EVALUATION OF DRIVER RESPONSE TO SAFETY MESSAGES ON DYNAMIC MESSAGE SIGNS

By

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ABSTRACT

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Between 2010 and 2020, many transportation agencies began displaying safety messages and crash facts to the traveling public using roadside dynamic message signs (DMS). The content of these messages varies from annual crash and fatality statistics to more detailed messages regarding specific driving behaviors or risk factors. Despite the widespread use of DMS for safety messaging purposes, evaluations of potential impacts on driver behavior and resultant impacts on traffic safety have been limited. This research addresses this gap through a series of investigations to determine the degree to which the use of DMS for safety messages impacts various aspects of driver behavior. Driver behavior was examined in response to different DMS messages while considering critical contextual factors, such as the type of messages displayed, traffic flow conditions, and roadway geometric characteristics.

The first set of field evaluations examined driver behavior as vehicles approached in-service emergency and MDOT service vehicles parked on the roadway shoulder in consideration of the state's move-over law. Compliance was measured in terms of speed reduction and lane selection and comparisons were made based upon a series of targeted messages displayed on upstream DMS. Logistic regression models were estimated to assess driver compliance with the law while considering important contextual factors, such as the type of vehicle on the shoulder and the message displayed on the DMS. The results indicate that drivers were more likely to move over or reduce their speeds when a police car was parked on the shoulder as compared to a transportation agency pickup truck. In general, the type of message displayed had minimal impact

on driver behavior. The one exception showed that drivers were less likely to exceed the speed limit when targeted move over messages were shown as compared to standard travel time messages. For all message types, both speed and lane compliance were improved if the roadside vehicle was a police car.

The second study examined cell phone use rates in consideration of enforcement activities that were conducted in conjunction with the display of targeted safety messages on roadside DMS. The results showed that cell phone use rates were lower during and, particularly, after the enforcement activities were conducted. Use rates were also found to vary based on age, gender, and race, allowing for the identification of target groups for public awareness and outreach campaigns. Cell phone use rates were also lower at freeway exit ramps compared to signalized and stop-controlled surface street intersections. Furthermore, cell phone-specific safety messages were associated with lower use rates than other message types.

Ultimately, the findings largely reinforce federal guidance on the use of DMS for secondary purposes, which include displaying road safety messages. As a stand-alone measure, DMS provide marginal impacts on driver behavior. Such messaging strategies are likely to be more effective when used as a part of active safety campaigns with a limited duration as compared to more frequent and continuous display of generic message types. The outcome of the field investigations also shows that combining targeted messaging with the presence of enforcement results in the most substantive improvements in driver behavior.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

KEY TO ABBREVIATIONS

DMS	Dynamic Message Sign
DOT	Department of Transportation
FHWA	Federal Highway Administration
MDOT	Michigan Department of Transportation
MOSD	Move over slow down
NSC	National Safety Council
NHTSA	National Highway Traffic Safety Administration
SD	Standard deviation

CHAPTER 1:INTRODUCTION

1.1 Background

Each year, more than 35,000 fatalities occur as a result of traffic crashes throughout the United States (NHTSA, 2020). In the state of Michigan, more than 1,000 road users are fatally injured on an annual basis (Michigan Traffic Crash Facts, n.d.). Starting in 2005, both U.S. and Michigan traffic fatality statistics showed a persistent decrease until 2009, as is shown in Figure 1-1. A subsequent plateau was experienced through approximately 2014, and recent increases, which indicated a u-shaped trend since 2005 to 2020, 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 because of improved economic conditions. Other issues, such as the legalization of marijuana, may also result in adverse impacts on traffic safety.

Consequently, 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 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 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.

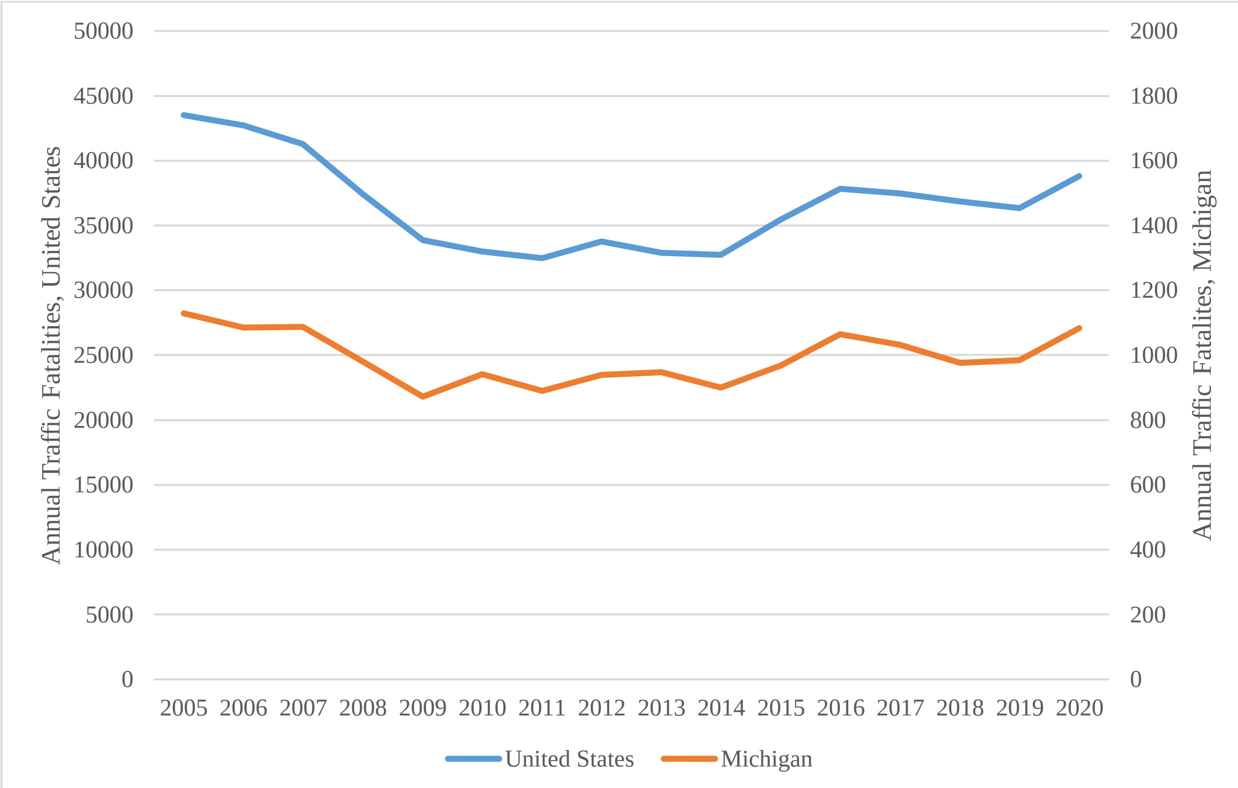


Figure 1-1 Annual Traffic Fatalities in United States vs. Michigan, 2005-2020

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 roadways and provide real-time information to drivers. Primarily, 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 used to communicate messages regarding these types of operational information to manage traffic more effectively through the provision of travel time, 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 displaying roadside safety messages and crash facts to the traveling public using dynamic message signs (DMS). 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.

