drive sober or get pulled over Buzzed driving is drunk driving don't do it Fans don't let fans drive drunk You drink & drive you lose Don't drink and drive Want to arrive? Don't drink and drive Don't drink and drive get a ride
Distracted Driving	Texting and driving increases crash risk by 23 times. Just drive, your phone can wait Stay alert. 63% of traffic death occur on dry roads A steering wheel is not a hands-free device Put your phone in park One text or call could wreck it all U text U drive U pay Don't text and drive. Drive with care
Seat Belt Use	Click it or ticket No seat belt, 32% of traffic deaths in Northern Michigan Buckle up every trip every time Buckle up. You've seen how other people drive
Fatality Statistics	152 traffic deaths to date. Down 34 from March 2017 91 traffic deaths to date. Up 24 over February 2017
Work Zone	Work zone safety is in your hands. Drive to zero crashes Work zone safety is everybody's responsibility Traffic fines are double in work zones
Aggressive Driving	Ice and snow don't cause crashes, drive too fast for conditions causes crashes Winter is here obey the basic speed law In ice and snow take it slow Avoid a crash don't tailgate Use caution watch for ice on ramps and bridges Stop speeding before it stops you Keep a safe following distance on ice & snow
Others	Deer crashes increase by 100% October-November Don't veer for deer Headlights on day and night Save a life look twice for motorcycle Heads up for cyclists Move over or slow down for emergency vehicles and tow trucks Use turn signal before changing lanes Lane departures. 76% of traffic deaths in northern Michigan Traffic crashes are leading cause of death for ages 15-24 Winter is here, check tires for sufficient tread

Table 4 provides a summary of the total number of messages (or DMS-days) per year that a safety message was displayed from 2012 through 2018. To clarify, these quantities represent the sum of the number of days that safety messages were displayed across all 202 fixed DMS throughout the state. Separate counts are provided for general and site-specific safety messages. For the general safety messages, these data show a persistent increasing trend in the number of messages displayed from 2012 to 2016. In 2017, the number dropped by more than 40 percent. One contributing factor towards this decrease was that until 2016, messages showing the number of traffic fatalities to date were displayed weekly on Wednesdays. However, starting in 2017, MDOT changed the frequency from four times a month to once a month.

Table 4. Number of Unique Safety Messages Displayed, 2012-2018

Year	General Safety Message	Site-Specific Safety Message
2012	998	1,114
2013	3,320	2,930
2014	8,773	4,061
2015	14,125	4,864
2016	17,394	9,731
2017	8,826	6,742
2018	12,115	6,110

It should also be noted that when safety messages are combined with travel time messages, every time the travel time information is updated, its paired safety message is also refreshed, resulting in duplication of the same safety message. Consequently, the unique number of safety messages displayed by day was obtained by removing these duplicate messages from each DMS location. For the purposes of this study, the five most recent years of DMS message data were used, covering the period from 2014 through 2018.

5.1.2 Crash Data

Crash data were obtained from the Michigan State Police for the same five-year period from 2014 to 2018. These data include detailed information at the crash-, vehicle-, and person-level for every police-reported crash that occurred in Michigan. The objective of this study was to explore the relationship between the annual number of crashes and the frequency in which safety messages were displayed. Consequently, data were collected for total crashes, as well as for two subsets of crashes that were frequent targets of safety messages. This included crashes occurring between 10:00 pm and 3:00 am and crashes due to speeds too fast for conditions. These two subsets were investigated to determine whether targeted messages focused on impaired driving and speeding/tailgating showed any relationship to the frequency of crashes due to such behaviors.

Crashes during the 10:00 pm – 3:00 am time period were used instead of crashes coded as alcohol involved given concerns as to underreporting of crashes. Data show that injury crashes involving alcohol are more prevalent during this period in Michigan (MSP OHSP, 2021). For crashes due to speeds too fast for road conditions, this information is obtained from a standard field on the police crash report form that describes any hazardous actions taken by the at-fault drivers (e.g., failure to yield, improper turn).

Crash data were obtained for the first segment immediately downstream of each DMS throughout the state. This allows for an explicit comparison as to trends in the number of crashes with respect to the frequency with which safety messages are displayed. Further details are provided below in the section detailing data integration.

5.1.3 Roadway and Traffic Data

Roadway and traffic information was obtained from a roadway inventory file maintained by MDOT. The file consists of 122 road attribute data for all state-maintained roads in Michigan. The data is disaggregated into segments of varying lengths based upon where changes occur with respect to traffic volumes or key geometric characteristics. For the purposes of this study, short segments were aggregated, where possible. For each road segment, the pertinent information obtained from the inventory file included the segment length, annual average daily traffic (AADT), speed limit, number of lanes, lane width, shoulder widths, and median width.

5.2 Data Integration

Data from these three sources were integrated to create a segment-level dataset. As noted previously, the primary emphasis was on examining whether the annual number of crashes on a downstream segment was impacted by the frequency with which safety messages were displayed on a DMS immediately upstream of that segment. Here, the assumption is that drivers will have noticed and read the safety messages that are displayed and, in turn, this information may impact their driving behavior and resultant crash risk. Figure 14 shows the layout of selected road segments downstream of DMS.

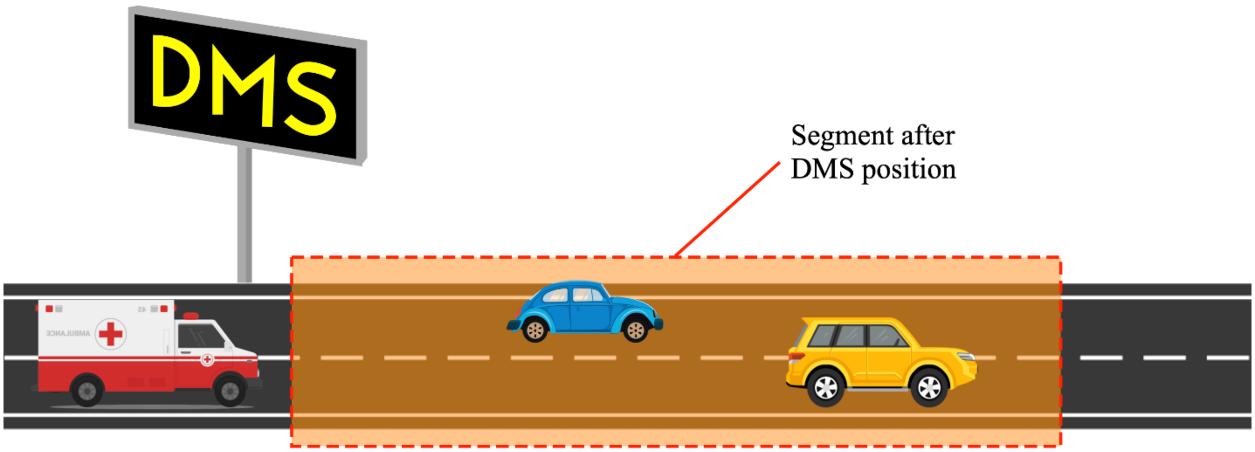


Figure 14. Layout of Downstream Segments Near DMS

After all segments were selected, roadway geometry, traffic volume, and crash information was integrated using unique route identifiers and mile point information that was common across these datasets. For each downstream segment, the DMS message database was used to calculate the number of days during each year that safety messages were displayed. This allows for an assessment as to whether increases or decreases in the number of messages displayed on a DMS impacts the frequency of crashes.

Table 5 provides descriptive statistics for the segments that were included in the final database. AADT values ranged from 2,469 to approximately 100,000 vehicles per day, with an average of 43,098 veh/day. The vast majority of the DMS are located in urban areas, particularly the MDOT Metro Region, which comprised 50 percent of the sample. The geometric characteristics were largely similar across the freeway network, with the exception of median width.

Table 5 also includes details as to the frequency with which various types of safety messages were displayed. On average, DMS displayed safety messages 61 days per year, with the number of messages ranging from 0 to 280 messages across the entire sample of devices. The rate at which specific types of safety messages were displayed was also tabulated for several of the more frequent types of messages. Messages related to speeding or tailgating messages were the most commonly used subset of messages. These messages were shown approximately 12 days per year on each DMS, up to a maximum of 132 days. Messages related to driver impairment and drunk driving were displayed five days per year per DMS on average.

Table 5. Descriptive Statistics

Variable	Min.	Max.	Mean	Std. Dev.
Segment Information				
Annual average daily traffic (veh/day)	2,469	98,359	43,098	23,884
Length (mi)	0.38	2.15	1.27	0.34
Speed limit: 55 – 65 mph (1 if yes; 0 otherwise)	0	1	0.16	0.37
Speed limit: 70 – 75 mph (1 if yes; 0 otherwise)	0	1	0.84	0.37
Number of lanes	2	6	2.86	0.85
Lane width (ft)	11	12	12.00	0.07
Median width (ft)	8	200	50.33	35.91
Right shoulder width (ft)	8	14	10.48	1.08
Left shoulder width (ft)	3	17	8.53	2.08
Michigan DOT Regional Information				
Metro (1 if yes; 0 otherwise)	0	1	0.50	0.50
Grand (1 if yes; 0 otherwise)	0	1	0.14	0.35
University (1 if yes; 0 otherwise)	0	1	0.14	0.35
Southwest (1 if yes; 0 otherwise)	0	1	0.10	0.30
Bay (1 if yes; 0 otherwise)	0	1	0.08	0.28
North (1 if yes; 0 otherwise)	0	1	0.02	0.14
Superior (1 if yes; 0 otherwise)	0	1	0.01	0.12
Number of days safety messages were displayed per DMS per year				
Total	0	280	60.63	45.95
Speeding/tailgating	0	132	12.10	14.83
Impaired/drunk driving	0	37	5.47	6.67
Crashes by type per year				
Total Crashes	0	142	27.68	26.06
Crashes due to speed too fast	0	50	6.04	5.95
Crashes between 10:00 PM and 3:00 AM	0	20	2.89	3.24

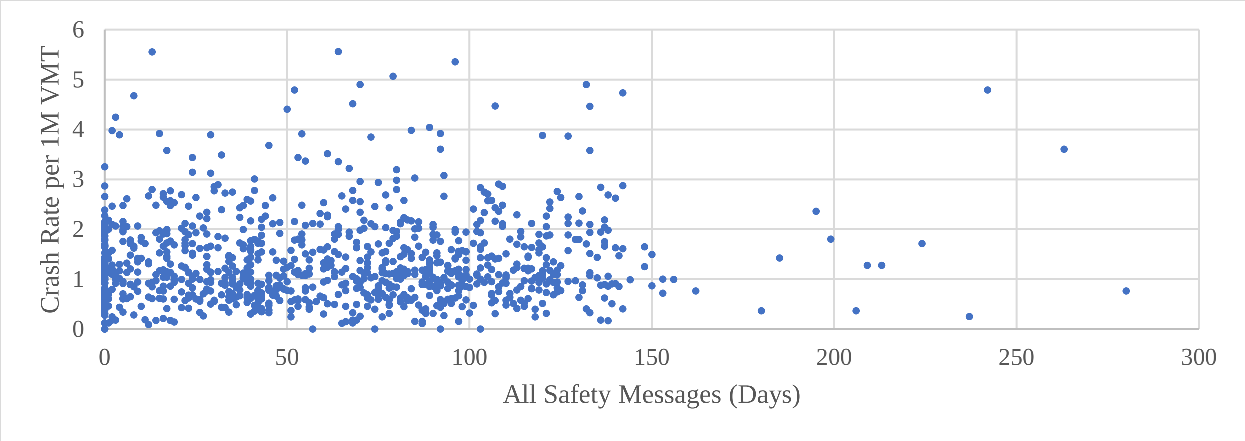


Figure 15a. Total Crashes vs. Days All Safety Messages were Displayed

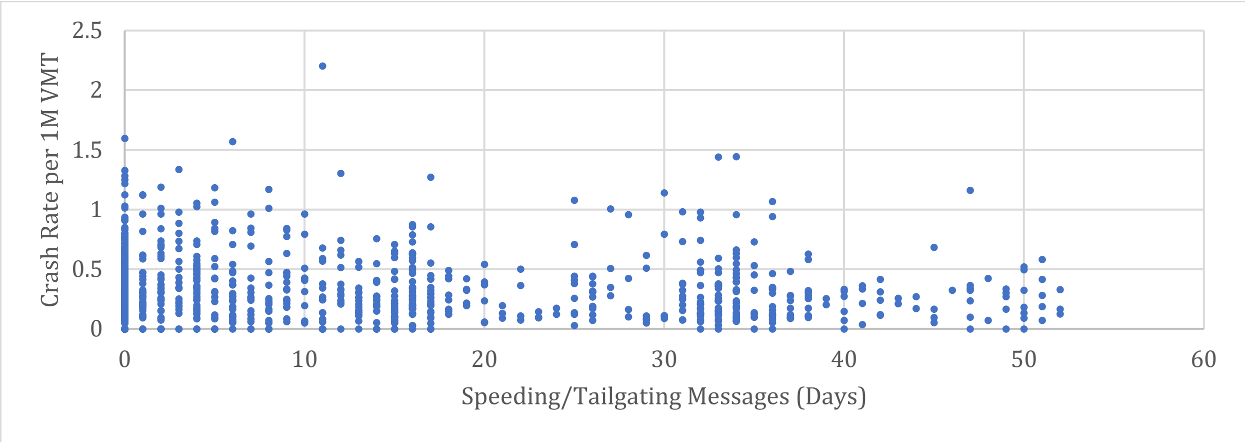


Figure 15b. Speeding-Related Crashes vs. Days Speeding/Tailgating Messages were Displayed

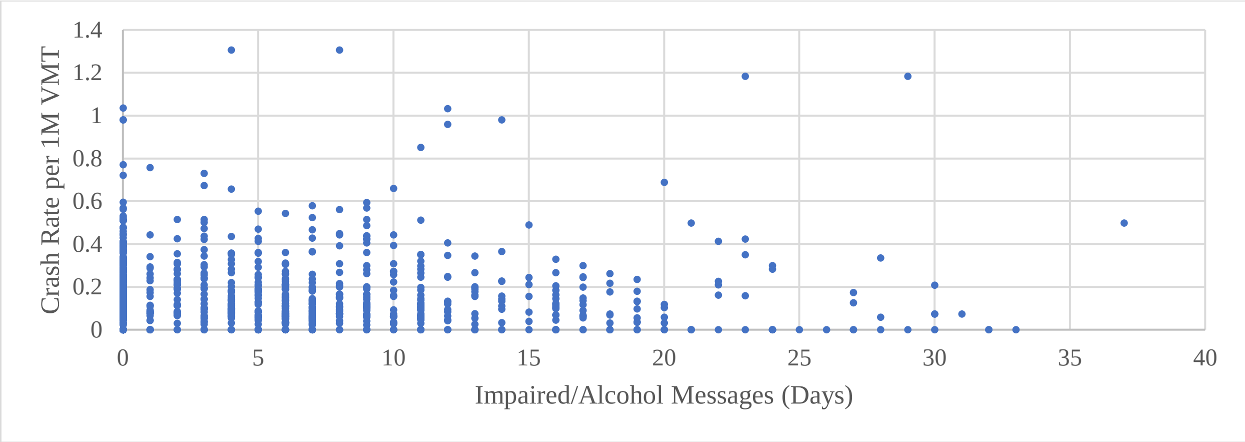


Figure 15c. Crashes from 10 pm to 3 am vs. Days Impaired Driving Messages were Displayed.

Figure 15 Annual Crashes per Mile vs. Number of Days Safety Messages were Displayed

Table 5 also provides details of the annual number of police-reported crashes that were observed on each segment. The total number of crashes per segment ranged from zero to nearly 150 per year, with an average of 27.7 crashes per segment per year. The average number of speeding related crashes was 6.0 per segment-year while crashes between 10 pm and 3 am averaged 2.9 per segment-year. Figure 15 provides a graphical representation of the relationships between annual crashes per million vehicle miles traveled (VMT) and the number of days that specific safety messages were displayed. There was no clear trend between total crashes and the total number of safety messages (of any type) displayed (Figure 15a). However, for the two subsets of crashes (Figure 15b and Figure 15c), both plots show a general decrease in crashes as the frequency of safety messages is increased.

5.3 Statistical Methods

To better understand the relationship between the frequency of traffic crashes and the number of times that safety messages were displayed on DMS, a series of regression models were estimated for total, speed too fast, and late night crashes. As the annual numbers of crashes on specific road segment are comprised of discrete and non-negative integers, negative binomial regression models have emerged as a preferred statistical method for the analysis of crash data. Within the context of this study, the probability of segment i experiencing y_i crashes during a specific year of the analysis period can be calculated as shown in equation 1:

$$P(y_i) = \frac{\Gamma((1/\alpha)+y_i)}{\Gamma(1/\alpha)y_i!}\left(\frac{1/\alpha}{(1/\alpha)+\lambda_i}\right)^{1/\alpha}\left(\frac{\lambda_i}{(1/\alpha)+\lambda_i}\right)^{y_i}, \quad (1)$$

where $\Gamma(.)$ is a gamma function, α is an overdispersion parameter, and λ_i is equal to the expected number of crashes on segment i. The λ_i parameter is related to a series of site-specific characteristics as shown in equation 2:

$$\lambda_i = EXP(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \varepsilon_i), \quad (2)$$

where X_1 to X_k are a series of independent variables (e.g., traffic volumes, geometric characteristics the number of safety messages displayed), β_1 to β_k are a series of parameters estimated from the regression model, and $EXP(\varepsilon_i)$ is a gamma-distributed error term with mean equal to one and variance of α.

Within the context of this study, a random parameters framework is introduced in order to account for unobserved heterogeneity. Given the fact that each site is observed five times (once per year from 2014 to 2018), this may introduce correlation in the crash counts within the individual sites over time as individual sites are likely to experience more (or less) crashes than other similar segments due to important site-specific factors that are not included in the model. This may potential lead to biased, inefficient, or inconsistent parameter estimates. In the random parameters negative binomial model, the constant term and the parameter estimates of independent variables are allowed to vary across locations as shown in equation 3:

$$\beta_{0i} = \beta_0 + \varphi_i, \tag{3}$$

where φ_i is a randomly distributed error term with mean zero and variance σ^2. This error term takes the same value for an individual site over each year of the study period and is allowed to vary across sites. The expected crash count from equation 2 is then conditional on the distribution of φ_i. This results in the following log-likelihood function:

$$LL = \sum_{\forall i} ln \int_{\varphi_i} g(\varphi_i) P(n_i|\varphi_i)\, d\varphi_i, \tag{4}$$

where $g(\cdot)$ refers to the probability density function of φ_i. Estimation is conducted by simulated maximum likelihood and 200 Halton draws are used as a more efficient alternative for numerical integration than random draws.