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 factual messages to more creative message.

Figure 1-2 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 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.

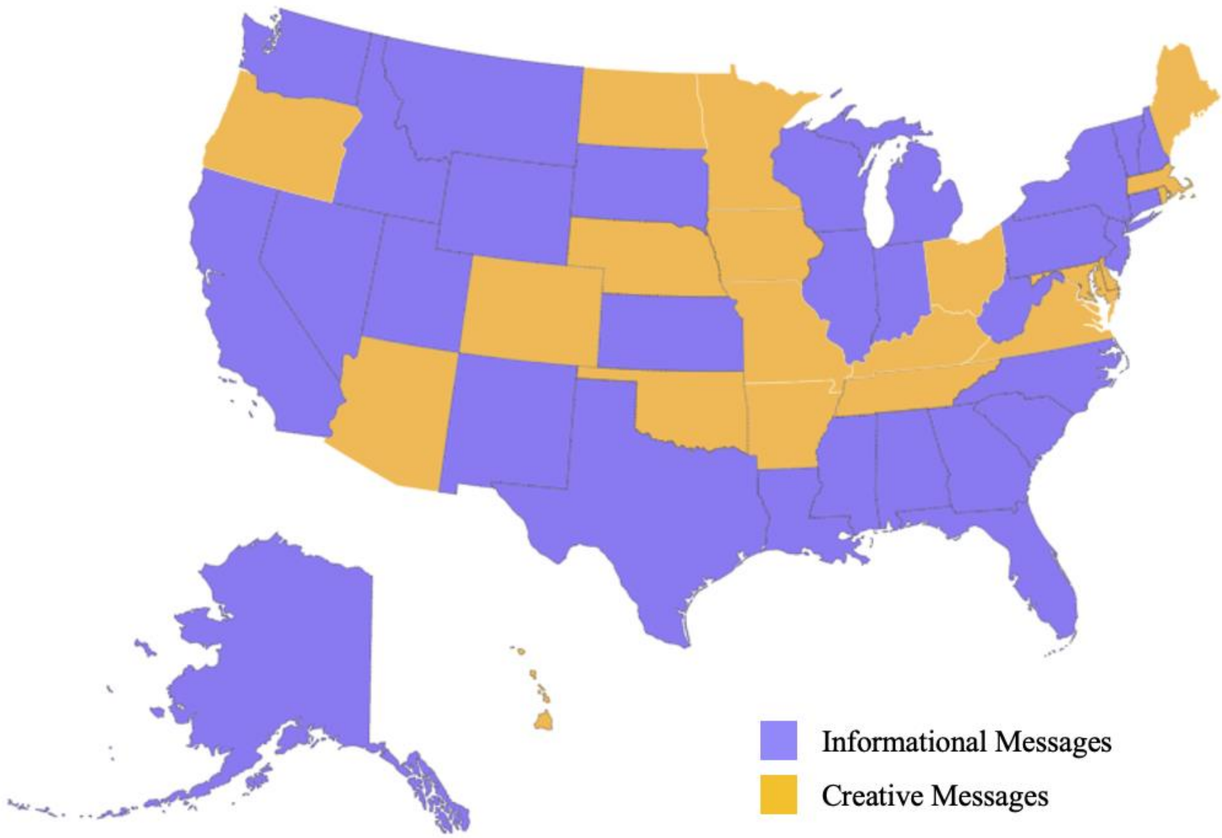


Figure 1-2 Safety Message Types Displayed on DMS by State

1.2 Problem Statement

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 safety message, as well as potential impacts on other surrogate measures of safety.

1.3 Research Objectives

To address these issues, a field study was performed on roadways with fixed DMS structure in Michigan to determine drivers' response to targeted safety messages on DMS. Two separate groups of targeted messages were considered in the study; messages related to the move-over law and messages related to cell phone use while driving. This study aims to determine the effect of driver response to these safety messages displayed on upstream dynamic message signs. This was completed using captured video data and roadside data collection. The main objectives of this dissertation are to:

1. Examine driver compliance with a move-over and slow down law in consideration of vehicle type and messages displayed on upstream dynamic message signs, and
2. Examine enforcement and dynamic message signs messaging campaign on reducing cell phone-related distracted driving.

The document is organized into five chapters. Chapter 1 consist of background introduction on crash trends and effort in improving road safety within the past decade, including the emerging use of dynamic message signs to display road safety messages. Chapter 2 consist of the summary of the extant literature on the use of safety messages on dynamic message signs, and three targeted messaging themes based on existing law. Chapter 3 and Chapter 4 demonstrates field investigations on the use of DMS as specified in the study objectives. The final chapter details the conclusion and recommendations as well as study limitations.

CHAPTER 2: LITERATURE REVIEW

2.1 Safety Messages on DMS

In recent years, state departments of transportation have begun displaying roadside safety messages and crash facts to the traveling public using DMS, as shown in the example from Figure 2-1. 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 2-1 Sample DMS Use for Safety Message

A review of published research and media content shows that all states have previously been, or are currently, using 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 informative (e.g., ‘‘440 TRAFFIC DEATHS IN MICHIGAN THIS YEAR’’ or ‘‘MOVE OVER OR SLOW DOWN FOR EMERGENCY VEHICLES’’) to more creative message (e.g., ‘‘GET YOUR HEADS OUT OF YOUR APPS. DRIVE SAFELY’’). Data from 2017 show that more than 75% of states used informative messages (e.g., safety facts), such as the number of road fatalities in the state as of the date the sign was in operation. Other states used creative messages, which included pop-culture references and humor (ATTSA, 2017). A state-of-the-state survey through media reports on the use of DMS by state revealed that in 2019, the creative form of messaging increased to 48 percent.

The utilization of DMS to display road-safety-related messages is a novel and potentially valuable means to utilize intelligent transportation systems infrastructure, particularly during times when such devices are not in use. However, the functionality, as well as the impact on road users, requires further study. The efficacy of these types of intervention programs is generally determined through evidence-based evaluations; however, reports on road safety 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 about evaluation costs (Boulanger et al., 2009).

2.1.1 Safety Message Development

Information collected from available resources on state of the state practice in shows that formulation of messages displayed was mostly based within the respective DOTs, often related to seasonal situation such as holiday seasons, or bad weather. In addition, some DOTs crowdsourced information from the public. For example, Maine, Arizona, and Nebraska initiated 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.