5.4 Results and Discussion

This section presents the results of three random parameters negative binomial models that were estimated to investigate the relationship between crashes and the frequency in which safety messages are displayed. Each model includes a variable that specifies the percentage of days per year that safety messages were displayed on a DMS while controlling for other variables of interest. These variables include AADT, segment length, median width, and shoulder widths.

For each model, parameter estimates are presented, along with their standard errors, t-statistic, and p-value. When interpreting the results from each model, a positive parameter estimate indicates that crashes increase as the independent variable is increased. The converse is true for negative parameter estimates. In general, random parameters are estimated if the standard deviation of the parameter estimates are statistically significant; otherwise, the parameters will be fixed across the population.

Four variables including the intercept were found to be random parameters, and three variables, AADT, percentage of days on which messages were displayed, and right shoulder width were fixed across the population. The results from Table 4 show that the frequency of DMS safety messages has virtually no relationship with the total number of crashes (p-value = 0.732).

Table 6 presents the results for all crashes, Table 7 presents results for crashes occurring between 10 pm and 3 am, and Table 8 presents results for speeding-related crashes.

Four variables including the intercept were found to be random parameters, and three variables, AADT, percentage of days on which messages were displayed, and right shoulder width were fixed across the population. The results from Table 4 show that the frequency of DMS safety messages has virtually no relationship with the total number of crashes (p-value = 0.732).

Table 6. Model Results for Total Crashes

Variable	Estimate	SE	Z-Value	P-Value
Intercept	-8.063	0.253	-31.910	<0.001
Standard deviation	0.275	0.010	27.31	<0.001
LN (AADT)	1.146	0.020	56.100	<0.001
LN (Segment length, mile)	0.652	0.037	17.610	<0.001
Standard deviation	0.319	0.029	10.940	<0.001
Percent of days with any type of safety message	0.000	0.001	0.340	0.732
Median width (ft)	-0.002	0.000	-6.160	<0.001
Standard deviation	0.003	0.000	14.900	<0.001
Right shoulder width (ft)	-0.046	0.011	-4.350	<0.001
Left shoulder width (ft)	-0.064	0.005	29.030	<0.001
Standard deviation	0.033	0.001	29.030	<0.001
Overdispersion parameter	0.042	0.003	14.000	<0.001

Note: LN = Natural logarithm; AADT = Average annual daily traffic; SE = Standard error

Several of the geometric characteristics were shown to have a strong relationship with crash frequency. Crashes were found to be virtually elastic with respect to traffic volumes (i.e., a one-percent increase in volume resulted in a one-percent increase in crashes) and crashes were reduced as the median or shoulder widths were increased. While the effects of these variables tended to vary from segment to segment (as reflected by the standard deviation parameters), roads with wider lanes, shoulders, and medians tended to experience fewer crashes in the vast majority of instances.

It should be noted that this initial analysis considered safety messages of any type, including general information (e.g., fatalities to date), as well as more targeted, behavior-specific messages (e.g., distracted driving, drinking and driving, speeding and tailgating). As many of these type of messages are somewhat ambiguous and do not target specific problem behaviors of interest, a series of subsequent analyses narrowed in on two behaviorally-focused types of messages to see if any trends emerged within specific subsets of crashes.

Table 7 displays the results for crashes occurring between 10 pm and 3 am as a function of the number of alcohol/impaired driving related messages that were displayed. All variables were found to be random parameters except for median width and right shoulder width. The results from Table 7 show that crashes tend to decrease as the frequency of messages increase. However, this mean effect was not statistically significant (p-value = 0.329), but was shown to vary substantially from location to location (p-value < 0.001). The effects of the other variables tended to be relatively consistent to the results for total crashes, though in this case, the effects of median width and right shoulder width tended to be homogeneous across segments.

Table 7. Model Results for Crashes between 10 pm and 3 am

Variable	Estimate	SE	Z-Value	P-Value
Intercept	-7.528	0.580	-12.980	<0.001
Standard deviation	0.368	0.023	16.340	<0.001
LN (AADT)	0.904	0.048	18.970	<0.001
Standard deviation	0.005	0.002	2.650	0.008
LN (Segment length, mile)	0.463	0.080	5.770	<0.001
Standard deviation	0.315	0.066	4.810	<0.001
Percent of days with alcohol/impaired messages	-0.013	0.014	-0.980	0.329
Standard deviation	0.040	0.010	4.190	<0.001
Median width (ft)	-0.002	0.001	-1.710	0.087
Right shoulder width (ft)	-0.039	0.025	-1.570	0.116
Left shoulder width (ft)	-0.091	0.011	-7.960	<0.001
Standard deviation	0.025	0.003	9.360	<0.001
Overdispersion parameter	0.082	0.020	4.100	<0.001

Note: LN = Natural logarithm; AADT = Average annual daily traffic; SE = Standard error

Lastly, Table 8 presents results for for crashes where the driver was speeding or otherwise traveling too fast for conditions as determined using standard fields on the police crash report form. Interestingly, analysis of these data showed that crashes decrease significantly based upon the frequency with which speeding and tailgating related messages are displayed. A one percent increase in the frequency of message display is associated with an average decrease of 1.5 percent in these types of crashes. It should be noted that speed limit increases occurred on more than 600 miles of rural freeway during calendar year 2017. Most of these increases occurred outside of the study area, but it is possible that associated enforcement and education/outreach campaigns may have had some effect. The effects of other variables (e.g., traffic volumes, segment length, median width, shoulder width) remain similar as compared to prior analyses.

Table 8. Model Results for Crashes due to Speed too Fast

Variable	Estimate	SE	Z-Value	P-Value
Intercept	-7.650	0.473	-16.160	<0.001
Standard deviation	0.106	0.017	6.170	<0.001
LN (AADT)	0.942	0.040	23.740	<0.001
Standard deviation	0.009	0.002	5.910	<0.001
LN (Segment length, mile)	0.765	0.067	11.390	<0.001
Standard deviation	0.314	0.050	6.280	<0.001
Percent of days with speeding/tailgating messages	-0.015	0.005	-3.080	0.002
Standard deviation	0.028	0.003	8.980	<0.001
Median width (ft)	-0.013	0.001	-1.960	0.050
Standard deviation	0.003	0.000	8.650	<0.001
Right shoulder width (ft)	-0.055	0.019	-2.980	0.003
Standard deviation	0.022	0.002	13.370	<0.001
Left shoulder width (ft)	-0.021	0.009	-2.290	0.022
Standard deviation	0.046	0.002	21.860	<0.001
Over dispersion parameter	0.090	0.011	8.182	<0.001

Note: LN = Natural logarithm; AADT = Average annual daily traffic; SE = Standard error

5.5 Summary

Ultimately, the results from these analyses did not show any meaningful differences in terms of total crashes. However, it is important to restate that this analysis considered all types of safety messages. Subsequent analyses into messages targeted towards specific types of high-risk behaviors, such as speeding or impaired driving, showed more promising results. Nighttime crashes decreased marginally as the frequency of alcohol and impaired driving messages increased.

The most pronounced effects were related to speed-related crashes where statistically significant reductions were observed. In spite of this result, additional research is warranted in this area, particularly since this study coincided with speed limit increases that occurred throughout rural areas of Michigan.

Beyond the results presented herein, additional analyses were conducted with other subsets of crashes (e.g., distracted driving), at other levels of detail (e.g., daily and weekly crashes), and with alternate model specifications (e.g., with upstream segments, with alternate specifications for message frequency and type). However, these analyses did not provide any additional insights as to the nature of the relationship between the use of safety messages and the occurrence of traffic crashes.

CHAPTER 6 – FIELD EVALUATIONS OF DRIVER RESPONSE TO TARGETED SAFETY MESSAGES

Chapter 5 showed that the frequency in which safety messages are displayed shows only marginal correlation in general with the frequency of traffic crashes at an aggregate level. However, there are several limitations to this analysis, which make it difficult do directly establish the impacts of the messaging campaign on fundamental driver behavior.

A more direct measure of the impacts of DMS messages is the actual behavior of drivers at the time they are observing these messages. To this end, a series of field studies were conducted in order to assess real-time changes in driver behavior using a series of surrogate safety measures. To this end, this chapter details the results from two field studies of road user behavior:

1. The first study focused on driver response when encountering an in-service MDOT or Michigan State Police vehicle on the outside shoulder. The State of Michigan has a law that requires drivers to slow down and, if possible, move over when they encounter such vehicles on multilane roadways. This study evaluated driver response to such vehicles, and compliance with the Move Over/Slow Down law, including a supplementary assessment of the degree to which upstream safety messages informed drivers of the law.
2. The second study examined driver response to speeding-related messages. A series of different safety messages were compared to assess the degree to which drivers adjusted their speeds as they passed the DMS sign.

6.1 Experimental Design for Field Evaluation

Initially, several sites were considered for potential use in field studies of driver behavior in response to DMS safety messages. The selection of the proposed sites was based on several factors. The first one was the suitability for safe and efficient setup of data collection equipment (i.e., cameras, LIDAR). The second was the topography of the site. Sites were prioritized if they were located on relatively flat, tangent sections with adequate sight distance before and after the DMS. The third one criteria was the distance between the DMS and the nearest downstream interchange. Sites were selected to minimize the potential for lane changes that would be due to factors other than the service vehicles and messaging campaign. In this case, a minimum distance of one mile was established. Ultimately, three final sites were selected to evaluate the effectiveness of these messaging campaigns. In each case, data were collected on weekdays under clear weather conditions.

6.1.1 Move Over and Slow Down Message Signs on Dynamic Message Signs

An expanded version of Michigan's Move Over/Slow Down law went into effect on February 13, 2019. The law requires motorists to slow down to at least 10 mph below the posted speed limit and move over for any stationary emergency or service vehicles (e.g., police, fire, ambulance, road service, road maintenance, utility service, etc.) when their lights are activated. Failure to do so may result in a maximum fine of $7,500 or not more than 15 years of imprisonment or both. Changes to the law were introduced to cover a broader range of service vehicles (as compared to the prior law, which focused on emergency vehicles).

This study was focused on examining driver compliance with this law through a field assessment of changes in driver behavior (e.g., lane and speed selection) when approaching an MDOT or Michigan State Police vehicle in-service with its lights and sirens activated. As a part of these studies, different safety messages were evaluated at two study locations, providing insights as to potential supplementary impacts of DMS messaging on driver behavior.

Table 9 shows detail information of the sites for the move over and slow down messages. Both sites are located in the MDOT Grand Region near Grand Rapids. Data were collected using high-definition (HD) cameras at upstream and downstream of DMS. The cameras were set up on elevated locations (e.g., on elevated crossroads or bicycle lane) at both sites. The first site was located on an eastbound (EB) of the M-6 freeway, as shown in Figure 16, where the distance of the upstream and downstream cameras to the DMS is approximately one mile. The staged stationary vehicles are parked on the shoulder, downstream of the DMS, approximately 600 ft from the camera. The second site is located on a section of westbound (WB) I-96, which is shown in Figure 17. The distance between the upstream and downstream cameras with the DMS is approximately 2.0 and 0.7 miles, respectively. The stationary vehicles was located after the DMS, 500 ft from the downstream camera. The speed limit for passenger vehicle and large truck are the same for both sites, which are 70 mph and 65 mph, respectively. In this research, two types of stationary vehicles were evaluated for both sites, vehicles from the Michigan State Police (as an emergency vehicle), and MDOT (as a service vehicle).

Table 9. Site Information for Move Over and Slow Down Messages

Highway	County	DMS Coordinate	Staged Emergency/MDOT Vehicle Coordinate	Camera Setup Locations
EB M-6	Kent	42.850844, -85.584278	42.846394, -85.563229 (approximately 1 mile downstream from the DMS)	Upstream: Elevated portion of Fred Meijer Trail east of Kalamazoo Ave (42.851539, -85.602870 Downstream: Protected bike lane on East Paris Eve (42.846142, -85.565397)
WB I-96	Kent	42.878465, -85.449180	42.878399, -85.462119 (approximately 0.7 mile downstream from the DMS)	Upstream: Morse Lake Ave SE cross road (42.878820, -85.410318) Downstream: Whitneyville Ave SE overpass (42.878492, -85.463955)

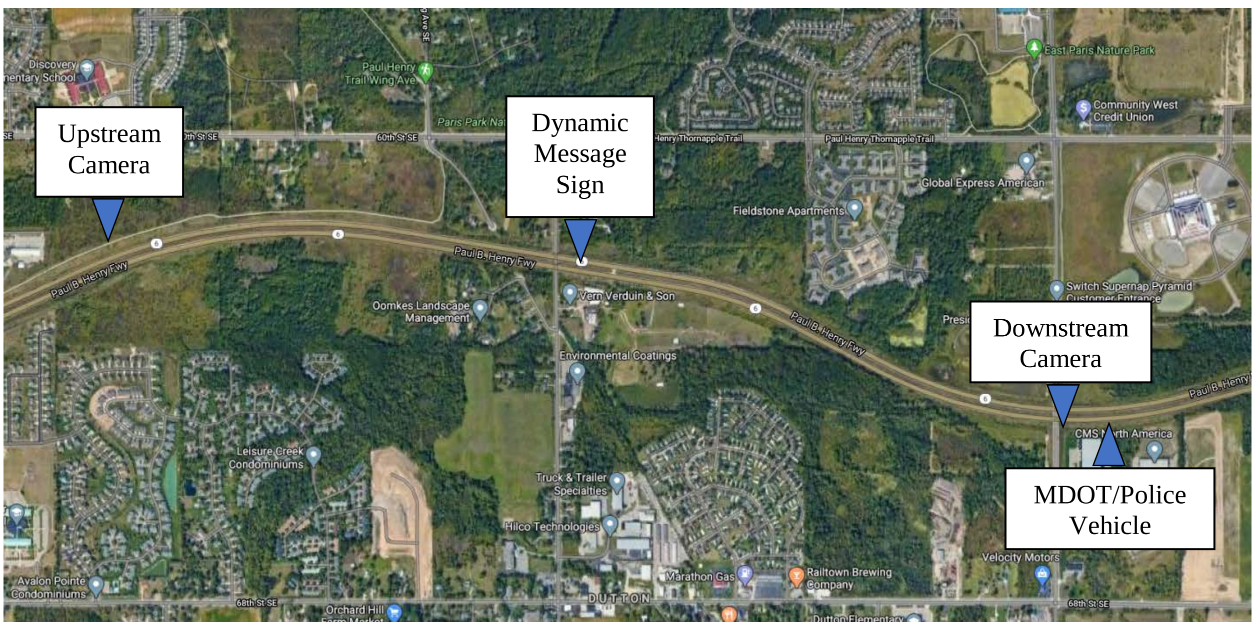


Figure 16. Eastbound M-6 Highway Site

Figure 17. Westbound I-96 Highway Site

Table 10 provides a list of the safety messages related to the move over and slow down law that were displayed at both sites. Information is provided with respect to the time-of-day and type of service vehicle that was parked on the shoulder. A series of targeted safety messages were displayed, along with a standard travel time message that provided a baseline measure for comparison purposes. To account for variability in time of day, note that the order of the message type displayed and stationary vehicles staged was reversed between the two sites. Data were collected for 30 minutes for each message. Only vehicles that were in the right lane at the upstream location were recorded as these are the vehicles that are expected to move over as they approach a vehicle on the right shoulder. Data were collected for the same vehicles at both the upstream and downstream locations. Data obtained from the videos included vehicle speeds (mph), lane position (left or right), headway (s), vehicle type (e.g., car, sport utility vehicle, pickup truck), traffic volume (veh/hr), and vehicle color. Approximately 200 vehicles were recorded for each message.

Table 10. Move Over and Slow Down Messages at Different Time Period with Different Vehicles at Downstream Shoulder

Time	M-6 Highway		I-96 Highway	
	Message	**Vehicle**	**Message**	**Vehicle**
9:30 – 10:00	Standard Travel Time	Police	Standard Travel Time	MDOT
10:00 – 10:30	Move Over & Slow Down for Emergency Vehicles and Service Vehicles	Police	Move Over & Slow Down for Service Vehicles | Prevent Fatalities	MDOT
10:30 – 11:00	Move Over & Slow Down for Emergency Vehicles | $400 Fine	Police	Move Over & Slow Down for Service Vehicles | Work with Us	MDOT
11:00 – 11:30	Move Over & Slow Down for Emergency Vehicles | Save a Life	Police	Move Over & Slow Down for Service Vehicles | Save a Life	MDOT
11:30 – 12:00	Move Over & Slow Down for Emergency Vehicles | Work with Us	Police	Move Over & Slow Down for Service Vehicles | $400 Fine	MDOT
12:00 – 12:30	Move Over & Slow Down for Emergency Vehicles | Prevent Fatalities	Police	Move Over & Slow Down for Emergency Vehicles and Service Vehicles	MDOT
13:00 -13:30	Move Over & Slow Down for Emergency Vehicles and Service Vehicles	MDOT	Move Over & Slow Down for Emergency Vehicles and Service Vehicles	Police
13:30 – 14:00	Move Over & Slow Down for Service Vehicles | $400 Fine	MDOT	Move Over & Slow Down for Emergency Vehicles | Prevent Fatalities	Police
14:00 – 14:30	Move Over & Slow Down for Service Vehicles | Save a Life	MDOT	Move Over & Slow Down for Emergency Vehicles | Work with Us	Police
14:30 – 15:00	Move Over & Slow Down for Service Vehicles | Work with Us	MDOT	Move Over & Slow Down for Emergency Vehicles | Save a Life	Police
15:00 – 15:30	Move Over & Slow Down for Service Vehicles | Prevent Fatalities	MDOT	Move Over & Slow Down for Emergency Vehicles | $400 Fine	Police
15:30 – 16:00	Standard Travel Time	MDOT	Standard Travel Time	Police

6.1.2 Speed-Related Message Signs on Dynamic Message Signs

Posted speed limits are used to notify drivers of the maximum speed that is considered safe and appropriate to operate vehicles under specific traffic and roadway conditions, as well as weather. Speeding is one of the most common road traffic violation and a big contributor to road crashes. Road authorities use various measures such as enforcement and education to get drivers to observe the speed limits. The main objective of evaluating the impact of displaying speed-related messages on DMSs is to assess driver behaviors, which in this case is the comparison of vehicle speed (mean speed, 85th percentile speed, and percent exceeding speed limit) at upstream (before encountering the message) and downstream (after encountering the message) of DMSs.

Data collection for speed-related messages were collected at two different locations: 1) on northbound (NB) I-75 at the Grayling Rest Area, and 2) on EB M-6 near Grand Rapids. Table 11 shows detailed information for each study site. The data collection for speed-related messages were done using two different approaches, by HD cameras and handheld LIDARs. The EB M-6 site used HD cameras to collect information on driver behaviors, a similar setup to the data collection for the move over and slow down messages was done for the EB M-6 site, as shown in Figure 18 (without the presence of MDOT or police vehicles at the downstream shoulder). For the NB I-75 site, handheld LIDARs were used to obtain information on driver behaviors. Two teams were located upstream and downstream of the DMS with a sufficient line of sight to the roadway. Vehicle data such as speed, type, position in lane, and color were identified by the first team. The information on the color, type, and lane position of the upstream vehicles were instantaneously relayed via communication device to the downstream team to collect the speed of the same vehicle at the downstream of the DMS. Figure 18 illustrates the setup of NB I-75 data collection.

Table 11. Site Information for Speed-Related Messages

Highway	**County**	**DMS Coordinate**	**Camera Setup/LIDAR Locations**	
			Upstream	**Downstream**
EB M-6	Kent	42.850844, -85.584278	Elevated portion of Fred Meijer Trail east of Kalamazoo Ave (42.851539, -85.602870)	Protected bike lane on East Paris Ave (42.846142, -85.565397)
NB I-75	Crawford	44.612520,-84.707747	Right shoulder of entry ramp north of W 4 Mile Rd cross road (44.601996, -84707470)	Right shoulder of entry ramp from MDOT rest area (44.616751, -84.707470)

Figure 18. Northbound I-75 Highway Site

Similar to the move over and slow down messages, different types of speed-related messages, as shown in Table 12 were tested, and the standard travel time/North Region Public

Service Announcement (PSA) messages were used as a baseline. For the EB M-6 site, the videos for each message was recorded for 30 minutes, and within this period, approximately 200 vehicles were reviewed by trained video analyst. Only vehicles with headway greater than five seconds at the upstream location were recorded, and the same vehicles were tracked at the downstream location to collect the same information. Similar information from NB I-75 site was collected at both upstream and downstream locations with one additional information added for M-6 site, which was the vehicle headways.

Unlike the EB M-6 site, data were collected for approximately 45 minutes for each message at the NB I-75 site. Around 125 vehicles on the mainline for every message were recorded. The five-second headway rule was also used for this site. The minimum target range used to obtain vehicle speeds using handheld LIDAR was 500 ft to avoid the cosine effect error.

Table 12. Safety-Related Messages at Different Time Period

Highway	Display Time	Message
EB M-6	12:00 – 12:30	Standard Travel Time
	12:30 – 13:00	Drive a Safe and Reasonable Speed
	13:00 – 13:30	Speed Limit | Obey the Sign or Pay the Fine
	13:30 – 14:00	Stop Speeding before it Stops You
	14:00 – 14:30	Don’t be that Person | Obey Speed Limit
	14:30 – 15:00	It’s Speed Limit not Speed Suggestion
WB I-75	14:30 – 15:15	Drive a Safe and Reasonable Speed
	15:15 – 16:00	Speed Limit | Obey the Sign or Pay the Fine
	16:00 – 16:45	Speed too Fast | 35% of Traffic Deaths in Northern Michigan
	16:45 – 17:30	Don’t be that Person | Obey Speed Limit
	17:30 – 18:15	It’s Speed Limit not Speed Suggestion
	18:15 – 19:00	North Region PSA

6.2 Data Summary

In this research, two approaches to field data collection conducted were using HD cameras and handheld LIDAR devices. Speed data were obtained instantaneously using the handheld LIDAR devices and the speeds of selected vehicles were recorded on data collection sheets. In addition to the vehicle speed, vehicle type (passenger vehicle, passenger vehicle with trailer, single unit truck, single unit truck with trailer, and tractor trailer), and lane position (right or left lane) were also recorded. General information was also obtained as to traffic volume, time of day, and the duration of data collection for each message. This information was imported into a spreadsheet for analysis.

The post-processing of the video data collection consists of a manual review by trained video analyst to obtain pertaining information on driver behavior. Each safety message displayed has two videos, which comprised of upstream and downstream locations. These videos were reviewed by the same staff members to ensure consistency in data processing.

The video reviews consist of selected vehicles that were identified and recorded from the upstream location to the downstream location. A video software (QuickTime™ Version 7.7.9) with the ability to replay frame-by-frame was utilized. The cameras used in this research can record video at a rate of 60 frames per second. The road markings were used as field reference markers, where two lines were drawn (100 ft. apart) perpendicularly to the roadway, as shown in Figure 19. The following information was obtained from the videos for selected vehicles traversing through the sites (this information were collected for both type of safety messages unless stated otherwise):

- Vehicle speed for upstream and downstream (immediately before the stationary vehicle on the shoulder for the move over and slow down messages) of DMSs;
- Time headway from a prior vehicle for both upstream and downstream locations (for the move over and slow down messages and M-6 site for speed-related messages only);
- Vehicle type, including: passenger vehicle, passenger vehicle with trailer, tractor-trailer truck, single unit truck/bus/recreational vehicle, and single unit truck with trailer;
- Vehicle lateral lane position at downstream of DMS, including: right lane, left wheel touching the centerline (for the move over and slow down messages only), left wheel entirely over the centerline (for the move over and slow down messages only), vehicle more than halfway over the centerline (for the move over and slow down messages only), and left lane;
- Whether the vehicle transitioned from the right lane to the left lane at the downstream location (for the move over and slow down message only); and
- Whether the left lane was occupied and restricting a subject vehicle from passing the service vehicle (for the move over and slow down messages only).

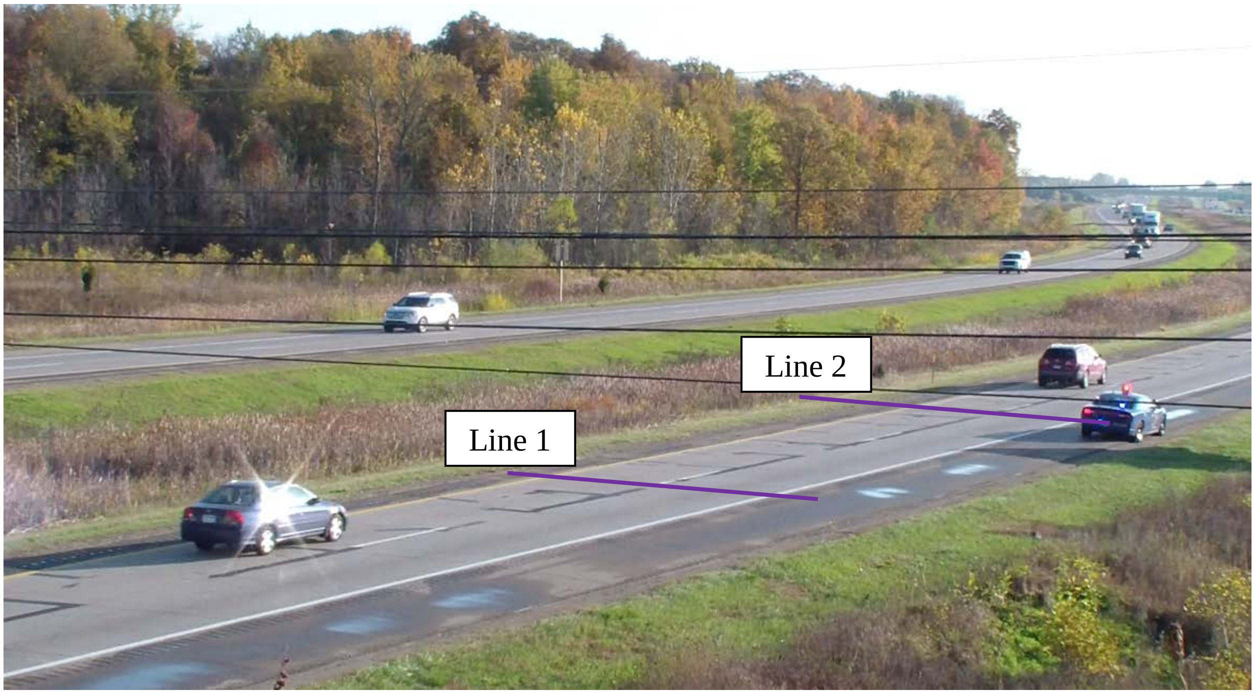


Figure 19. Reference Line to Measure Vehicle Speed

6.2.1 Move Over and Slow Down Messages

Table 13 shows the descriptive statistics for the move over and slow down (MOSD) messages for both I-96 and M-6 sites. Initially, this research targeted to have data for 2,400 vehicles for each site (200 vehicles per message). However, due to several issues, including technical issues with the video files, site issues, and incomplete data set collected, a total of 4,588 vehicles were utilized (total for both sites) for the analysis. The distribution of the number of samples used in this study was the same for both sites.

The initial analysis showed that on average, vehicle speed dropped down from 69.10 mph at an upstream location to 65.73 mph at downstream of the DMS. Note that the speed limits at both sites for passenger vehicle and heavy truck are 70 and 65 mph, respectively. On average, the vehicle headway for both upstream and downstream locations were approximately the same. However, the standard deviation for the downstream location was more than twice the value of the upstream location. The 15-minute traffic volume ranged from 230 to 548 for passenger vehicles, and from 51 to 91 for trucks, as shown in Table 7.

The distribution of the number of vehicles collected for each MOSD message was approximately 17 percent. However, the baseline message (standard travel time message) had only

13 percent of the total vehicle collected. For the type of vehicles, the majority of these vehicles were passenger vehicles without trailers, which include a sedan, pickup truck, SUV, and van. This category comprised 68 percent of the total vehicles collected. In terms of lane position at the downstream location, about 68 percent of vehicles passed the stationary vehicle on the shoulder using the left lane. Approximately 24 percent of the vehicles stayed on the right lane, with 33 percent of them were due to the presence of other vehicles on the left lane.

Table 13. Descriptive Statistics of Move Over and Slow Down Messages (n = 4,588)

Variable	Mean	Std. Dev.
Type of DMS Message Displayed		
Standard Travel Time Message	0.13	0.34
MOSD Message (1 if yes; 0 if no)	0.17	0.38
MOSD Message + $400 Fine (1 if yes; 0 if no)	0.18	0.38
MOSD Message + Save a Life (1 if yes; 0 if no)	0.17	0.38
MOSD Message + Work with Us (1 if yes; 0 if no)	0.17	0.38
MOSD Message + Prevent Fatalities (1 if yes; 0 if no)	0.17	0.38
Type of Service Vehicle on Shoulder		
MDOT Pickup Truck (1 if yes; 0 if no)	0.48	0.50
Police Car (1 if yes; 0 if no)	0.52	0.50
Volumes During Study Period		
Passenger Vehicle Volume (veh/15-min)	338	75
Large Truck Volume (veh/15-min)	65	10
Type of Vehicle Observed		
Passenger Vehicle (1 if yes; 0 if no)	0.68	0.47
Single Unit Truck (1 if yes; 0 if no)	0.07	0.26
Tractor Trailer (1 if yes; 0 if no)	0.21	0.41
Passenger Vehicle with Trailer (1 if yes; 0 if no)	0.03	0.17
Single Unit Truck with Trailer (1 if yes; 0 if no)	0.01	0.09
Vehicle Lateral Position at Downstream Location		
Vehicle in Right Lane (1 if yes; 0 if no)	0.24	0.43
Left Wheel on Centerline (1 if yes; 0 if no)	0.03	0.18
Left Wheel over Centerline (1 if yes; 0 if no)	0.02	0.12
Vehicle Halfway over Centerline (1 if yes; 0 if no)	0.03	0.17
Vehicle in Left Lane (1 if yes; 0 if no)	0.68	0.50
Vehicle Operational Characteristics		
Vehicle Speed Upstream of DMS (mph)	69.10	5.91
Vehicle Speed Downstream of DMS (mph)	65.73	8.67
Vehicle Headway Upstream of DMS (s)	4.27	3.12
Vehicle Headway Downstream of DMS (s)	4.43	8.36

Figures 20 – 28 show the disaggregate level of speed variables and lane positions based on a different type of messages. Three different speed variables are presented in Figures 20 – 25, which are average speed, 85th percentile speed, and standard deviation of speed. These figures compared the speeds of vehicles at upstream and downstream of DMSs with different stationary vehicles on the shoulder of downstream location. Data presented in these figures are divided based on vehicle types, passenger vehicle (passenger vehicle with or without trailer) and truck (single unit/heavy truck, tractor-trailer/semi-truck, and single-unit/heavy truck with trailer). Figures 27 and 28 represent five lateral positions of vehicle at downstream of DMSs.

Figure 20 depicts the average speed of passenger vehicles at upstream and downstream of DMSs. The difference between upstream and downstream average speeds was more pronounced when the police vehicle was on the downstream shoulder as compared to the MDOT vehicle. The highest drop in the average speed was when the standard travel time was displayed with the police vehicle on the shoulder. The finding suggests that this may due to the period that the standard travel time was displayed on the DMS. According to

Table 10, both sites, when the police vehicle was on the shoulder, the standard travel time message was displayed during the peak hour. High traffic volume may negatively impact the speed on the roadway, further impeded by the presence of the police vehicle on the shoulder.

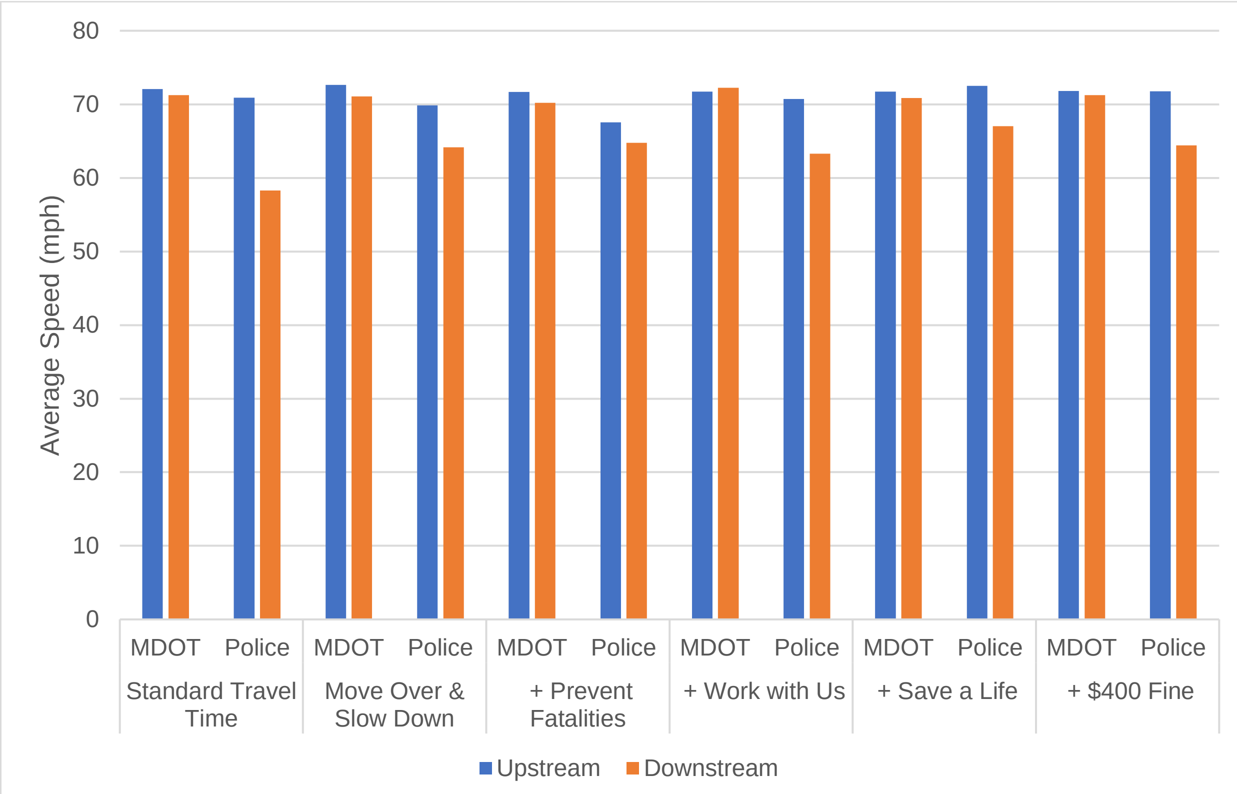


Figure 20. Average Speed of Passenger Vehicles at Upstream and Downstream of DMS

The highest reduction in average speed was found when the MOSD message with an additional message of WORK WITH US was displayed (7.5 mph), followed by the $400 FINE message (7.4 mph) (police vehicle was on the shoulder). Figure 20 also shows that, despite the reduction in average speed between upstream and downstream locations, none of the MOSD messages managed to reduce the average speed to less than 10 mph of the speed limit as required by the recent change in the MOSD law.

Figure 21 shows the 85th percentile speed of passenger vehicles with different MOSD messages and a baseline message of standard travel time. When the MDOT vehicle was present on the downstream shoulder, there was a marginal change in the 85th percentile speed, regardless of the type of messages displayed. However, when the police vehicle was parked on the shoulder at the downstream of DMS, the change in 85th percentile speeds was more pronounced, with

MOSD message with an additional message of WORK WITH US had the highest drop in speed between the upstream and downstream of DMSs, 5.9 mph.