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 & 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, & 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 & Walker, 2013). Supporting study shows that in addition to threat type messages, assertive language was found to affect driver behavior (Boyle et al., 2014).

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.

2.1.2 Impact of DMS Safety Message on Traffic Speed

Among the limited research that has been conducted in this area, several studies have examined the effects of safety messages on driver speed selection. 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 speeds were found to be reduced when the animal advisory message was displayed, especially during dark lighting conditions. The same study also found that speeds increased when generic transportation messages were displayed instead of safety messages. It was hypothesized that the general message was assumed to be a default message when no condition of concern was present (Hardy, Lee & Al-Kaisy, 2006). A study in Canada on the effect of anti-speeding messages displayed on DMS saw little change in mean speed during the message display phase. There was, however, a significant reduction in the standard deviation in speeds, which could potentially lead to more stable flow and reduced potential for rear-end crashes (Tay & De Barros, 2010).

2.1.3 Public Perception of Safety Messages on Dynamic Message Signs

Shealy et al. (2020) conducted a survey 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.

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).

Like the Californian study, a survey in Minnesota indicated that many 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 in influencing their driving behavior compared to other form of delivery such as television, websites, and social media platforms (Rolland and Kline, 2019).

However, studies have also shown that there is weak correlation between reported and actual behavior (AAA Foundation for Traffic Safety, 2016; 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 & Nathanail, 2017). Research is warranted in this area, as well as into the potential impacts of safety messaging programs on surrogate safety measures such as driver compliance with speed reductions and lane compliance in the vicinity of police or agency service vehicles.

2.1.4 Guidelines on Displaying Safety Messages on DMS

FHWA's Changeable Message Sign Operation and Messaging Handbook provides guidance as to the display of messages associated with traffic safety campaigns, though its blanket policy statement examples do not provide detailed information on the implementation of such safety messages (Dudek, 2004). International guidelines, such as the Use of Variable Message Signs by the Road Traffic Authority of the New South Wales Government in Australia, have outlined policies on the implementations of DMS that detail message development and provide recommendations for DMS positioning. This guideline also provides a priority list for message displays based on urgency with general safety messages being identified as ''stand-by'' messages of the lowest priority. A tabulated protocol for several stand-by messages were included in the guideline, stating the suitability or otherwise, of each message to type of traffic, time-of-day, day of-week, and type of road (Road and Traffic Authority of New South Wales, 2010).

2.2 Move Over Laws

From 2009 to 2018, a total of 122 officers were killed in the line of duty in the United States as a result of being struck by a vehicle. This accounts for approximately 8 percent of all officer deaths and 23 percent of deaths related to on road motor vehicles (National Law

Enforcement Officers Memorial Fund, 2020). A study in Ohio showed that these types of crashes accounted for only 4 percent of all patrol-car-related crashes; however, 55 percent resulted in injuries. Among such crashes, almost two-thirds occurred on high-speed and high-volume roads (Law Enforcement Stops and Safety Subcommittee, 2006). Traffic crashes are also a primary cause of work-related fatalities, as recorded by the U.S. Bureau of Labor Statistics (U.S. Bureau of Labor Statistics, 2018).

In general, drivers are instructed to slow down and, if possible, move over when encountering an active service vehicle on the shoulder. Given the risks posed to these traffic safety professionals, since the early 2000s, states have begun introducing legislation requiring approaching motorists to move over, slow down, or both when approaching a service vehicle with its lights activated. These laws are generally referred to as ‘‘move-over laws.’’ States have also introduced greater fines and penalties to protect workers in specific contexts (e.g., work zone areas).

State-level data on move-over laws show that, although differing in the specific provisions and penalties, all states have enacted some form of move-over law with the most recent state being Hawaii in 2012. Most states require drivers to move over for emergency vehicles, including police, fire, and emergency medical services. However, only 50 percent of these state laws were found to cover road agency maintenance and recovery (e.g., tow trucks) vehicles. All states also require drivers to reduce their speed as part of their move-over laws. Among these, 11 states include specific speed reductions ranging from 5 to 20 mph under the posted speed limit. However, most states do not explicitly specify the need to slow down once drivers have changed lanes.

Michigan is an exception as one of the few states that requires drivers to move over when possible, and slow down regardless of what lane the vehicle is located in. Michigan expanded its move-over and slow down (MOSD) law on February 13, 2019, to include all service vehicles, including maintenance and utility service vehicles. The prior law covered only emergency vehicles. The revised law requires motorists to slow down to at least 10 mph below the posted speed limit and move over when approaching any stationary emergency or service vehicles when their lights are activated.

Despite the nationwide adoption of move-over laws, there has been little information on the effectiveness of the law in preventing crashes (Carrick & Washburn, 2012). According to Move Over, America, whereas 90% believe that traffic stops and roadside emergencies are dangerous for law enforcement and first responders, more than 70% of Americans have not heard of move-over laws (5). Various campaigns have focused on disseminating information about move-over laws to the public, including online media articles. Dynamic message signs (DMS) have also been used as a part of public awareness and outreach campaigns. Although various studies have investigated the effects of DMS messages on traffic operations, very few studies have examined the impacts of alternative messages, such as those related to traffic safety.

2.3 Cell Phone Use While Driving Laws

Driver distraction has been shown to affect 9 to 10 percent of all fatal crashes in the United States (NHTSA, 2020). Distraction has been defined as 'the diversion of attention away from activities critical for safe driving towards a competing activity' (Regan, 2005), while a distraction-affected crash is any collision in which a driver was identified to have been distracted at the time of the crash. In 2019, 3,142 people were killed, and an estimated 424,000 people were injured in vehicular traffic crashes involving distracted drivers. Drivers who were distracted at the time of fatal crashes in 2019 accounted for 6 percent of all fatal crash drivers. Furthermore, 566 non-motorized road users (pedestrians, bicyclists, and others) were killed in distracted-affected traffic incidents in 2019 (NHTSA, 2020). In Michigan, distracted affected crashes accounted for 7 percent of fatal crashes in 2019. Although lower than the national average, the trend of distracted affected fatal crashes in Michigan has increased from 4 percent in 2016 (Michigan Traffic Crash Facts, n.d.).

Studies have investigated the prevalence of various types of distraction, as well as the impacts of these distractions on measurable aspects of driving behavior. For example, the second Strategic Highway Research Program (SHRP 2) Naturalistic Driving Study (NDS) evaluated more than 50 types of secondary tasks (i.e., distractions), including various types of cell phone use (e.g., talking, texting), talking to passengers, eating, or adjusting the instrument panel (Flannagan et al, 2019). Among these, cell phone use by drivers has received considerable attention. Traffic crash data indicate that cell phone use comprise 12 to 14 percent of all distracted affected fatal crashes (NHTSA, 2020).