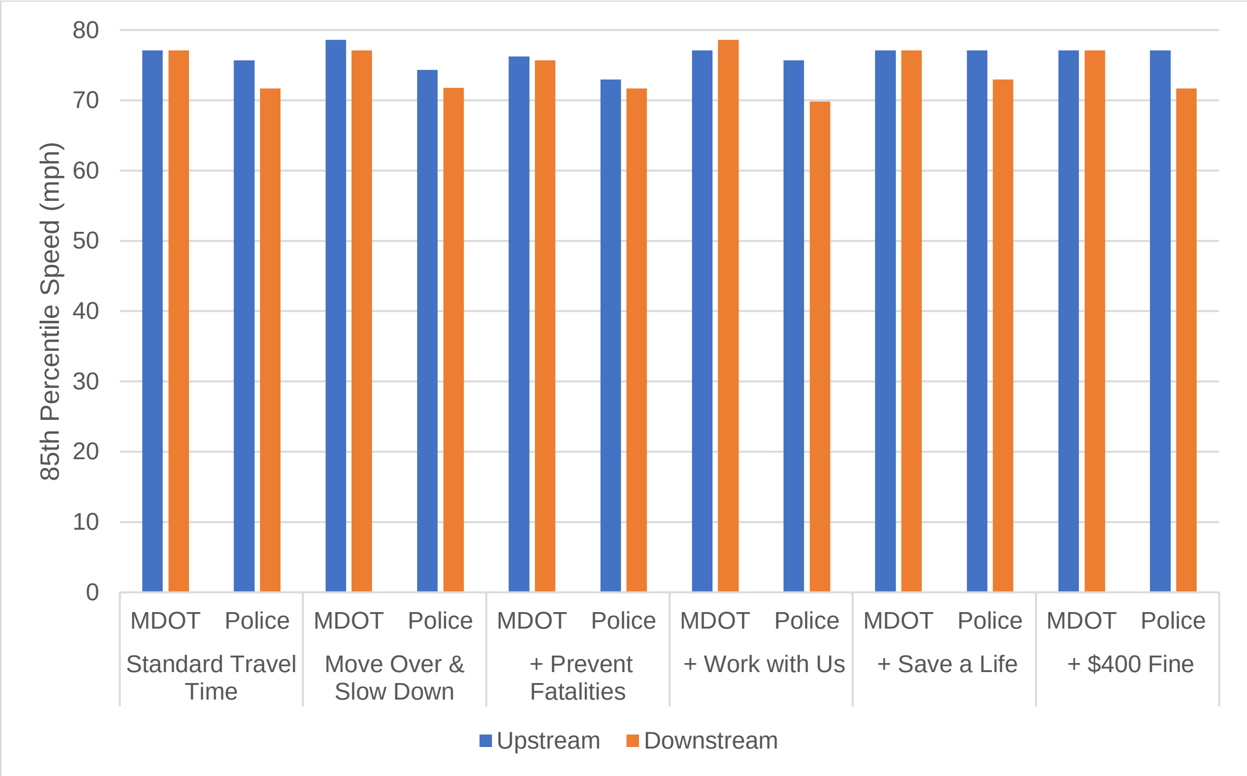


Figure 21. 85th Percentile Speed of Passenger Vehicles Upstream and Downstream of DMS

Figure 22 illustrates the standard deviation (SD) of speed for passenger vehicles between the upstream and downstream of DMS. This figure clearly shows that the downstream location had higher SD speeds when compared to the upstream location (except for the MOSD with SAVE A LIFE message when a police vehicle was on the shoulder). This finding suggests that some drivers did not reduce their speed enough, while others had their speed reduced significantly, creating higher variability in speed.

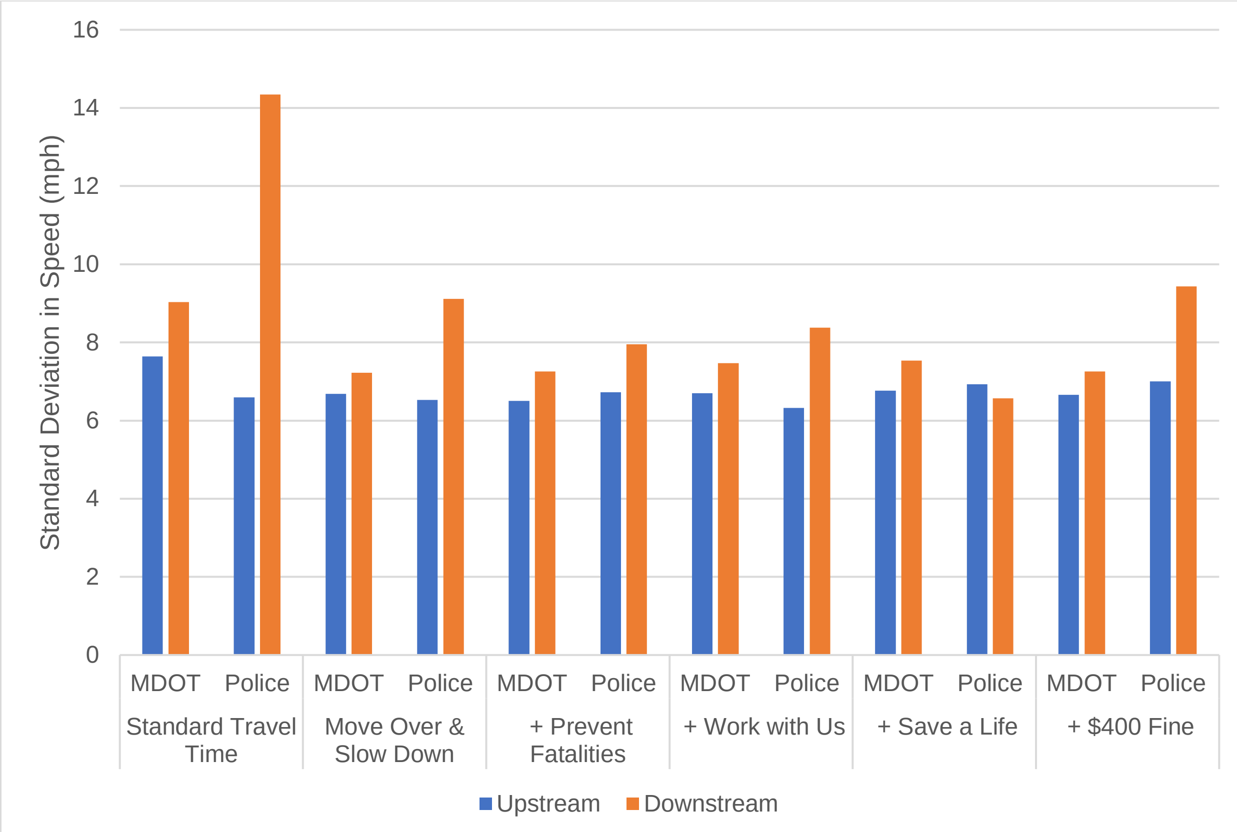


Figure 22. Standard Deviation of Passenger Vehicle Speeds Upstream and Downstream of DMS

Figure 23 demonstrates the average speed of trucks for both upstream and downstream of DMSs. When the MDOT vehicle was present on the shoulder, the average speed had marginal changed between upstream and downstream locations, irrespective of the types of messages displayed. However, when the police vehicle was on the shoulder, a noticeable drop in average speed was found for most of the messages. This is particularly true for the standard travel time message, where the average speed dropped by 11.8 mph. This effect is similar to the passenger vehicle, probable attribution to the impact of peak hour traffic.

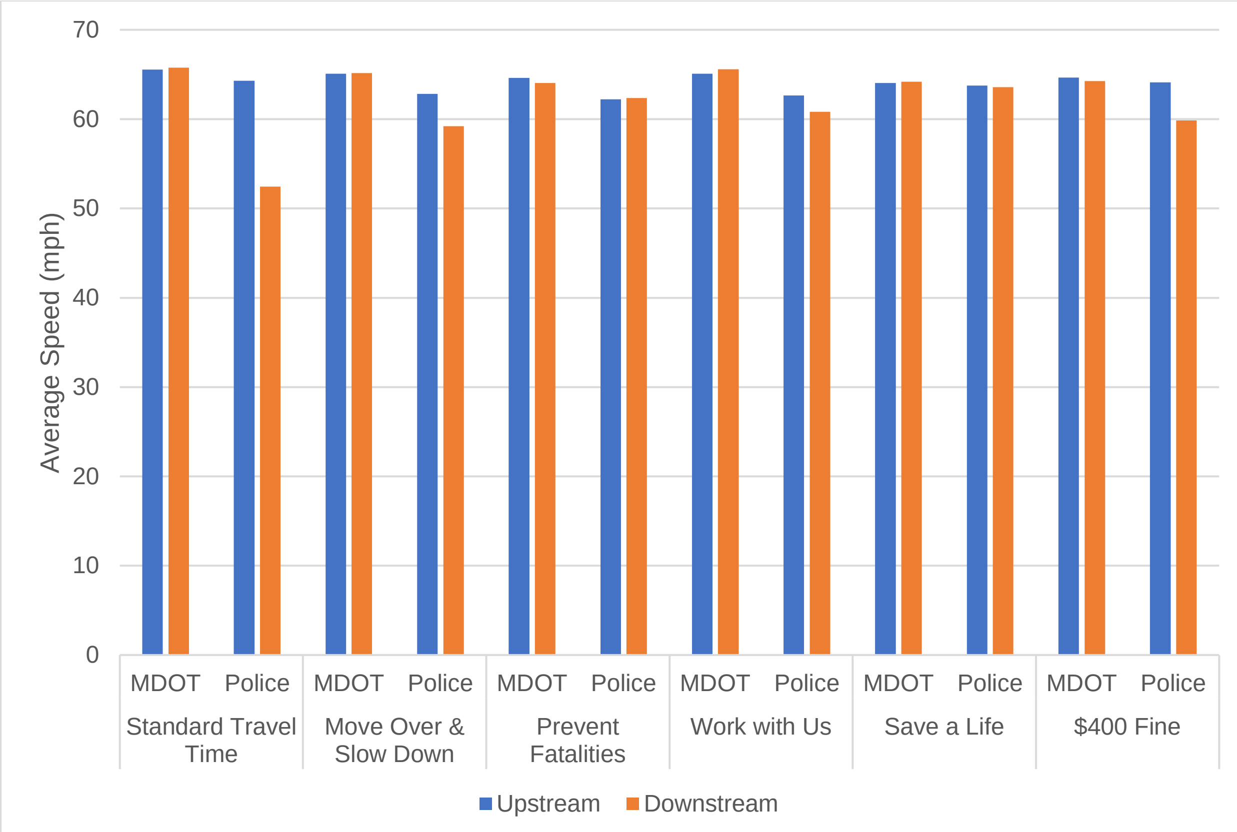


Figure 23. Average Speed of Trucks Upstream and Downstream of DMS

The MOSD message with the highest reduction in average speed between the upstream and downstream of DMS for trucks was when the additional message of $400 FINE being displayed (4.3 mph). Note that the speed limit for trucks at both sites is 60 mph. However, based on Figure 22, none of the MOSD messages managed to reduce the average speed to 50 mph as required by law.

Figure 24 shows the 85th percentile speed of trucks at upstream and downstream of DMS for a different combination of DMS-messages and shoulder-parked vehicles. The change in speed between upstream and downstream of DMS was negligible for most of the messages. However, a noticeable drop in speed was found when the additional message "$400 FINE" was displayed.

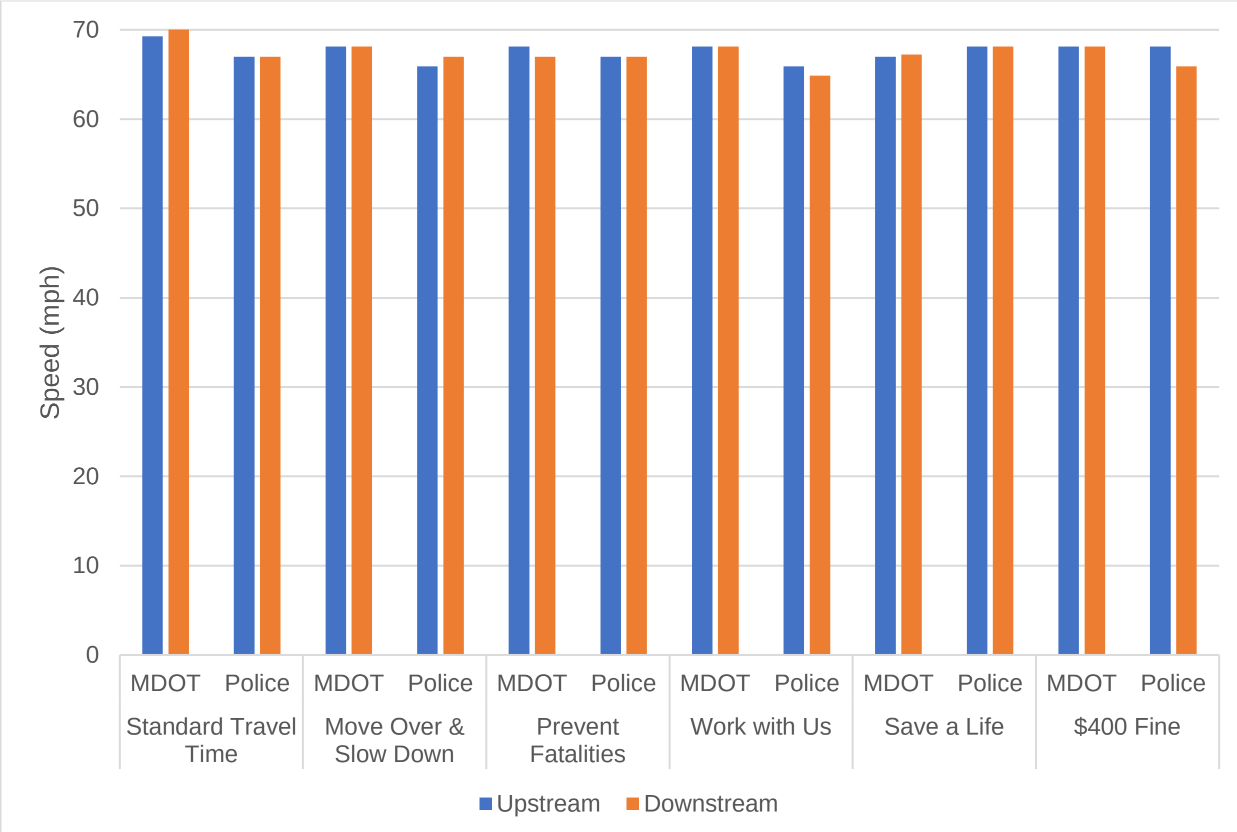


Figure 24. 85th Percentile Speed of Trucks Upstream and Downstream of DMS

Similar to the SD speed for the passenger vehicles, the SD speed of trucks increased at the downstream location when compared to the upstream location, as shown in Figure 25. The highest change was recorded when the standard travel time message display was combined with the presence of the police vehicle on the shoulder (8 mph difference).

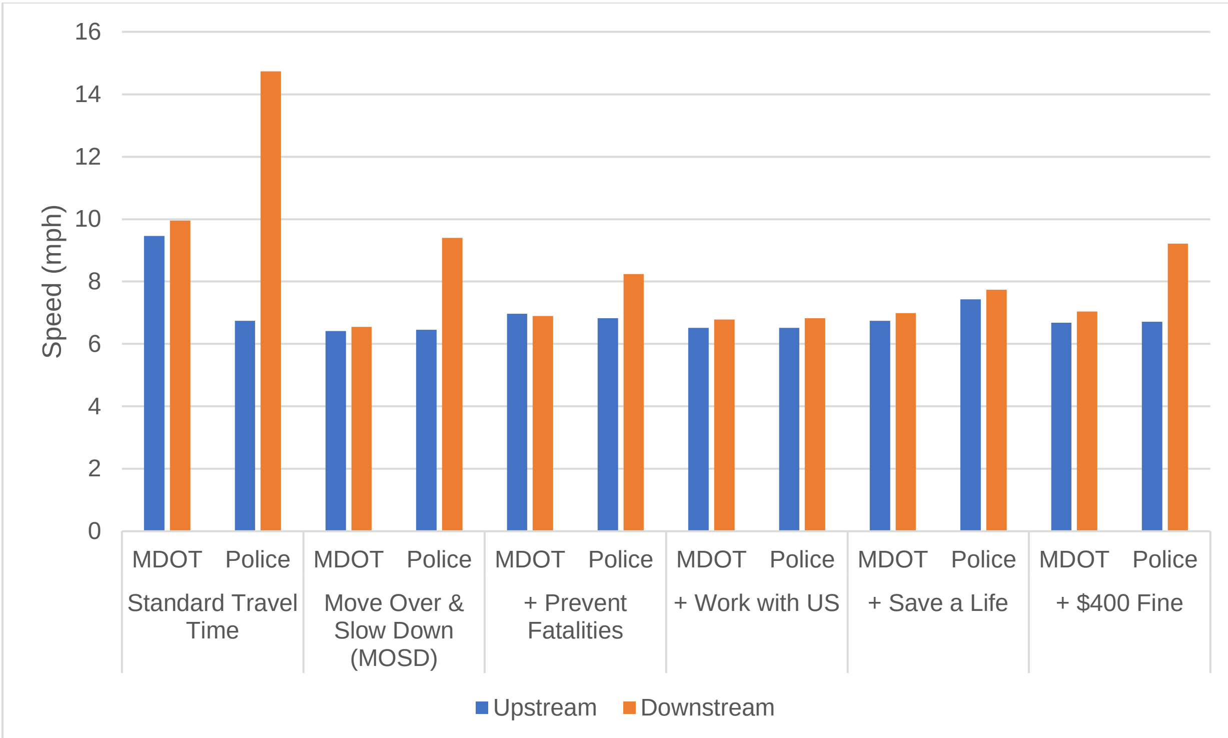
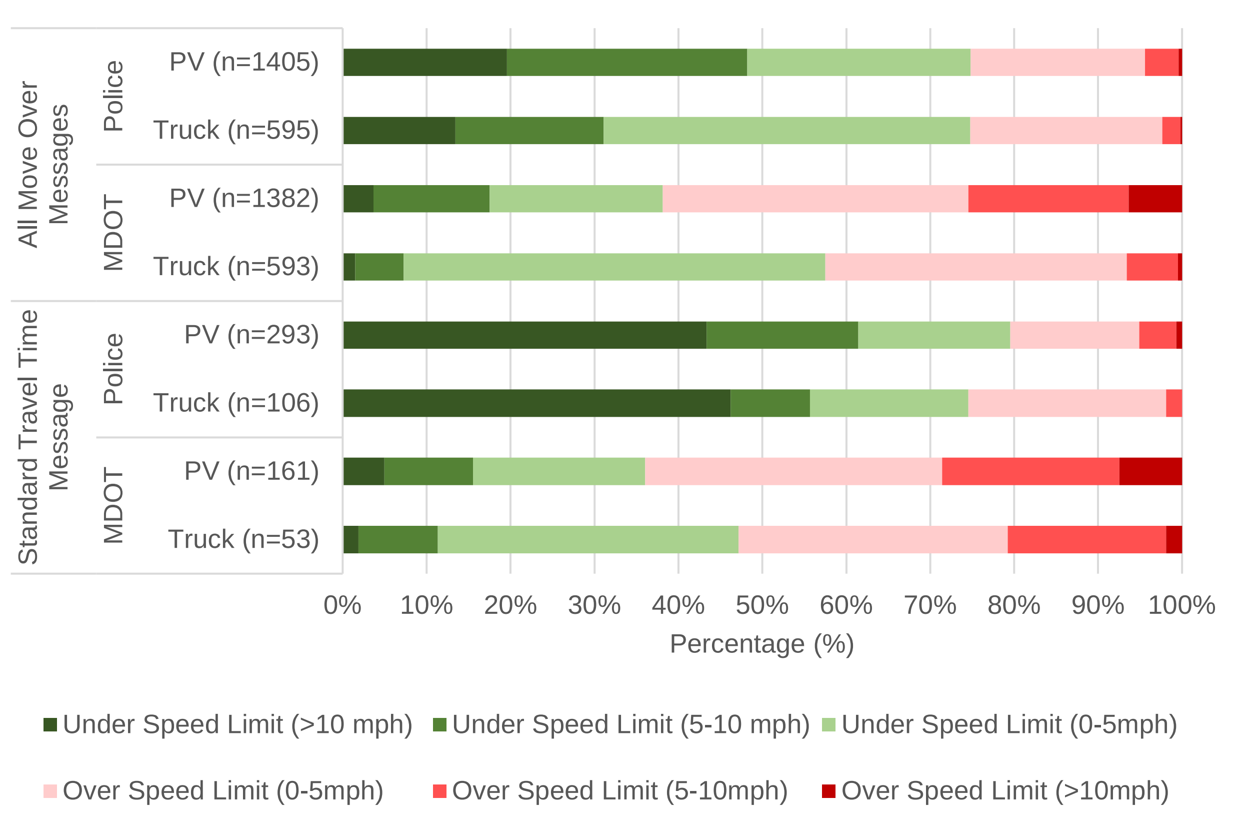


Figure 25. Standard Deviation of Speed of Trucks at Upstream and Downstream of DMS

Figure 26 illustrates the percentage of vehicles operating over or under the speed limit downstream of DMS for a different combination of messages type and stationary vehicle-type on the shoulder. Six different categories of speed thresholds were created to assess the impact of MOSD messages on driver behavior:

- Driving 0-5 mph below the speed limit,
- Driving 5-10 mph below the speed limit,
- Driving more than 10 mph below the speed limit (as required by law),
- Driving 0-5 mph over the speed limit,
- Driving 5-10 mph over the speed limit, and
- Driving more than 10 mph over the speed limit.

The percentage of compliance based on the MOSD law showed that drivers were more compliance when the police vehicle was on the shoulder as compared to the MDOT vehicle for both types of messages. A significant difference was shown when the MOSD messages were displayed between the police and MDOT vehicles. Approximately 20 percent of passenger vehicles slowed down to more than 10 mph below the speed limit when the police vehicle was on the shoulder as compared to the MDOT vehicle, 4 percent. In addition, the percentage of compliance for trucks is higher by 6.5 times when the police vehicle was on the shoulder as compared to the MDOT vehicle. Overall, the percentage of vehicles operating below the speed limit for MOSD messages were between 38 and 75 percent.



Note: Posted speed limit - Passenger vehicles (PV), 70 mph; Trucks, 65mph.

Figure 26. Vehicles Driving Over or Under the Speed Limit by Type of Messages and Service Vehicles

The standard travel time message showed that the percentage of compliance when the police vehicle was present for both passenger vehicles and trucks was higher when compared to the MOSD messages, as shown in Figure 26. Ultimately, drivers were less likely to exceed the speed limit when the police vehicle was on the shoulder compared to the MDOT vehicle, regardless of the types of messages being displayed.

Figure 27 details the lateral positions of passenger vehicles downstream of DMS when passing the stationary vehicles on the shoulder. There is a distinct difference in terms of compliance rate between a police vehicle and an MDOT vehicle. For all message types, 38 to 54 percent of the passenger vehicles made a complete lane change from right lane to the left lane when passing the MDOT vehicles. In contrast, when the police vehicle was on the shoulder, the compliance rate increase significantly as compared to when the MDOT vehicle was on the shoulder. More than 90 percent of the passenger vehicles moved over to the left lane when MOSD messages were displayed. While for standard travel time message, about 83 percent of the passenger vehicles changed lane. Over a quarter of the passenger vehicles (26.55 percent) that remained on the right lane when passing the staged vehicles are due to the presence of other vehicles on the left lane. The remaining intermediate categories of lateral positioning (left wheel touching center line, left wheel fully over center line, and vehicle more than half way over the center line) make up approximately 10 percent of the sample compared to the absolute positions of driving in the right or left lanes, for all message types.

Figure 27. Percentage of Downstream Passenger Vehicle Lateral Position by Type of Service Vehicle

Figure 28 demonstrates the position of trucks when passing the MDOT or police vehicles on the shoulder. Similar to the passenger vehicle from Figure 27, less compliance was found for the MDOT vehicle when compared to the police vehicle, regardless of the type of messages displayed. However, trucks had a much lower compliance rate when the MDOT vehicle was on the shoulder as compared to the passenger vehicles. About 33 to 42 percent of trucks moved over from the right lane to the left lane. From 306 trucks that passed the MDOT vehicles using the right lane, about 45 percent had other vehicles on the left lane. Overall, there is no clear difference between types of messages displayed on the downstream lane positions when the MDOT vehicle was on the shoulder.

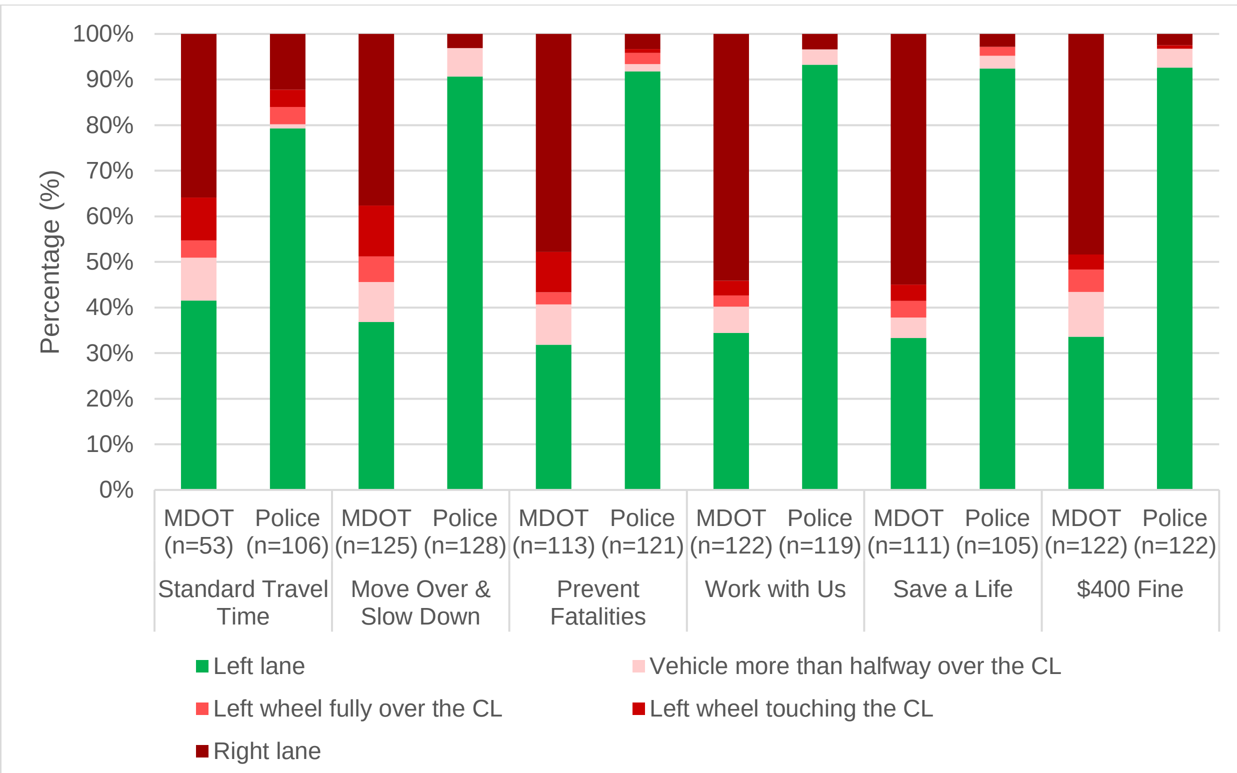


Figure 28. Percentage of Downstream Truck Lateral Position by Type of Service Vehicle

A similar trend with the passenger vehicles on the MOSD messages was observed, where more than 90 percent of the trucks moved to the left lane when passing the police vehicle. While, the standard travel time message recorded about 79 percent of the trucks moved over.

6.2.2 *Speed-Related Messages*

Table 14 shows the descriptive statistics for the speed-related messages for I-75 and M-6 sites. A total of 1,798 samples were collected, 62 percent from the M-6 site. The speed limit for M-6 and I-75 sites is 70 and 75 mph, respectively. Initially, five identical speed-related messages were proposed to be tested at both sites. However, a slight change was made to the North Region-specific message related to the travel speed. The message was substituted from STOP SPEEDING BEFORE IT STOPS YOU to SPEED TOO FAST | 35% OF TRAFFIC DEATHS IN NORTHERN MICHIGAN. Thus, only four similar speed-related messages were tested at both sites.

Table 14. Descriptive Statistics of Speed-Related Messages (n = 1,798)

Variable	Min.	Max.	Mean	Std. Dev.
Speed Upstream of the DMS (mph)	48	95	75	6
Speed Downstream of the DMS (mph)	52	95	74	6
15 minutes Traffic Volume of Passenger Vehicles	211	413	304	48
15 minutes Traffic Volume of Trucks	7	72	40	23
Observation Site				
M-6 Freeway (Speed Limit 70 mph)	0	1	0.62	0.48
I-75 Freeway (Speed Limit 75 mph)	0	1	0.38	0.48
Type of DMS Message Displayed				
Standard Travel Time/North Region PSA	0	1	0.17	0.38
Drive a Safe and Reasonable Speed	0	1	0.17	0.38
Speed Limit | Obey the Sign or Pay the Fine	0	1	0.17	0.38
Stop Speeding Before it Stops You	0	1	0.12	0.33
Don't be that Person | Obey Speed Limit	0	1	0.18	0.40
It's Speed Limit | Not Speed Suggestion	0	1	0.12	0.36
Speed too Fast | 35% of Traffic Deaths in Northern Michigan	0	1	0.07	0.30
Type of Vehicle Observed				
Passenger Vehicle	0	1	0.85	0.36
Single Unit/Heavy Truck	0	1	0.05	0.23
Tractor Trailer/Semi-Truck	0	1	0.08	0.28
Passenger Vehicle with Trailer	0	1	0.01	0.14
Motorcycle	0	1	0.00	0.14
Bus	0	1	0.00	0.17
Lane Position				
Right Lane at Upstream of the DMS	0	1	0.53	0.50
Left Lane at Upstream of the DMS	0	1	0.47	0.50
Right Lane at Downstream of the DMS	0	1	0.63	0.48
Left Lane at Downstream of the DMS	0	1	0.37	0.48

The aggregate level of analysis from Table 14 shows that the average speed between upstream and downstream of DMSs is relatively the same. Only one mile per hour drop in average travel speed between upstream and downstream locations was found. The 15-minute traffic volume ranged from 211 to 413 for passenger vehicles and from 7 to 72 for trucks, as shown in Table 14. Note that for I-75, the volume was collected for the whole duration of each message display. If each message took 45 minutes to complete, the volume recorded is for 45 minutes. In order to establish consistency between sites, the traffic volumes for I-75 site were aggregated in 15-min intervals. The average number of vehicles sampled for each message-type at M-6 and I-75 sites is 200 and 100, respectively. For the types of vehicles, the majority were passenger vehicles without a trailer, which comprised 85 percent of the total vehicles recorded.

Figure 29 – 32 show the disaggregate level of average speed by vehicle types and different messages. The plots are presented by each site since the speed limits are different between the two sites. These figures compared the average speed of vehicles between the upstream and downstream locations.

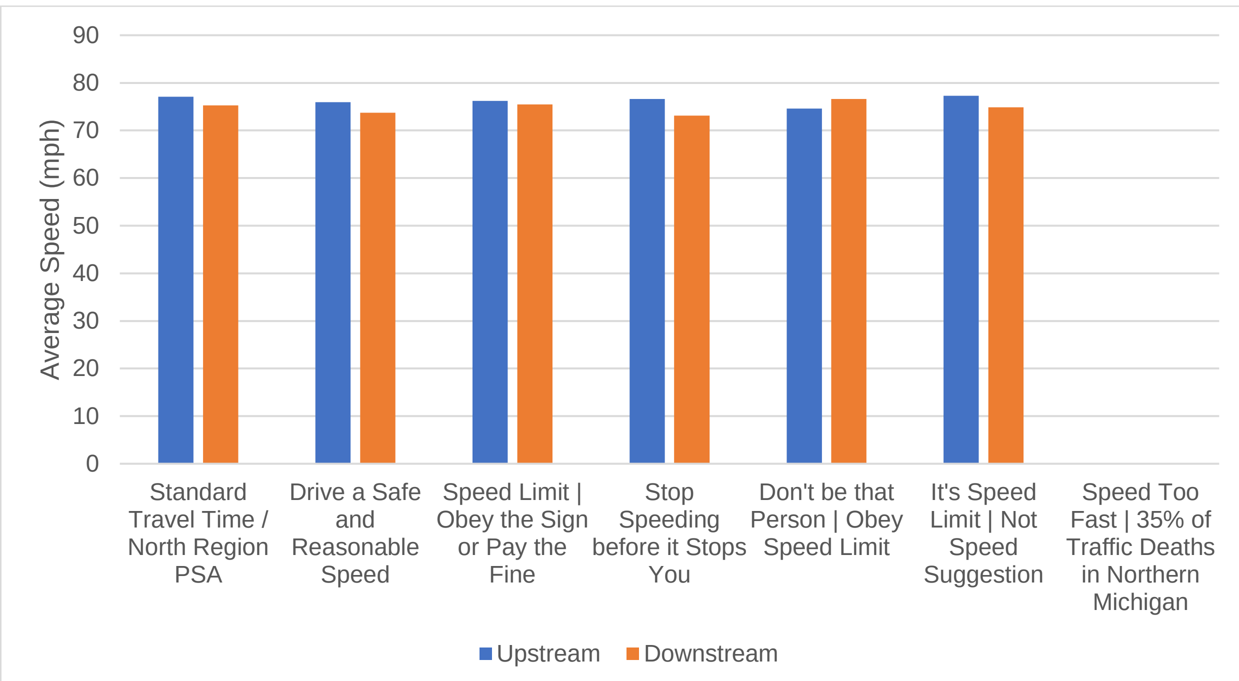


Figure 29. Average Speed of Passenger Vehicles at M-6 Site by Message Type

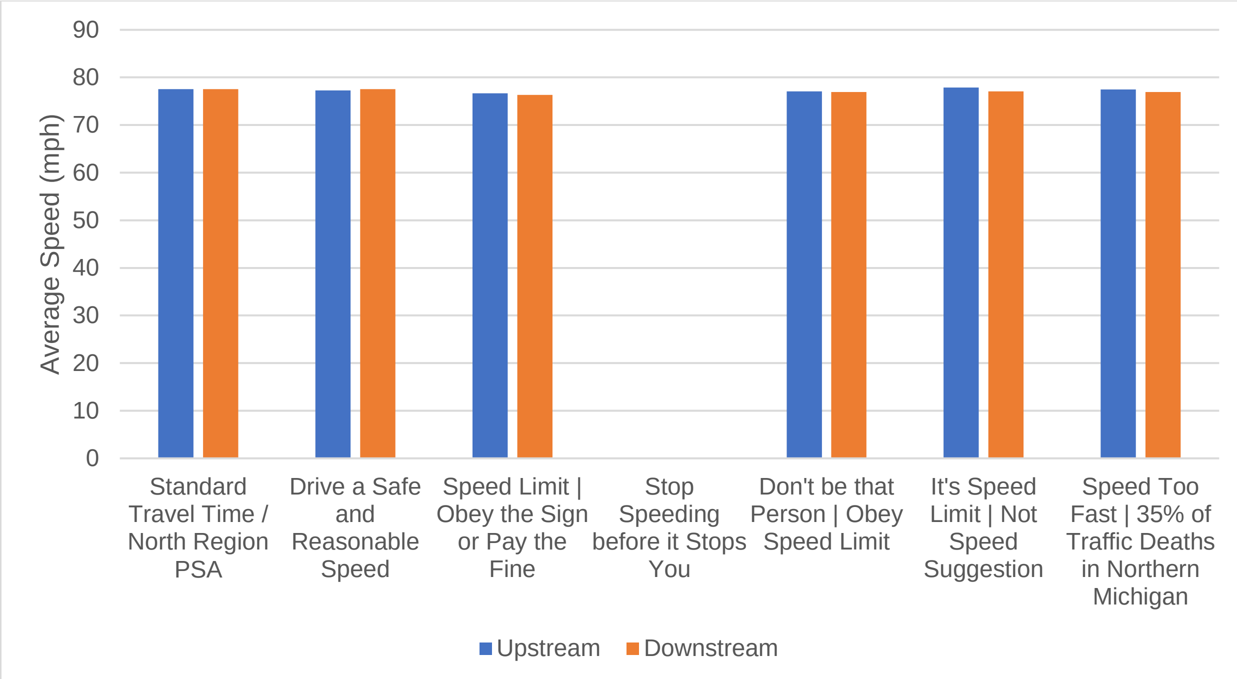


Figure 30. Average Speed of Passenger Vehicles at I-75 Sites by Message Type

Figure 29 and Figure 30 show the average speeds of passenger vehicles for M-6 and I-75 sites, respectively. Observation of the M-6 site revealed that the average speed decreased between 0.7 to 3.5 mph when the speed-related messages were displayed, except for the DON'T BE THAT PERSON | OBEY SPEED LIMIT message (increased by 2.0 mph). During the standard travel time message display for M-6 site, average speed decreased by 1.8 mph. Overall, despite the decrease in average speed for most of the speed-related messages, the average speed were still greater than the speed limit of the roadway.