Research on distracted driving related to cell phone use has been increasing these recent years. Different types of approaches have been utilized such as using driving simulator, self-reporting/survey, naturalistic driving study, and observational study to investigate how the use of cell phone while driving affect the behavior and performance of drivers, as well as to identify which group of population are more prone to be involved in this type of distracted driving. According to a study conducted in Spain, cell phone use was the most answered regarding the type of driving distractions among 426 participants (Prat et al., 2017). Similar finding was found from a survey study where most respondents reported to use a cell phone while driving within the prior 30 days (Gliklich et al., 2016). In addition, a survey study focused on motorcyclist among university students (741 respondents) in Vietnam found that majority of respondents are most likely to use a cell phone while riding with 57 percent used for talking and 62 percent used for texting (De Gruyter et al., 2017).

Since 2001, cell phone ownership in America has increased from 60 percent to approximately 97 percent. Similarly, smart phone ownership in the US has increased from 35 percent in 2011 to 85 percent in 2021 (Perrin, 2021). The ubiquity of smart phones has also translated into increased use while driving. A survey conducted by State Farm in 2016 of drivers aged 18 and up found that 91 percent of all drivers surveyed (n=962) had a smart phone of which 82 percent talked and 95 percent texted while driving (State Farm, 2016).

Organizations at the national and state levels have taken initiatives to improve awareness and prevent texting-while-driving incidences, particularly among newly licensed drivers. For example, the Missouri Coalition for Roadway Safety has developed various public education and outreach materials, including real-world case videos, and driving safety brochures (Missouri Coalition for Roadway Safety, 2021). The Texas Department of Transportation has created a program called "Teens in the Driver Seat", which uses interactive resources to educate teenagers about various distractions and hazards, including cell phone use, before they begin driving (Henk et al., 2007). More broadly, the National Safety Council (NSC) has designated April as Distracted Driving Awareness Month, while the US Department of Transportation launched a national distracted driving enforcement and advertising campaign, titled "U Drive. U Text. U Pay." (NHTSA, 2021).

Cell phone advocacy campaigns have also leveraged roadside dynamic message signs (DMS), where cell phone specific messages such as “One Text or Call Could Wreck It All” or “Drop Your Phone Cold Turkey, Focus on Driving” have been displayed on DMS in various states (ATSSA, 2017). Research on the impact of safety messages has shown that targeted messaging can influence safety, but such use is most effective when the messages are used on a more targeted basis.

The enforcement of cell phone use laws presents interesting challenges. Although no state bans all cell phone use, texting on cell phones is prohibited for all drivers in 48 states (Governors Highway Safety Association, n.d.). In Michigan, cell phone related offenses fall under primary enforcement and law enforcement officers may issue a citation any time such a violation is observed. However, the law applies only to texting (reading, typing or sending text messages) for all drivers, while an all-cell phone ban is applicable to novice drivers with a Level 1 or Level 2 license, and a handheld ban is in place for school bus drivers. At present, a first infraction of Michigan's texting statute results in a $100 fine, while a second offense carries a $200 fine (MCL 257.602b, 1949). Legislation is being discussed during the 2021 legislative session that would make it illegal to use a cellphone while driving, in addition to introducing more significant penalties for doing so (House Bill No. 4277).

Cell phone prohibition while driving is often difficult to enforce because it is hard to ascertain infractions, especially in states where there are grey areas in terms of what types of offenses are subject to the law. Drivers have also been reported to persist in using their cell phones (Ortiz et al., 2018; Oviedo, 2018; Atchley et al., 2011) and make conscious effort to conceal their texting-driving behavior (Gauld, Lewis, & White, 2014). Given the lack of effectiveness of legislation and people's acute connection to their mobile phones, law enforcement agencies have adopted various strategies to address distracted driving issues, including "roaming spotters", where law enforcement officers ride in mass transit vehicles to observe distracted drivers, as well as various forms of high-visibility enforcement campaigns (Stewart et al., 2021; Skousen, Guldbrandsen, & Patience, 2019; McCready, 2019; Retting et al., 2017). In Michigan, Operation

Ghost Rider was launched in 2017, which involves surveillance by law enforcement passengers in unmarked spotter vehicles. When the spotters notice a distracted motorist, they call for a fully marked police vehicle to conduct a traffic stop (Wingrove, 2019).

Research has demonstrated four emerging themes that are important determinants of the effectiveness of distracted driving campaigns: culture (e.g., ubiquity and prevalence of cell phone use); the legal system (e.g., different laws between state, unclear legislation); the nature of police work (e.g., physical challenges such as restricted view of drivers using cell phones); and issues with prevention (Rudisill et al., 2019).

Combined enforcement and advocacy effort have proven to yield positive result in raising awareness and reducing the number of cell phone while driving offences. Stewart et al. evaluated a multifaceted campaign in London, Canada, from 2014 to 2016 (Stewart et al., 2021). Advocacy programs in the form of videos, social media ad campaigns, billboards, and movie theater trailers were evaluated using a survey on attitudes, behaviors, and opinions related to cell phone use while driving. Cell phone enforcement activity was conducted concurrently with these media campaigns. Before the campaign, there was a significant increase in distracted driving offenses per year. Encouragingly, distracted driving citations showed a significant drop during each successive year after the campaign was implemented. Survey responses from the study indicated that passive media (including billboard display, transit shelter advertisement, and movie theater trailer) was most effective in creating campaign visibility. In contrast, another study on cell phone enforcement strategies and media campaigns revealed no significant changes overall in roadside observations of texting behavior or handheld phone use through pre- and post-enforcement evaluations in Connecticut and Massachusetts (Retting et al., 2017).

CHAPTER 3: EXAMINING DRIVE COMPLIANCE WITH A MOVE-OVER AND SLOW DOWN LAW IN CONSIDERATION OF VEHICLE TYPE AND MESSAGES DISPLAYED ON UPSTREAM DYNAMIC MESSAGE SIGNS

An expanded version of Michigan's move-over and 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.

3.1 Study Design

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., high-definition cameras). 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 criterion 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, two final sites were selected to evaluate the effectiveness of these messaging campaigns. In each case, data were collected on weekdays under clear weather conditions.

Table 3-1 shows detail information of the sites for the move over and slow down messages. Both sites are in the MDOT Grand Region near Grand Rapids. Data were collected using high-definition (HD) cameras at upstream and downstream of DMS (Figure 3-1). For the optimum vantage view of the vehicles and roadway, the cameras were set up on elevated locations (e.g., on elevated crossroads or bicycle lane) at both sites.