For I-75 site, there was no change in average speed for the North Region PSA message. Additionally, the change in average speeds for all speed-related messages was relatively small (less than 0.8 mph difference).

Figure 31 and Figure 32 show the average speed of trucks for upstream and downstream of DMSs for M-6 and I-75 sites, respectively. There was no change in average speed for standard travel time message on the M-6 site. The highest reduction in average speed for speed-related messages at M-6 site was 5.2 mph, which was the STOP SPEEDING BEFORE IT STOPS YOU message. For I-75 site, a similar trend with the passenger vehicles was found, where the change in average speed was marginal.

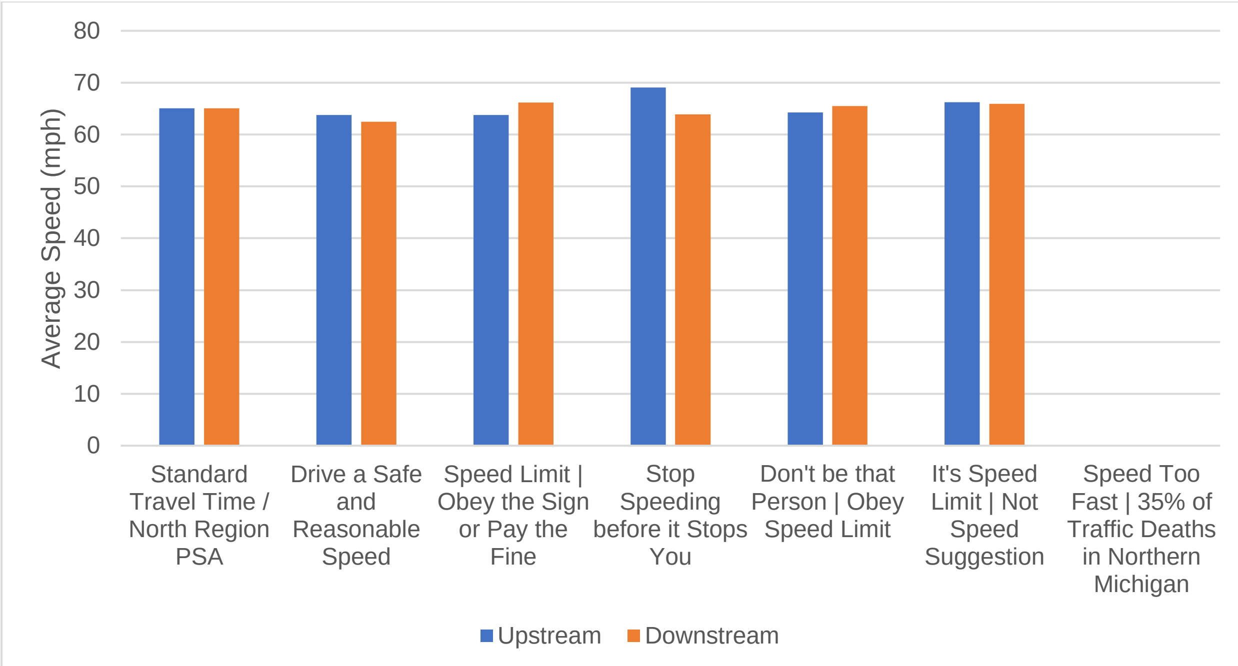


Figure 31. Average Speed of Trucks at M-6 Site by Message Type

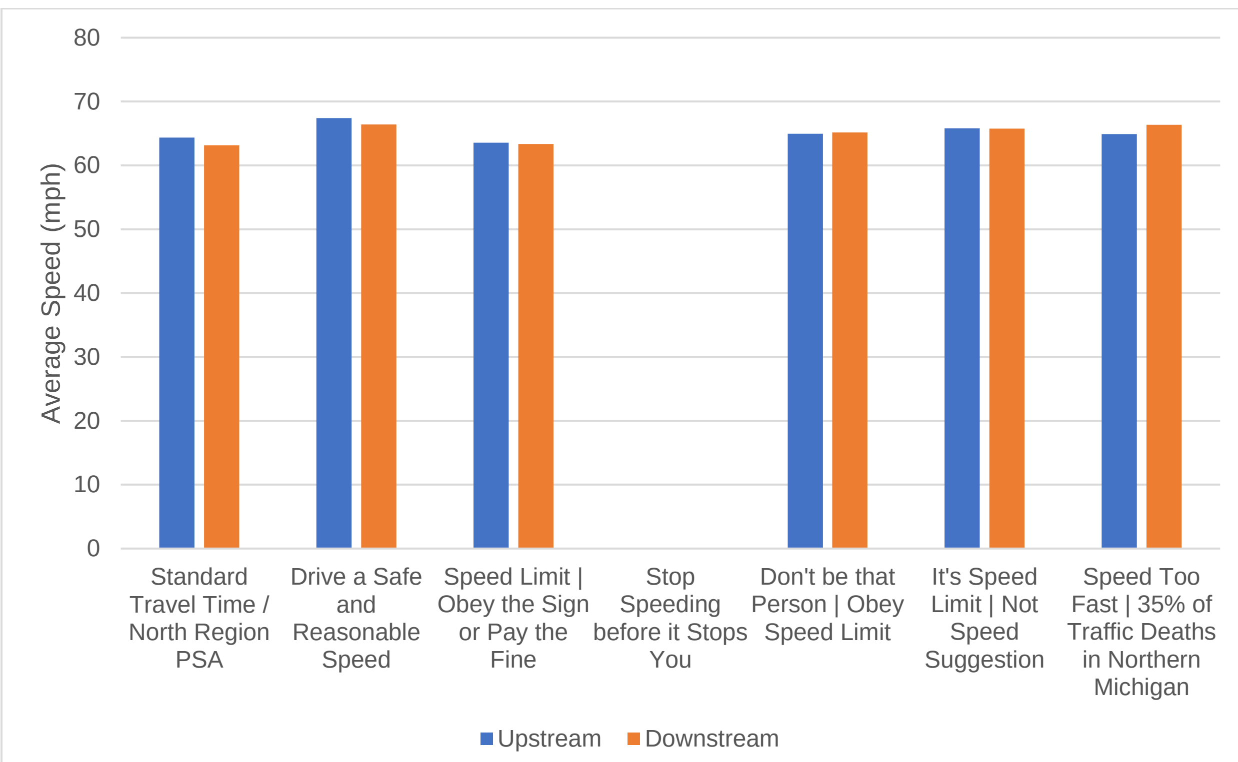


Figure 32. Average Speed of Truck at I-75 Site by Location

Figure 33 shows the percentage of vehicles exceeding the speed limit. The plot was divided based on the types of messages and vehicle-type. Displaying the speed-related messages on DMSs were able to improve the number of vehicles operating under the speed limit at downstream as compared to the upstream of DMSs. For the passenger vehicles, the percentage of compliance increased from 19.0 to 24.0 percent, while for the trucks, it increased from 54.0 to 65.0 percent. The travel time/North Region PSA messages showed similar results for the passenger vehicles, but different for the trucks. The number of passenger vehicles that reduced their speed below the speed limit increased from 12.0 to 20.0 percent between the upstream and downstream locations. While for the trucks, the percentage of compliance decreased slightly by 2.5 percent.

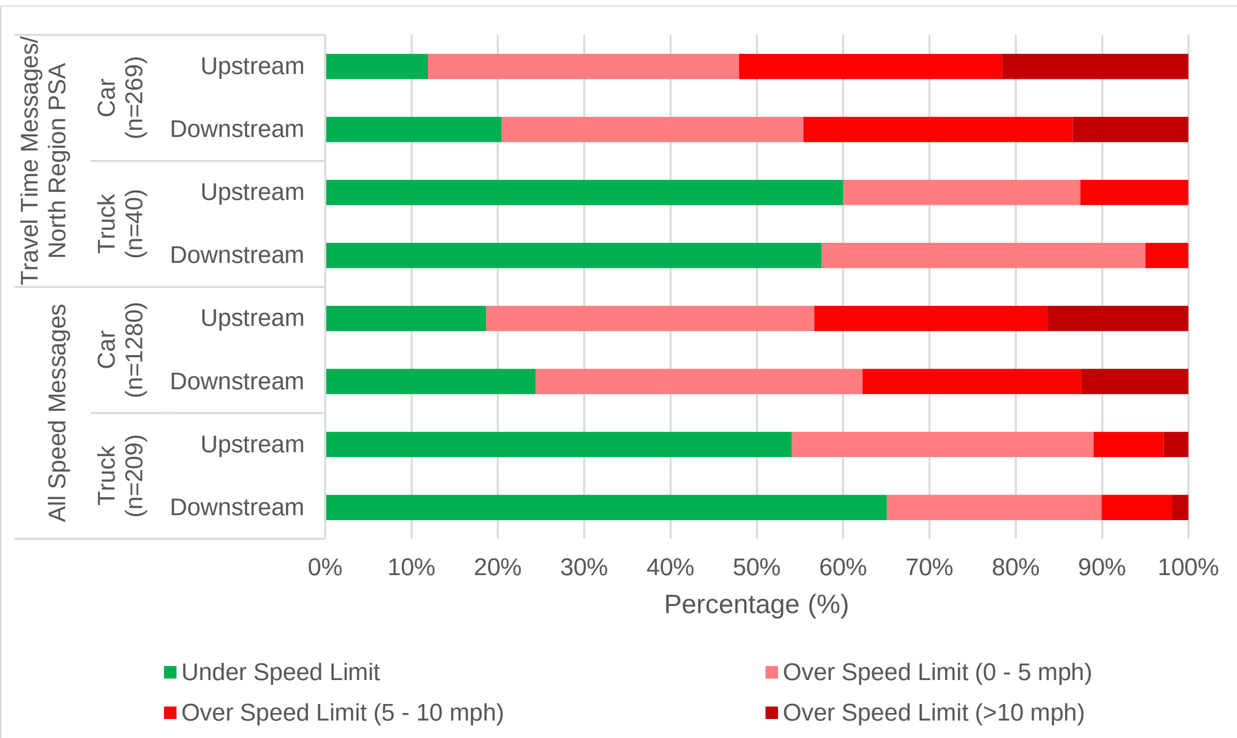


Figure 33. Vehicle Exceeding the Speed Limit by Type of Messages

6.3 Statistical Methods

Several aspects related to driving behavior, including speed and lane positions, were analyzed in this study. The effectiveness of DMS displays of MOSD messages, and speed-related messages on driver behavior was analyzed using two different statistical approaches, multiple linear regression and binary logistic regression models. Depending on the nature of the response variables, a statistical model between these two regression models was selected.

6.3.1 Multiple Linear Regression

Multiple linear regression analysis is a linear approach to regress the relationship between the dependent variable (i.e., typically, it is a continuous variable) and more than one independent variable. This model uses the least-square method to fit the best-fitting line by minimizing the sum of square error between the observed data and the predicted data. The general form of multiple linear regression model is shown below:

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \tag{5}$$

where Y is the dependent variable (i.e., individual speed at downstream of DMS, speed differential between regulatory speed limit and individual speed, etc.); X_1 to X_n are the explanatory variables (i.e., type of message displayed, type of emergency vehicle on the shoulder, vehicle type, headway, etc.); β_o is the estimate coefficient of intercept; β_1 to β_n are the estimate coefficients corresponding to each explanatory variable obtained from the regression model; and ε is the error term that follows normal distribution. The adjusted R^2 is used as the goodness-of-fit of the model to describe how well the model fits the observed data.

In this research, the individual speed at the downstream of the DMS for both types of safety messages were analyzed using this model. Different independent variables were tested for both models, depending on the types of messages being displayed.

6.3.2 Logistic Regression

Logistic regression is appropriate for the evaluation of binary outcome data (e.g., whether a vehicle moves over from the right lane to the left lane when passing the emergency vehicles on the shoulder). The main difference between this model and a linear regression model is the nature of the response variable, where it takes binary type instead of a continuous variable. Additionally, this model estimates the coefficient of variables using maximum likelihood of estimation method rather than ordinary least-square method. The general form of binary logistic regression model is shown below:

$$Y_i = logit(P_i) ln\left[\frac{P_i}{1-P_i}\right] = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \tag{6}$$

where Y_i is the logistic transformation of the probability, and P_i is the probability of success. In this research, two dependent variables were analyzed using logistic regression model which include whether vehicles move over from right lane to the lane left lane when passing the stationary emergency vehicle on the shoulder, and whether vehicles are speeding at the downstream of the DMS or not.

6.4 Results and Discussion

6.4.1 Field Study of Driver Compliance with Move Over and Slow Down Law

6.4.1.1 Comparison of Vehicle Speeds between Upstream and Downstream Locations

Estimation results for the random effects linear regression model for vehicle speed are shown in Table 15. A subset data of vehicles with headways of 3 seconds and above (for both upstream and downstream) was used to analyze the difference between downstream and upstream vehicle speeds. This filter was used to select vehicles that were traveling at free-flow speeds, unimpeded by leading vehicles. The total vehicle volume of this subset data is 1,195. When interpreting the results from Table 15, the intercept term corresponds to the average speed of a vehicle at the downstream location when all other parameters are set to zero. These parameters can be varied to assess how speeds vary under different scenarios of interest.

Table 15. Linear Regression Model for Average Vehicle Speeds

Variable	Estimate	Standard Error	P-Value
Intercept	62.800	7.745	<0.001
Natural Log of Traffic Volume (15-minute)	-15.073	2.841	<0.001
Vehicle Speed Upstream (mph)	-0.415	0.033	<0.001
Site I-96 (Baseline)	-	-	-
Site M-6	1.466	0.382	<0.001
Heavy Vehicle (Baseline)	-	-	-
Passenger Vehicle	3.372	0.358	<0.001
Police Vehicle on the Shoulder (Baseline)	-	-	-
MDOT Vehicle on the Shoulder	3.787	0.301	<0.001
Standard Travel Time (Baseline)	-	-	-
MOSD Message	-1.619	0.658	0.014
MOSD Message + $400 Fine	-1.939	0.644	0.003
MOSD Message + Save a Life	-1.143	0.652	0.080
MOSD Message + Work with Us	-0.867	0.626	0.166
MOSD Message + Prevent Fatalities	-0.662	0.624	0.289

When examining the analysis results, the parameter estimates provide an estimate of the relative changes in travel speeds between the upstream and downstream locations as compared to default baseline conditions. For example, on average, the speeds of passenger vehicles were 3.4 mph greater than those of large trucks. In both cases, the mean speeds upstream were roughly equal to the posted speed limit (62.8 mph vs. 65 mph limit for trucks, 66.1 mph vs. 70 mph for passenger vehicles). It should be noted that at the upstream locations, neither the DMS nor the service vehicles were visible.

At the downstream location, speeds were reduced by 1.1 to 4.8 mph when a police car was located on the shoulder. All of these reductions were statistically significant at 95-percent confidence. In contrast, no significant reductions were observed when the MDOT pickup truck was parked on the shoulder. In fact, speeds were generally higher under these scenarios.

Turning to the effects of the specific messages that were displayed, the MOSD messages were found to influence speed reduction of between 0.6 mph to 1.6 mph compared to the standard travel time messages. Of targeted messages, speeds were lowest when a move over/slow down message was displayed along with details of the $400 fine for violating the move-over law. However, overall, the specific message that was displayed tended to have minimal impacts on driver behavior.

6.4.1.2 Speeding at Downstream Location

Unlike the majority of states, Michigan's move-over law explicitly requires drivers to slow down, even when they have moved over to the adjacent lane. Data shows that compliance with the law's 10-mph reduction below the posted speed limit was very low. Of the total 4,520 vehicles, only 600 (13 percent) reduced their speed by 10 mph or more relative to posted speed limit. Further, among the 1,108 vehicle that did not move over, only 10 percent reduced their speeds by 10 mph or more. These results are consistent with a Florida study, which revealed high compliance with respect to moving over (75.9 percent), but even lower compliance to the required speed reduction as compared to this study (5.8 percent). However, this can also be attributed to the magnitude of speed reduction required in Florida, where the slow down speed for the move-over law was 20mph below the posted speed limit (Carrick and Washburn, 2012).

While speed reductions were generally low, particularly in the case where an MDOT vehicle was present, there was reasonably good compliance with the posted speed limit as compared to the 10-mph reduction. It appears that drivers are adapting their behavior to a degree, if not necessarily to the level required by law. To further investigate this issue, a logistic regression model was estimated to identify conditions under which a vehicle complied with the "normal" posted speed limit.

Table 16 shows the result of the logistic regression for speeding downstream of the DMS display. A positive parameter estimate indicates that speeding is more likely as that variable is increased. Conversely, a negative is reflective of conditions where vehicles are traveling at or below the posted limit.

Table 16. Logistic Regression Results for Downstream Speeding

Variable	Estimate	Standard Error	P-Value
Intercept	2.345	2.713	0.387
Natural Log of Traffic Volume (15-minute)	-1.969	0.946	0.037
Proportion of Trucks	3.285	1.808	0.069
Not Speeding Upstream (Baseline)	-	-	-
Speeding Upstream	1.399	0.074	<0.001
Downstream Headway	0.009	0.004	0.024
I-96 Highway (Baseline)	-	-	-
M-6 Highway	1.160	0.109	<0.001
Police Vehicle on the Shoulder (Baseline)	-	-	-
MDOT Vehicle on the Shoulder	1.404	0.073	<0.001
Passenger Vehicle (Baseline)	-	-	-
Single Unit/Heavy Trucks	-0.102	0.136	0.453
Tractor Trailer/Semi-Truck	0.045	0.090	0.616
Passenger Vehicle with Trailer	-0.649	0.233	0.005
Single Unit/Heavy Trucks with Trailer	-0.422	0.396	0.286
Standard Travel Time Message (Baseline)	-	-	-
MOSD Message	-0.412	0.150	0.006
MOSD Message + $400 Fine	-0.450	0.145	0.002
MOSD Message + Save a Life	-0.287	0.153	0.060
MOSD Message + Work with Us	-0.493	0.136	0.001
MOSD Message + Prevent Fatalities	-0.318	0.138	0.021

While volumes showed minimal influence on average speeds, drivers were less likely to speed as the traffic volume increased. Interestingly, speeding was more likely when a higher proportion of trucks was present in the traffic stream. Due to the larger size of trucks in the traffic stream, the increased proportion of trucks may result in reduced available gaps that may influence driver behavior. Chandra and Shukla (2012) reported that accelerative overtaking is observed when drivers do not find sufficient gaps to overtake slow moving vehicle in front.

Vehicles that were traveling above the speed limit upstream of the DMS were also more likely to speed downstream of the DMS. When larger headways were available downstream, vehicles were more likely to exceed the posted limit. As was the case with respect to mean speeds, drivers were more likely to exceed the speed limit when an MDOT vehicle was parked on the shoulder as compared to a police vehicle. Truck drivers were less likely to speed compared to drivers of passenger vehicles, despite the lower limit for such vehicles.

Additionally, as observed earlier (Figure 23 and Figure 25), the increase in speed variability between upstream and downstream locations may be due to the drivers' level of comfort when passing shoulder-parked stationary vehicles. Some drivers may reduce their speed significantly, and others may keep to their upstream speed (depending on which lane drivers used to pass the stationary vehicles).

Interestingly, speeding was less likely to occur when any of MOSD safety message were displayed. In contrast to the analysis of average speeds, this effect held when both the MDOT and police vehicles were parked on the shoulder, though the effect was more pronounced for the police vehicle as noted previously. On average, the odds of exceeding the speed limit were 24.9 to 38.9 percent lower when any of the targeted messages were displayed. Consequently, though drivers did not reduce to the prescribed 10 mph below the speed limit, there was some degree of reduction demonstrated in general.

6.4.1.3 Lateral Position while Passing a Service Vehicle

The primary emphasis of the move-over law on high-speed, multilane roads is to encourage drivers to move over to the adjacent lane as the name of the law implies. Initially, analyses were conducted that included the entire sample of vehicles. Figure 27 and Figure 28 present data as to the lane positions of passenger vehicles and trucks, respectively, when these vehicles were downstream of the DMS and passing the service vehicles on the shoulder.

Starting with passenger vehicles, there is again a distinct difference in terms of compliance rates depending upon whether the service vehicle was a police car or an MDOT pickup truck. For all message types, about 38 to 55 percent of the passenger vehicles moved over to the left lane when passing the MDOT vehicle.

In contrast, when the police vehicle was on the shoulder, the compliance rates increased significantly. Among passenger vehicles, more than 90 percent moved over to the left lane when MOSD messages were displayed. While for standard travel time message, about 83 percent of the passenger vehicles changed lanes. Similar summary data was found for trucks. Consistent with the evaluation results discussed previously, compliance was significantly lower for MDOT vehicles when compared to police cars, regardless of the type of message displayed. When the MDOT vehicle was on the shoulder, 33 to 42 percent of trucks moved entirely from the right lane to the left lane.

Overall, there was no clear difference in compliance between the different messages that were displayed when the MDOT vehicle was on the shoulder. As in the case of passenger cars, the MOSD messages were more effective when a police car was present. In this case, 92 percent of trucks moved to the left lane as compared to 89 percent when the standard travel time message was displayed.

An in-depth investigation of these data showed that confounds emerged when attempting to analyze the entire sample. Many of the vehicles that did not move over faced insufficient headways in the left lane while approaching the downstream service vehicles. This scenario was encountered by approximately 68 percent of passenger vehicles and 45 percent of trucks that were unable to move over. Consequently, subsequent investigation focused only on those vehicles that had headways of 3 seconds available both upstream and downstream of the DMS. This reduced the sample to 1,195 vehicles, which accounts for 26 percent of all data collected.

When examining results in Table 17, a positive parameter estimate indicates scenarios in which the subject vehicle was more likely to move over while a negative sign is indicative of vehicles maintaining their position in the right lane downstream of the DMS.

These results show that when traffic volume increases, drivers were less likely to move over to the left lane downstream of the DMS. This effect remained even when filtering based upon the 3-s minimum headway as noted previously. Related to this point, trucks were less likely to move over than passenger cars. This is largely a function of the space constraints faced by larger vehicles when attempting to merge into the left lane.

At both study locations, distinct differences were observed with respect to the type of vehicle that was located on the shoulder. Drivers were again less likely to change lanes when an MDOT vehicle was present versus a patrol car. This was seen for both passenger vehicles, as well as trucks. In comparing the standard time message and the targeted MOSD messages, no distinct pattern emerges. The use of the MOSD Message with ‘Save a Life’ showed lower compliance, though the reason for this result is unclear.

Table 17. Logistic Regression Results for Move Over Lane Compliance

Variable	Estimate	Standard Error	P-Value
Intercept	14.360	3.090	<0.001
Natural Log of Traffic Volume (15-minute)	-3.394	1.090	<0.001
Proportion of Truck	-5.740	1.988	0.004
I-96 Highway (Baseline)	-	-	-
M-6 Highway	-0.955	0.138	<0.001
Police Vehicle on the Shoulder (Baseline)	-	-	-
MDOT Vehicle on the Shoulder	-2.635	0.090	<0.001
Passenger Vehicle (Baseline)	-	-	-
Single Unit/Heavy Trucks	-0.412	0.146	0.005
Tractor Trailer/Semi-Truck	-0.462	0.095	<0.001
Passenger Vehicle with Trailer	-0.543	0.224	0.015
Single Unit/Heavy Trucks with Trailer	-1.108	0.388	0.004
Standard Travel Time Message (Baseline)	-	-	-
MOSD Message	-0.027	0.171	0.874
MOSD Message + $400 Fine	0.033	0.165	0.844
MOSD Message + Save a Life	-0.356	0.170	0.037
MOSD Message + Work with Us	0.047	0.150	0.756
MOSD Message + Prevent Fatalities	-0.100	0.154	0.515

6.4.2 Field Study of Speeding-Related Messages

At each location, six different speed-related messages were tested to examine the impact on driver behavior. However, for comparative purposes, only observations with the same messages that were shown at both sites were included in the analysis. Consequently, vehicle observations during STOP SPEEDING BEFORE IT STOPS YOU and SPEED TOO FAST | 35% OF TRAFFIC DEATHS IN NORTHERN MICHIGAN messages were removed from the analysis. This reduced the number of observations in the sample from 1,798 to 1,468.

Table 18 shows estimates for a multiple linear regression model for downstream speed. Four different variables included in the model were upstream speed, site location, type of vehicle, and different speed-related messages displayed. The traffic volume, which is the only exposure variable in the data, shows insignificant results, and exhibits correlations with other predictor variables, was removed from the model. The descriptive statistics show that, on average, the M-6 highway has higher traffic volume when compared to the I-75 highway by 89 vehicles (based on 15-minute volume). However, results from Table 18 indicates that the M-6 highway differs by only a one-mph lower in terms of speed compared to the I-75 highway, despite being 5-mph lower in regulatory speed limit. This finding suggests that the I-75 highway experiences higher traffic volume, contradictory to the predicted 15-minute volume, which intuitively will affect the vehicle speed. The proportioning of the I-75 highway traffic volume to a 15-minute interval might be the reason for the insignificant results for the traffic volume variable.

Table 18. Linear Regression for Downstream Speed

Variable	Estimate	Std. Error	t-value	p-value
Intercept	35.166	1.781	19.746	<0.001
Upstream Speed (mph)	0.538	0.023	23.895	<0.001
I-75 Highway (Baseline)				
M-6 Highway	-1.011	0.230	-4.391	<0.001
Passenger Vehicle (Baseline)	-	-	-	-
Single Unit/Heavy Truck	-4.265	0.529	-8.066	<0.001
Tractor Trailer/Semi-Truck	-4.914	0.501	-9.800	<0.001
Passenger Vehicle with Trailer	0.027	0.999	0.027	0.978
Default Message (Baseline)	-	-	-	-
Drive a Safe and Reasonable Speed	-0.699	0.339	-2.063	0.039
Speed Limit | Obey the Sign or Pay the Fine	0.250	0.338	0.740	0.459
Don't be that Person | Obey Speed Limit	1.352	0.335	4.035	<0.001
It's Speed Limit | Not Speed Suggestion	-0.339	0.370	-0.917	0.360

The types of vehicles have a significant impact on speed. Larger vehicles, including single unit, heavy truck, and tractor trailer, had significantly lower speeds downstream of DMS when compared with passenger vehicle. For passenger vehicles with trailer, there was no impact on speed as the estimate coefficient is approximately equal to zero with an extreme p-value. The sample size for this categorical variable was relatively small as it only comprises of one percent of the total vehicles recorded.

Different speed-related messages showed different impacts on travel speed. The results from Table 18 are shown to be random for the speed-related messages. It is initially expected that messages with negative emotions such as SPEED LIMIT | OBEY THE SIGN OR PAY THE FINE which illustrates the punishable consequences of speeding would have measurable impact on driver speeding behaviors. Chaurand, Bossart, and Delhomme (2015) indicated that speed is lower when drivers pass both gain- and loss-framed (or positive and negative emotion) messages compared to control-frame conditions (displaying time of day). However, the results show virtually no impact on vehicle speed when this message is being displayed. Differences were observed with respect to two of the speeding-related messages. However, no clear pattern emerged and, in general, drivers did not appear to significantly adjust their speeds based upon the types of messages that were displayed on the DMS.

Table 19 represents results for the logistic regression model to identify those factors that influence the likelihood of a driver speeding (any speed above the posted limit) at the location downstream of the DMS. The same variables described previously are included as a part of this analysis. When interpreting the estimated coefficients, a positive sign is indicative of a variable that is positively correlated with (i.e., increases) the likelihood of speeding, and vice versa for negative coefficients.

Table 19. Logistic Regression for Speeding at Downstream (1 if Speeding; 0 Otherwise)

Variable	Estimate	Std. Error	t-value	p-value
Intercept	-16.073	1.397	-11.504	<0.001
Upstream Speed (mph)	0.217	0.018	12.110	<0.001
I-75 Highway (Baseline)	-	-	-	-
M-6 Highway	1.472	0.161	9.166	<0.001
Passenger Vehicle (Baseline)				
Single Unit/Heavy Truck	-1.574	0.353	-4.455	<0.001
Tractor Trailer/Semi-Truck	-3.129	0.740	-4.226	<0.001
Passenger Vehicle with Trailer	-0.039	0.586	-0.067	0.946
Default Message (Baseline)	-	-	-	-
Drive a Safe and Reasonable Speed	-0.178	0.223	-0.799	0.424
Speed Limit | Obey the Sign or Pay the Fine	0.265	0.230	1.153	0.249
Don't be that Person | Obey Speed Limit	0.458	0.227	2.021	0.043
It's Speed Limit | Not Speed Suggestion	-0.026	0.245	-0.105	0.916

The results show that vehicles are more likely to speed at M-6 site when compared to the I-75 site, even though the M-6 site experienced a one-mph lower in travel speed as per Table 18. During the data collection/reduction, about 200 vehicles were captured within 30 minutes with headways greater than five seconds for M-6 site, while only 100 vehicles were recorded for I-75 site within 45 minutes with the same headways criteria. This finding indicates that M-6 site has less traffic when compared to the I-75 sites, which allowing vehicles to have greater headway. Similar to the speeding model for MOSD messages (Table 16), heavy vehicles are less likely to speed at the downstream of the DMS when compared to passenger vehicle without trailer.

Turning to the safety messages displayed on the DMS, there was no significant impact on vehicle speed at the downstream area, except for the DON'T BE THAT PERSON | OBEY THE SPEED LIMIT message. However, as in earlier analyses, no consistent trend emerged with respect to the targeted safety messages. Overall, based on the results from Table 18 and Table 19, speed-related messages did not exhibit substantive impacts on driver behavior.

7 CONCLUSIONS

The purpose of this study was to assess the degree to which the display of crash facts and safety messages on dynamic message signs (DMS) impact driver behavior and the resultant crash risk. To this end, the research involved a range of evaluations that assessed this fundamental research question from different perspectives. First, an analysis of media content and a statewide public policy survey was conducted to discern public opinions and preferences as to the use of DMS for safety messages as compared to other purposes. This was followed by a comprehensive investigation of the degree to which trends in traffic crashes, including specific subsets of crashes, were correlated with the frequency in which safety messages were displayed on roadside DMS. Finally, field evaluations were conducted to evaluate immediate impacts of the signs on the behavior of motorists using various surrogate safety measures.

7.1 Public Opinion on DMS

The use of dynamic message signs (DMS) to display safety messages has become increasingly popular, particularly during periods when the signs are not needed for other purposes (e.g., travel time information). The results of the Michigan State-of-the-State Survey showed that the public was very supportive of using DMS for messages related to travel conditions. Both travel advisories and weather-related messages showed that more than 90 percent of respondents were in favor of use for such purposes. In contrast, respondents were nearly evenly split regarding their support for use of DMS to display safety messages and crash facts. The media content analysis reinforced some of these general themes from the survey and generally found that messages related to travel conditions are preferred as compared to more generic safety messages.

7.2 Traffic Safety Impact of DMS

Much of the prior research on safety messages has focused on feedback from drivers as to the efficacy of different types of messages, including the specific behaviors and issues that are targeted, as well as in the form of the actual messages with respect to tone, creativity, etc. Despite their widespread use, evaluations as to potential impacts on driver behavior and the resultant impacts on traffic crashes has been very limited. To that end, this study assessed the relationship between traffic crashes and the frequency with which specific safety messages are displayed. The evidence from this study suggests a potential disconnect between these stated preferences and actual driving behavior.

Over the study period, safety messages were displayed approximately 17 percent of the time (61 days per year) on average across all DMS in the state. In examining the relationship between crash frequency and type of safety messages displayed, results did not show any meaningful differences in terms of total crashes. This high-level analysis considered all types of safety messages. Subsequent analyses focused on messages that were targeted towards specific types of high-risk behaviors, such as speeding or impaired driving. Nighttime crashes were marginally lower as the frequency of alcohol and impaired driving messages increased, though this result was not statistically significant.

Significant reductions were shown when comparing speeding-related crashes to the frequency of messages that were pertinent to speeding and aggressive driving. It should be noted that this study coincided with speed limit increases on many rural freeways and two-lane highways throughout the state. Consequently, speeding-related messages and general outreach were conducted by both MDOT and the Michigan State Police, which may reflect some of this effect. The results also showed significant variability in terms of the effects from segment to segment, which suggests there are other important factors that are not explicitly captured in the safety message and roadway databases. These types of public awareness campaigns, as well as any related enforcement activities, provide examples of such factors.

Beyond the results presented herein, additional analyses were conducted with other subsets of crashes (e.g., distracted driving), at other levels of detail (e.g., daily and weekly crashes), and with alternate model specifications (e.g., with upstream segments, with alternate specifications for message frequency and type). However, these analyses did not provide any additional insights as to the nature of the relationship between the use of safety messages and the occurrence of traffic crashes.

7.3 Field Studies of Road User Behavior

A series of field studies provided insights as to the immediate impacts of safety messages on fundamental aspects of driving behavior. This included field evaluations that examined driver behavior towards type of move over messages displayed on DMS, while approaching in-service emergency and MDOT service vehicles parked on the roadway shoulder in consideration of a move-over law. Additional field studies assessed driver response to safety messages focused on speeding.

Michigan's move-over law now requires drivers to move over if possible, and reduce their speeds, for both emergency (police, fire and ambulance) and service (DOT, tow trucks, and maintenance vehicles) vehicles. Empirical evidence suggests that drivers may still be unaware of the extent of this law, which previously applied only to emergency vehicles. Overall compliance with the law, both in terms of speed reduction and lane selection, was markedly higher for police vehicles as compared to transportation service vehicles. These improvements are largely consistent with prior research, which shows speeds are significantly reduced when drivers encounter marked police vehicles (Galizio, Jackson, and Steele, 1979). Beyond the type of vehicle that is present on the roadside, the findings also show that traffic volume, and the percentage of heavy vehicles in the traffic stream had a significant influence on compliance. Turning to safety messages, there were minimal differences in compliance rates when comparing targeted move-over/slow-down messages to default travel time messages. The one exception was when considering vehicle speeds with respect to the posted limit (i.e., whether the driver was speeding). In this specific case, each of the targeted messages provided improved behavior as compared to the travel time messages.

Additional field studies focused on speeding were also conducted, but these findings showed virtually no change in driver speeds upstream and downstream of the DMS when the targeted safety messages were displayed. The same was true for the default travel time messages. Consequently, it is recommended that speeding messages be coupled with targeted enforcement where possible as the use of DMS only did not show promising results.

7.4 Recommendations

Ultimately, the findings from this study largely reinforce the FHWA Memorandum on the use of DMS with nonstandard syntax, which included safety messages (Kehrli, 2021). The memo suggests that DMS safety messages should be used as a part of active safety campaigns with limited duration as compared to the continuous display of safety messages such as in the case of crash facts and fatality statistics.