Table 3-1 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)

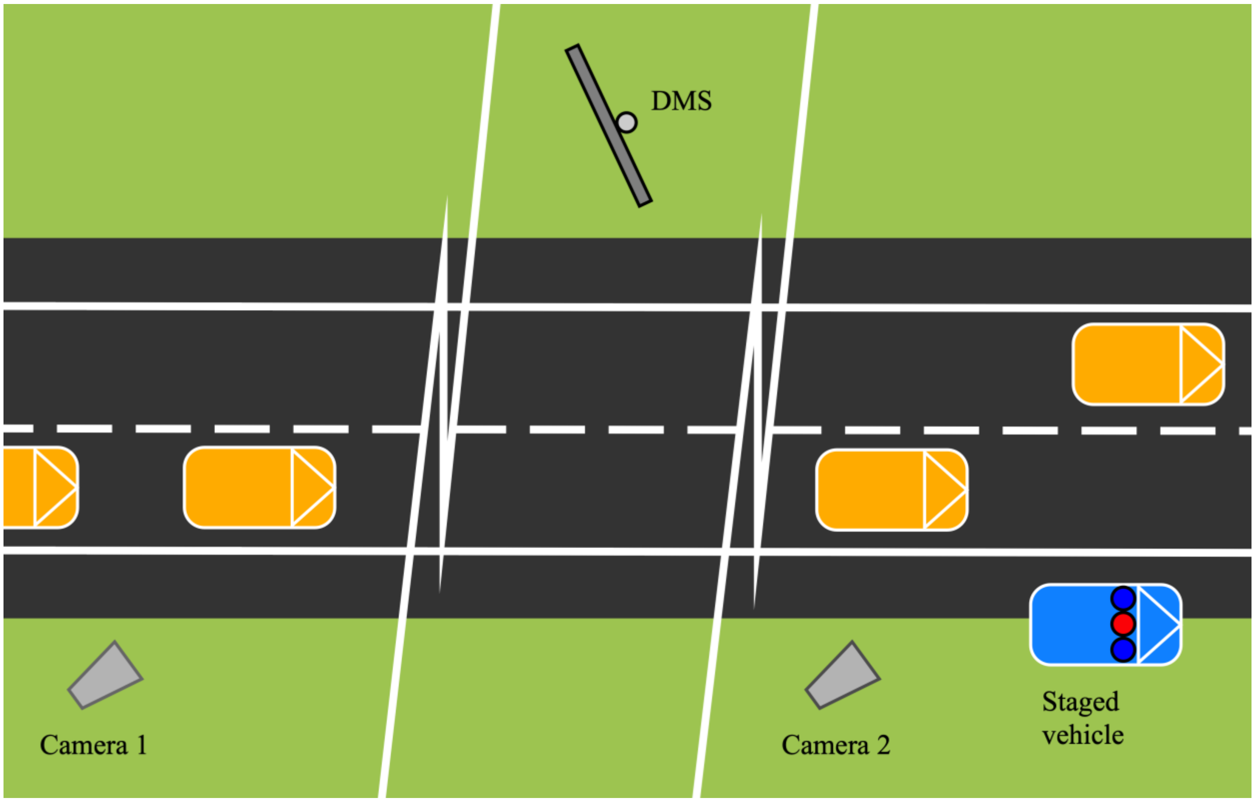


Figure 3-1 Schematic Setup Using HD Camera Upstream and Downstream of DMS

The first site was located on an eastbound (EB) of the M-6 freeway, as shown in Figure 3-2, 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 3-3. The distance between the upstream and downstream cameras with the DMS is approximately 2.0 and 0.7 miles, respectively. The staged stationary vehicles were 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).

Figure 3-2 Eastbound M-6 Highway Site

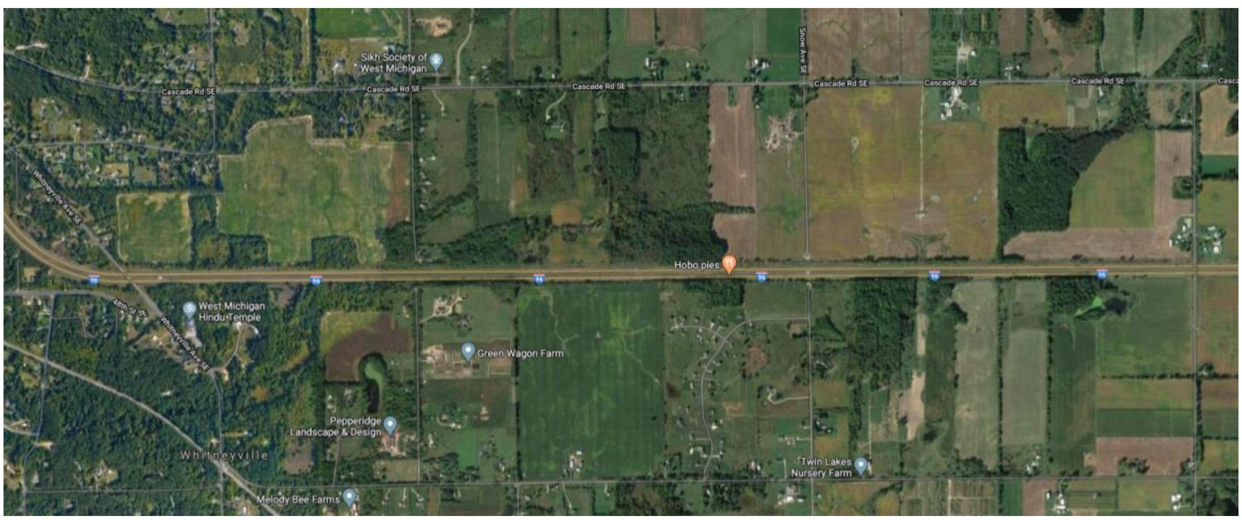


Figure 3-3 Westbound I-96 Highway Site

Table 3-2 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 stationary vehicle that was parked on the shoulder.

Table 3-2 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

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 type. 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.

3.2 Data Collection

In this study, field data collection was conducted were using HD cameras. 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 video analyst 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 (QuickTimeTM Version 7.7.9) with a frame-by-frame replay ability 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 100 ft apart, were drawn perpendicularly to the roadway, as shown in Figure 3-4.

The following information was obtained from the videos for selected vehicles traversing through the sites:

- Vehicle speed for upstream and downstream (immediately before the stationary vehicle on the shoulder) of DMSs.
- Time headway from a prior vehicle for both upstream and downstream locations.

- 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, left wheel entirely over the centerline, vehicle more than halfway over the centerline, and left lane.
- Vehicle transitioning from the right lane to the left lane at the downstream location.
- Whether the left lane was occupied and restricting a subject vehicle from passing the service vehicle.

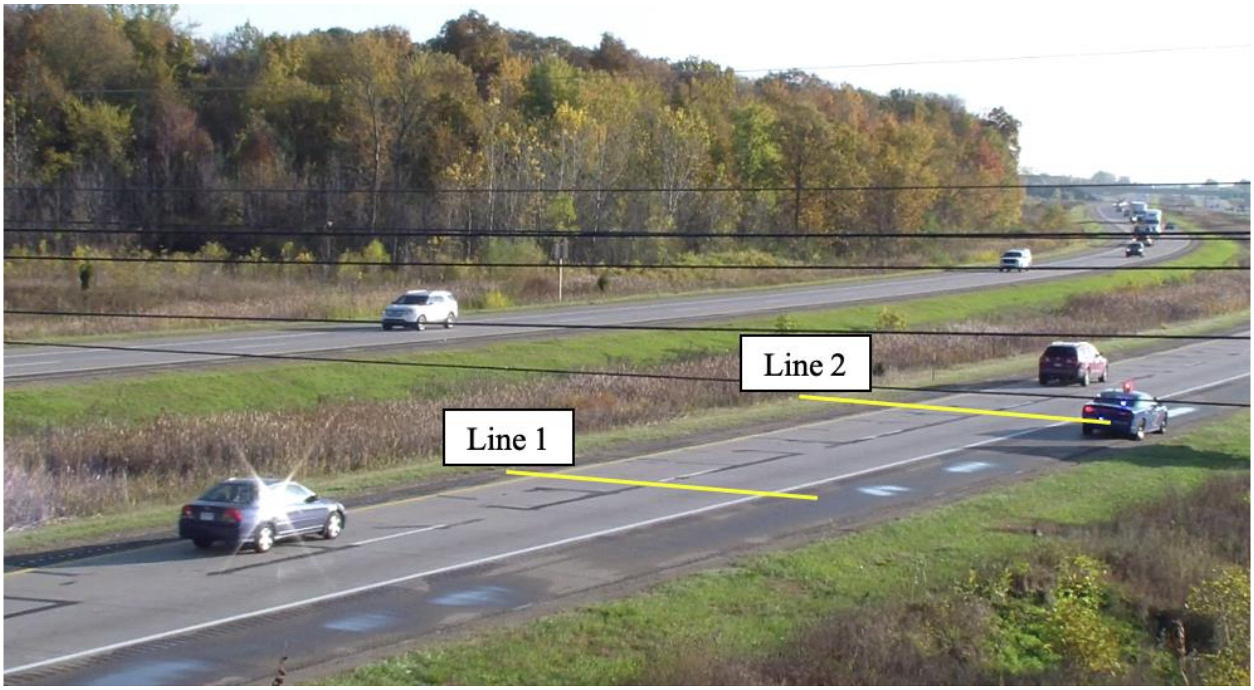


Figure 3-4 Reference Line to Measure Vehicle Speed

3.3 Data Summary

Table 3-3 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 collect data for 2,400 vehicles for each site (200 vehicles per message shown). However, due to several issues, including technical issues with the video files, site constraint issues, and incomplete data set collected, a total of 4,520 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.

Table 3-3 Descriptive Statistics of Move Over and Slow Down Messages (n = 4,520)

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

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.

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.

Figures 3-5 to 3-13 show the disaggregate level of speed variables and lane positions based on a different type of messages. Three different speed variables presented 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 3-11 and 3-12 represent five lateral positions of vehicle at downstream of DMSs

3.3.1 Average Speed

3.3.1.1 Passenger Vehicles

Figure 3-5 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 be due to the period that the standard travel time was displayed on the DMS. As shown in Table 3-2 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.

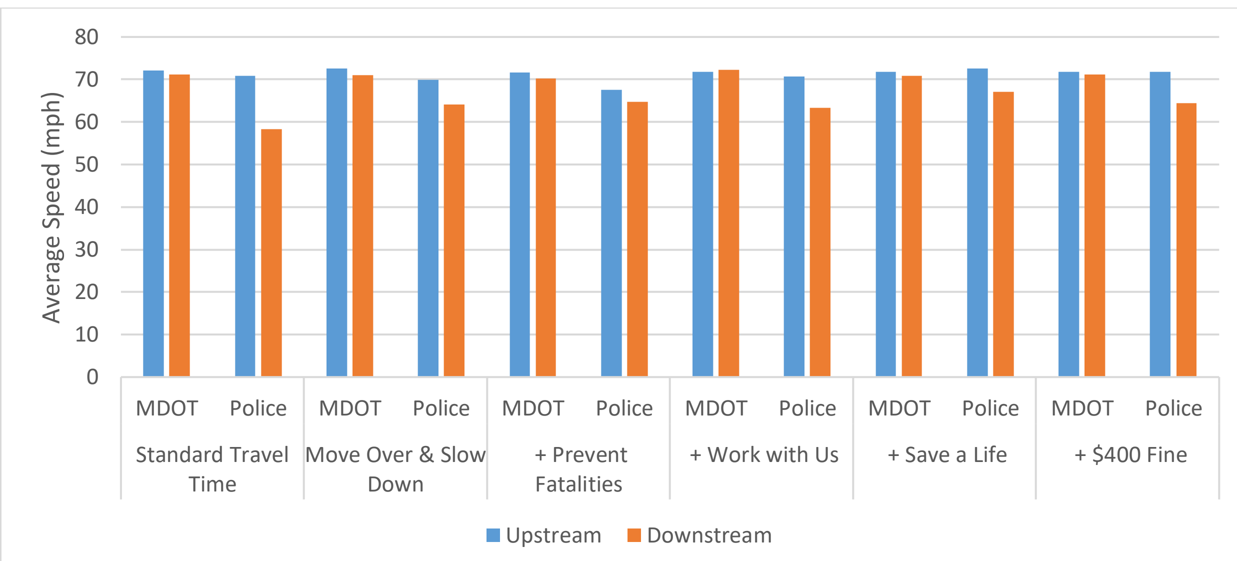


Figure 3-5 Average Speed of Passenger Vehicles at Upstream and Downstream of DMS

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 3-5 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.

3.3.1.2 Trucks

Figure 3-6 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.