In this study, the evaluation of the move-over laws reinforce this result as driver behavior was predominantly influenced by the type of vehicle present on the roadside. When the vehicle was a police car, as compared to an MDOT service vehicle, compliance rates were significantly higher. Targeted safety messages showed some incremental effects, specifically as it related to speeding, but there were limited impacts observed overall. Other campaigns with heavy enforcement components, such as those focused on distracted driving or impaired driving, would be good candidates for continuing use of safety messages as such messages can be displayed in conjunction with national targeted road safety campaigns.

Moving forward, amendments are proposed to the next edition of the Manual on Uniform Traffic Control Devices (MUTCD) that are pertinent to the use of DMS. Current guidance suggests agencies should develop and establish a policy regarding the display of the types of messages to be used on CMS. The revised content would change this from guidance to a standard. Further, the proposed language states, "The policy shall define the types of messages that will be allowed, the priority of messages, the proper syntax of messages, the timing of messages, and other important messaging elements to ensure messages displayed meet the basic principles that govern the design and use of traffic control devices in general (see Section 1D.01) and traffic signs in particular as provided for in this Manual."

As it relates to safety messages, the following additional language of interest is proposed in Section 2L.02 Applications of Changeable Message Signs (relocated from 2L.01):

"When displayed, traffic safety campaign and transportation-related messages should be simple and direct (see Section 1D.01). Traffic safety campaign messages should emphasize the applicable regulation or warning and reference any penalties associated with violations of the regulation. Messages with obscure or secondary meanings, such as those with popular culture references, unconventional sign legend syntax, or that are intended to be humorous, should not be used as they may be misunderstood or understood only by a limited segment of road users and require greater time to process and understand. Similarly, slogan-type messages and the display of statistical information should not be used."

Traffic safety campaign and transportation-related messages should be relevant to the road user on the roadway on which the message is displayed. For example, messages regarding school bus-stop safety should not be displayed on freeways where school bus stops are not found.

The proposed language that would have the most substantive impact has been added to a standard, noting that "Traffic safety campaign messages shall not be displayed on CMS unless they are part of an active, coordinated safety campaign that uses other media forms as the primary means of outreach." Subsequent guidance is proposed, stating "Traffic safety campaigns using

CMS should include coordinated enforcement efforts where penalties or enforcement type warnings are part of the message displayed on the CMS."

While the results of this study are consistent with the recommendations of the FHWA, the public feedback suggests that a substantive portion of drivers find value in safety messages. While travel and weather advisory information should take precedence, there is a reasonable argument for displaying safety messages, particularly at locations where these higher priority messages are very infrequent. Ultimately, MDOT's policy should consider the final language that is approved for the next edition of the MUTCD.

7.5 Limitations and Directions for Future Research

It should be noted that designing a study to effectively ascertain safety impacts of DMS messages is challenging for several reasons. First, it is unclear how many of the drivers read, understood, and ultimately retained these messages. This is particularly true when trying to assess the impacts of messages that have been displayed a limited number of times. Secondly, there are a variety of confounds that are difficult to control for. This includes the dense spacing of DMS in urban environments, variation in the manner in which messages are deployed across different areas of the state, and issues with respect to the underlying DMS message data. Extensive quality assurance efforts were required in order to leverage the output from MDOT's historical message inventory.

The empirical study used a staging procedure where the emergency and service vehicles were parked on the roadside with their lights active. However, this scenario is generally less conspicuous than cases where the service vehicle was associated with ongoing activity by the law enforcement or road agency personnel. Consequently, differences may be observed under these settings. Additionally, the study was also conducted under low to moderate traffic volumes. Under more congested conditions, important concerns arise with respect to requiring vehicles to move over under limited headways. Given the risks involved, evaluation under these contexts was not considered as a part of this evaluation. However, this aspect warrants careful consideration when implementing and enforcing move-over laws. Moving forward, additional research is warranted as to other high-priority behaviors that may be influenced through safety messaging campaigns, particularly those with a potential enforcement component. For example, cell phone use by drivers, non-use of seatbelts, and speeding would seem to be the most promising behaviors to target as a part of such studies.

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APPENDIX A. DETAILS OF TYPES OF SAFETY MESSAGES IN USE BY STATE DOTS

Summary of Message Types in Use by State Departments of Transportation

No	State	Type	Frequency/Work Plan	Web source
1	Alabama	Non-Creative		ATSSA
2	Alaska	Non-Creative		ATSSA
3	Arizona	Creative		azdot
4	Arkansas	Creative		thv11
5	California	Non-Creative		abc7nes
6	Colorado	Creative	Wednesdays	Denver Post
7	Connecticut	Non-Creative		ATSSA
8	Delaware	Creative		delaware online
9	Florida	Non-Creative		fdot
10	Georgia	Non-Creative		Info from Michigan DOT FAQ
11	Hawaii	Creative	Weekly	hidot.hawaii.gov
12	Idaho	Non-Creative		ATSSA
13	Illinois	Non-Creative		Info from Michigan DOT FAQ
14	Indiana	Non-Creative		ATSSA
15	Iowa	Creative	Mondays	qconline
16	Kansas	Non-Creative		ATSSA
17	Kentucky	Creative	Thursday - Saturday	richmondregister.com
18	Louisiana	Non-Creative		ATSSA
19	Maine	Creative		Press Herald
20	Maryland	Creative	Campaign Week	baltimoremagazine
21	Massachusetts	Creative		apnews
22	Michigan	Non-Creative	Wednesdays	Mlive.com
23	Minnesota	Creative	Mondays	Stratribune
24	Mississippi	Non-Creative		ATSSA
25	Missouri	Non-Creative		Info from Michigan DOT FAQ
26	Montana	Non-Creative		ATSSA
27	Nebraska	Creative	Friday	omaha.com
28	Nevada	Non-Creative		Info from Michigan DOT FAQ
29	New Hampshire	Non-Creative		Info from Michigan DOT FAQ
30	New Jersey	Non-Creative		ATSSA
31	New Mexico	Non-Creative		ATSSA
32	New York	Information		nysdotVMSguideline
33	North Carolina	Non-Creative		ATSSA
34	North Dakota	Creative		myndnow.com
35	Ohio	Creative		cleveland.com
36	Oklahoma	Creative		kgou.org
37	Oregon	Creative		ATSSA

No	State	Type	Frequency/Work Plan	Web source
38	Pennsylvania	Non-Creative		ATSSA
39	Rhode Island	Non-Creative		Info from Michigan DOT FAQ
40	South Carolina	Non-Creative		ATSSA
41	South Dakota	Non-Creative		ATSSA
42	Tennessee	Non-Creative		Info from Michigan DOT FAQ
43	Texas	Non-Creative		Info from Michigan DOT FAQ
44	Utah	Creative	Mondays	udot.utah.gov
45	Vermont	Non-Creative	Wednesdays in 2016	Citylab.com
46	Virginia	Creative		fox5dc
47	Washington	Non-Creative		ATSSA
48	West Virginia	Non-Creative		ATSSA
49	Wisconsin	Creative		CBS58,Wisconsin.gov
50	Wyoming	Non-Creative		trib.com

APPENDIX B. STATE-OF-THE-STATE SURVEY QUESTIONS

>driving01<
Michigan uses electronic signs to display road safety messages, such as "don’t drink and drive" or "Stop texting."
Have you ever seen these road safety message signs in Michigan?
<1> YES
<5> NO
<8>[commandbutton <DO NOT KNOW>]
<9>[commandbutton <REFUSED THIS QUESTION>]

>driving02< [if driving01 ne <1> goto driving21]
Do the messages remind you of a good driving behavior that you were not complying with at the time?
<1> YES
<3> SOMETIMES
<5> NO
<7> DO NOT DRIVE / N/A
<8>[commandbutton <DO NOT KNOW>]
<9>[commandbutton <REFUSED THIS QUESTION>]

>driving11< [if driving02 ge <4> goto driving21]
How often does reading the messages improve your driving behavior immediately? Would you say always, most of the time, some of the time, rarely, or never?
<1> ALWAYS
<2> MOST OF THE TIME
<3> SOME OF THE TIME
<4> RARELY
<5> NEVER
<8>[commandbutton <DO NOT KNOW>]
<9>[commandbutton <REFUSED THIS QUESTION>]

>driving12<
Using the same options, how often does reading these messages improve your driving behavior long-term?
(Would you say always, most of the time, some of the time, rarely, or never?)
<1> ALWAYS
<2> MOST OF THE TIME
<3> SOME OF THE TIME
<4> RARELY
<5> NEVER
<8>[commandbutton <DO NOT KNOW>]
<9>[commandbutton <REFUSED THIS QUESTION>]

>driving13< [if driving11 eq <5> and driving12 eq <5> goto driving21] What specific message had the greatest effect on your driving behavior?
[red]IWER: FIELD CODE RESPONSE - THIS MEANS DO NOT READ THE RESPONSES BUT CHOOSE THE RESPONSE THAT BEST FITS THE RESPONDENTS ANSWER - IF A RESPONSE DOES NOT FIT, USE THE OTHER SPECIFY TO ENTER THE TEXT[n]
<1> SPEEDING
<2> SEAT BELT USE
<3> CELL PHONE USE/TEXTING
<4> LANE DISCIPLINE/STAY IN LANE
<5> AGGRESSIVE DRIVING
<6> DRUNK DRIVING/DRINKING AND DRIVING
<7> CHILDREN SAFETY/CAR SEATS
<8> TAILGATING
<9> GENERAL SAFETY MESSAGES

```
        <90>[specify][commandbutton <SPECIFY:OTHER>]
        <98>[commandbutton <DO NOT KNOW/CAN'T REMEMBER>]
        <99>[commandbutton <REFUSED THIS QUESTION>]

>driving13b< [if driving13 ne <98> goto driving14] Can you recall what the message was about?
  (What specific message had the greatest effect on your driving behavior?)
    [red]IWER: FIELD CODE RESPONSE - THIS MEANS DO NOT READ THE RESPONSES BUT CHOOSE THE RESPONSE
    THAT BEST FITS THE RESPONDENTS ANSWER - IF A RESPONSE DOES NOT FIT, USE THE OTHER SPECIFY TO
    ENTER THE TEXT[n]
        <1> SPEEDING
        <2> SEAT BELT USE
        <3> CELL PHONE USE/TEXTING
        <4> LANE DISCIPLINE/STAY IN LANE
        <5> AGGRESSIVE DRIVING
        <6> DRUNK DRIVING/DRINKING AND DRIVING
        <7> CHILDREN SAFETY/CAR SEATS
        <8> TAILGATING
        <9> GENERAL SAFETY MESSAGES
        <90>[specify][commandbutton <SPECIFY:OTHER>]
        <98>[commandbutton <DO NOT KNOW/CAN'T REMEMBER>]
        <99>[commandbutton <REFUSED THIS QUESTION>]

>driving14< [if driving13 eq <99> or driving13b ge <98> goto driving15]
  Did this message evoke a positive or negative emotion in you, or did you have no emotional
  reaction?
        <1> POSITIVE
        <2> NEGATIVE
        <3> NO EMOTIONAL REACTION/NEUTRAL
        <8>[commandbutton <DO NOT KNOW>]
        <9>[commandbutton <REFUSED THIS QUESTION>]

>driving15<
  Did this message primarily imply a personal, societal, or law-enforced consequence, or no
  consequence?
        <1> PERSONAL/SELF CONSEQUENCE
        <2> SOCIETAL/COMMUNITY CONSEQUENCE
        <3> LAW-ENFORCED/LEGAL CONSEQUENCE
        <4> NO CONSEQUENCE
        <8>[commandbutton <DO NOT KNOW>]
        <9>[commandbutton <REFUSED THIS QUESTION>]

>driving16a< [if driving13b ne <98> goto driving17][if randdrive eq <2> goto driving16b]
  How likely would it be for a road sign with the message "152 traffic deaths to date, down 34
  from April 2018"
  to affect your driving behavior? Would you say very likely, likely, unlikely, or very
  unlikely?
    [red]IWER: THERE ARE MULTIPLE VERSIONS OF THIS QUESTION; PLEASE READ CAREFULLY[n]
        <1> VERY LIKELY
        <2> LIKELY
        <3> UNLIKELY
        <4> VERY UNLIKELY
        <8>[commandbutton <DO NOT KNOW>]
        <9>[commandbutton <REFUSED THIS QUESTION>]

>driving16b< [if randdrive eq <1> goto driving17]
  How likely would it be for a road sign with the message "152 traffic deaths to date, up 34
  from April 2018"
```

to affect your driving behavior? Would you say very likely, likely, unlikely, or very unlikely?
[red]IWER: THERE ARE MULTIPLE VERSIONS OF THIS QUESTION; PLEASE READ CAREFULLY[n]
<1> VERY LIKELY
<2> LIKELY
<3> UNLIKELY
<4> VERY UNLIKELY
<8>[commandbutton <DO NOT KNOW>]
<9>[commandbutton <REFUSED THIS QUESTION>]

>driving17<
When does this message lose its effectiveness? Would you say seeing the same message twice, seeing it three to nine times, seeing it ten to twenty times, seeing it more than twenty times, or never?

<1> TWICE / MORE THAN ONCE
<2> 3-9 TIMES
<3> 10-20 TIMES
<4> MORE THAN 20 TIMES
<5> NEVER / ALWAYS EFFECTIVE
<8>[commandbutton <DO NOT KNOW>]
<9>[commandbutton <REFUSED THIS QUESTION>]

>driving21<
I will now ask you about your reactions in response to reading specific road safety messages while driving in Michigan.

For each of the following, indicate whether it is very likely, likely, unlikely, or very unlikely to affect your driving behavior.
"Be safe drivers."
<1> VERY LIKELY
<2> LIKELY
<3> UNLIKELY
<4> VERY UNLIKELY
<8>[commandbutton <DO NOT KNOW>]
<9>[commandbutton <REFUSED THIS QUESTION>]

>driving22<
"Stay alert. 63% of traffic deaths occur on dry roads"
(Is this road safety message very likely, likely, unlikely, or very unlikely to affect your driving behavior?)
<1> VERY LIKELY
<2> LIKELY
<3> UNLIKELY
<4> VERY UNLIKELY
<8>[commandbutton <DO NOT KNOW>]
<9>[commandbutton <REFUSED THIS QUESTION>]

>driving23<
"152 traffic deaths in Michigan this year"
(Is this road safety message very likely, likely, unlikely, or very unlikely to affect your driving behavior?)
<1> VERY LIKELY
<2> LIKELY
<3> UNLIKELY
<4> VERY UNLIKELY
<8>[commandbutton <DO NOT KNOW>]
<9>[commandbutton <REFUSED THIS QUESTION>]
@
>driving24<

```
  "152 traffic deaths in your area this year."
  (Is this road safety message very likely, likely, unlikely, or very unlikely to affect your
  driving behavior?)
        <1> VERY LIKELY
        <2> LIKELY
        <3> UNLIKELY
        <4> VERY UNLIKELY
        <8>[commandbutton <DO NOT KNOW>]
        <9>[commandbutton <REFUSED THIS QUESTION>]

>driving25<
  "Distractions are deadly, just drive."
  (Is this road safety message very likely, likely, unlikely, or very unlikely to affect your
  driving behavior?)
        <1> VERY LIKELY
        <2> LIKELY
        <3> UNLIKELY
        <4> VERY UNLIKELY
        <8>[commandbutton <DO NOT KNOW>]
        <9>[commandbutton <REFUSED THIS QUESTION>]

>driving26<
  "Drive carefully, 90% of all people are caused by accidents"
  (Is this road safety message very likely, likely, unlikely, or very unlikely to affect your
  driving behavior?)
        <1> VERY LIKELY
        <2> LIKELY
        <3> UNLIKELY
        <4> VERY UNLIKELY
        <8>[commandbutton <DO NOT KNOW>]
        <9>[commandbutton <REFUSED THIS QUESTION>]
        @
>driving27<
  "Don’t drive wicked, avoid a ticket."
  (Is this road safety message very likely, likely, unlikely, or very unlikely to affect your
  driving behavior?)
        <1> VERY LIKELY
        <2> LIKELY
        <3> UNLIKELY
        <4> VERY UNLIKELY
        <8>[commandbutton <DO NOT KNOW>]
        <9>[commandbutton <REFUSED THIS QUESTION>]

>driving28<
  "Don’t drive wild. Think of your child."
  (Is this road safety message very likely, likely, unlikely, or very unlikely to affect your
  driving behavior?)
        <1> VERY LIKELY
        <2> LIKELY
        <3> UNLIKELY
        <4> VERY UNLIKELY
        <8>[commandbutton <DO NOT KNOW>]
        <9>[commandbutton <REFUSED THIS QUESTION>]

>driving29<
  "Goodbye John. Good luck and you’ll be missed"
  (Is this road safety message very likely, likely, unlikely, or very unlikely to affect your
  driving behavior?)
```

```
        <1> VERY LIKELY
        <2> LIKELY
        <3> UNLIKELY
        <4> VERY UNLIKELY
        <8>[commandbutton <DO NOT KNOW>]
        <9>[commandbutton <REFUSED THIS QUESTION>]

>driving31<
  I will now ask you about your preferences regarding reading messages
  on electronic road signs while driving in Michigan. Please respond with "yes" or "no" on
  whether you would like to read each one.
  Road safety messages with fatality statistics
        <1> YES
        <5> NO
        <8>[commandbutton <DO NOT KNOW>]
        <9>[commandbutton <REFUSED THIS QUESTION>]

>driving32<
  Road safety messages with humor, like "get your head out of your apps"
  (Would you like to read this messages on electronic road signs while driving in Michigan?)
        <1> YES
        <5> NO
        <8>[commandbutton <DO NOT KNOW>]
        <9>[commandbutton <REFUSED THIS QUESTION>]

>driving33<
  Travel advisories, like "10 minutes to I-96"
  (Would you like to read this messages on electronic road signs while driving in Michigan?)
        <1> YES
        <5> NO
        <8>[commandbutton <DO NOT KNOW>]
        <9>[commandbutton <REFUSED THIS QUESTION>]

>driving34<
  Weather advisories
  (Would you like to read this messages on electronic road signs while driving in Michigan?)
        <1> YES
        <5> NO
        <8>[commandbutton <DO NOT KNOW>]
        <9>[commandbutton <REFUSED THIS QUESTION>]
```