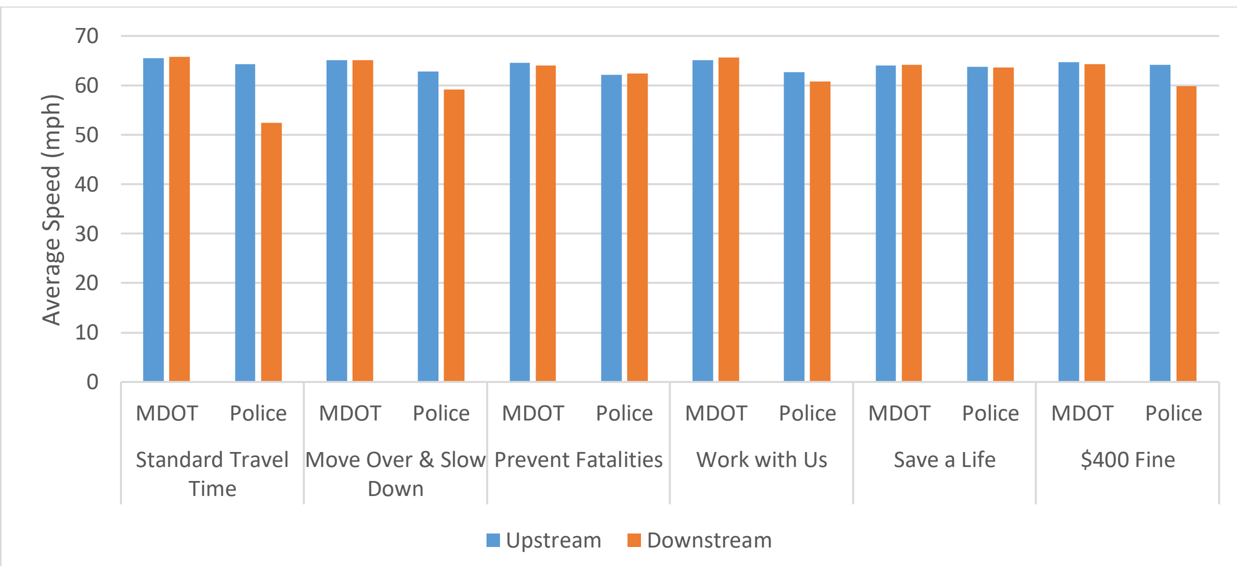


Figure 3-6 Average Speed of Trucks Upstream and Downstream of DMS

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. According to the Michigan MOSD law, drivers should reduce their speed by 10 mph. Thus, the speed of trucks should be 50 mph when approaching a vehicle on the roadside. However, the average speed of trucks downstream of the DMS remains above 60 mph for most of the MOSD messages shown.

3.3.2 85th Percentile Speed

3.3.2.1 Passenger Vehicles

Figure 3-7 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.

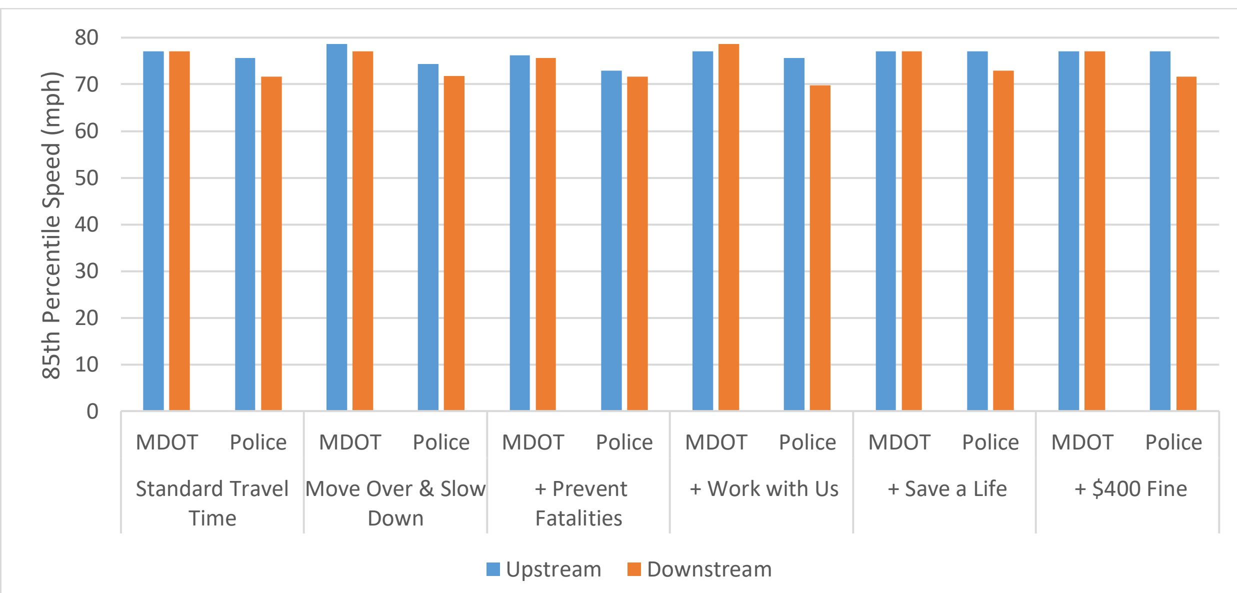


Figure 3-7 85th Percentile Speed of Passenger Vehicles Upstream and Downstream of DMS

3.3.2.2 Trucks

Figure 3-8 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.

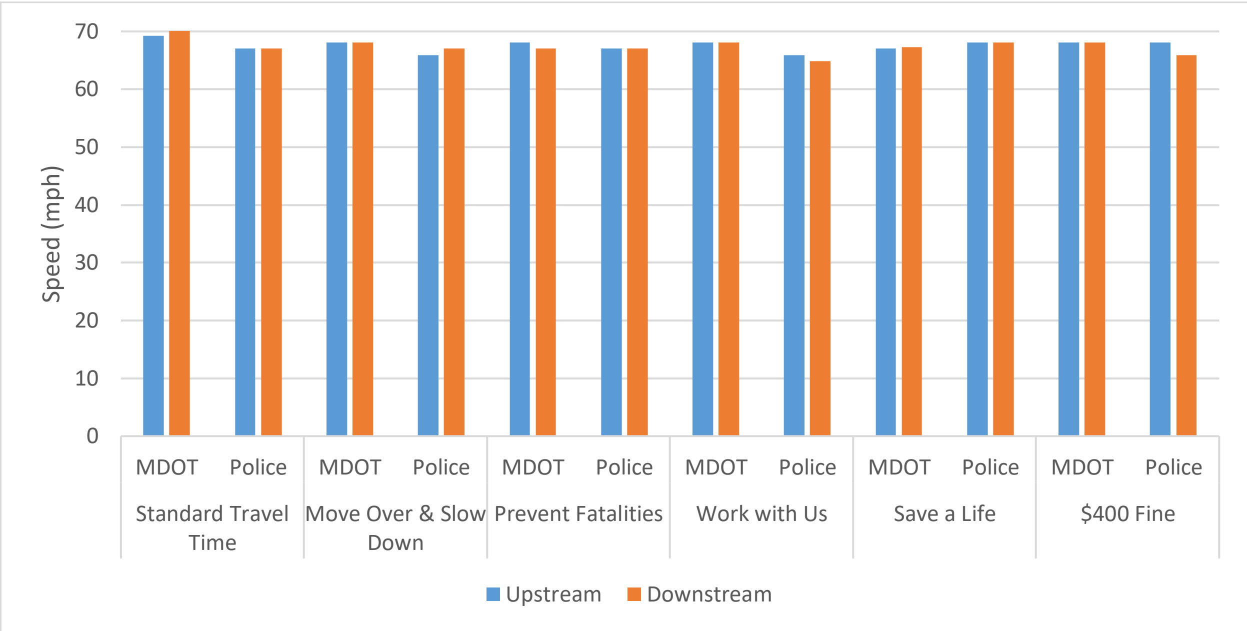


Figure 3-8 85th Percentile Speed of Trucks Upstream and Downstream of DMS

3.3.3 Standard Deviation of Speed

3.3.3.1 Passenger Vehicles

Figure 3-9 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.

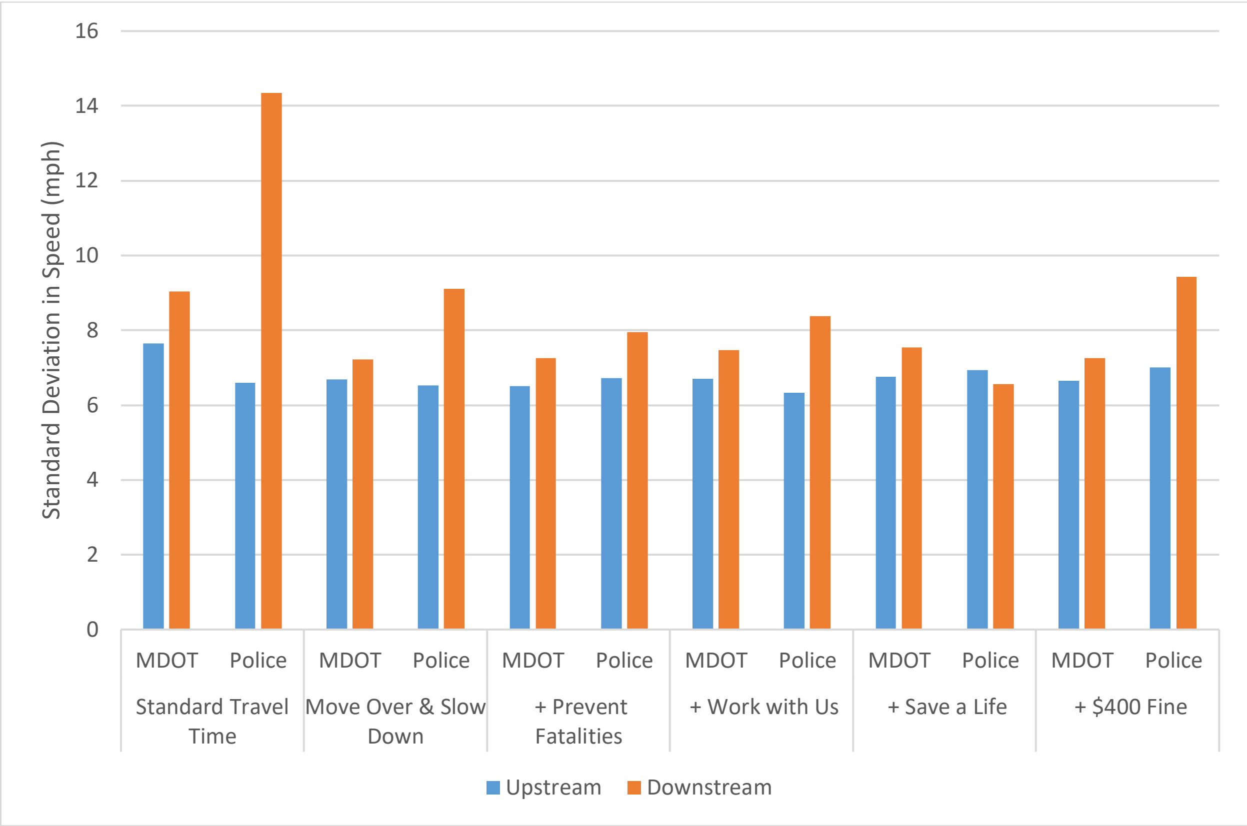


Figure 3-9 Standard Deviation of Passenger Vehicle Speeds Upstream and Downstream of DMS

3.3.3.2 Trucks

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 3-10. 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).

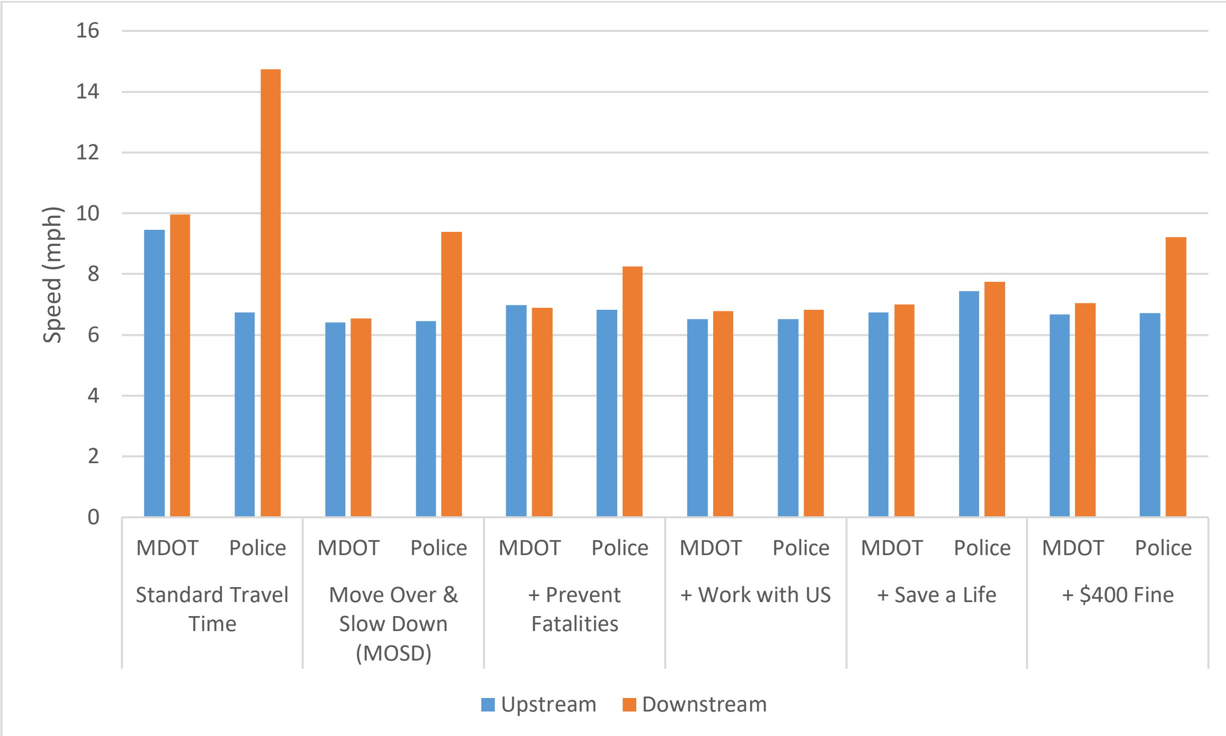
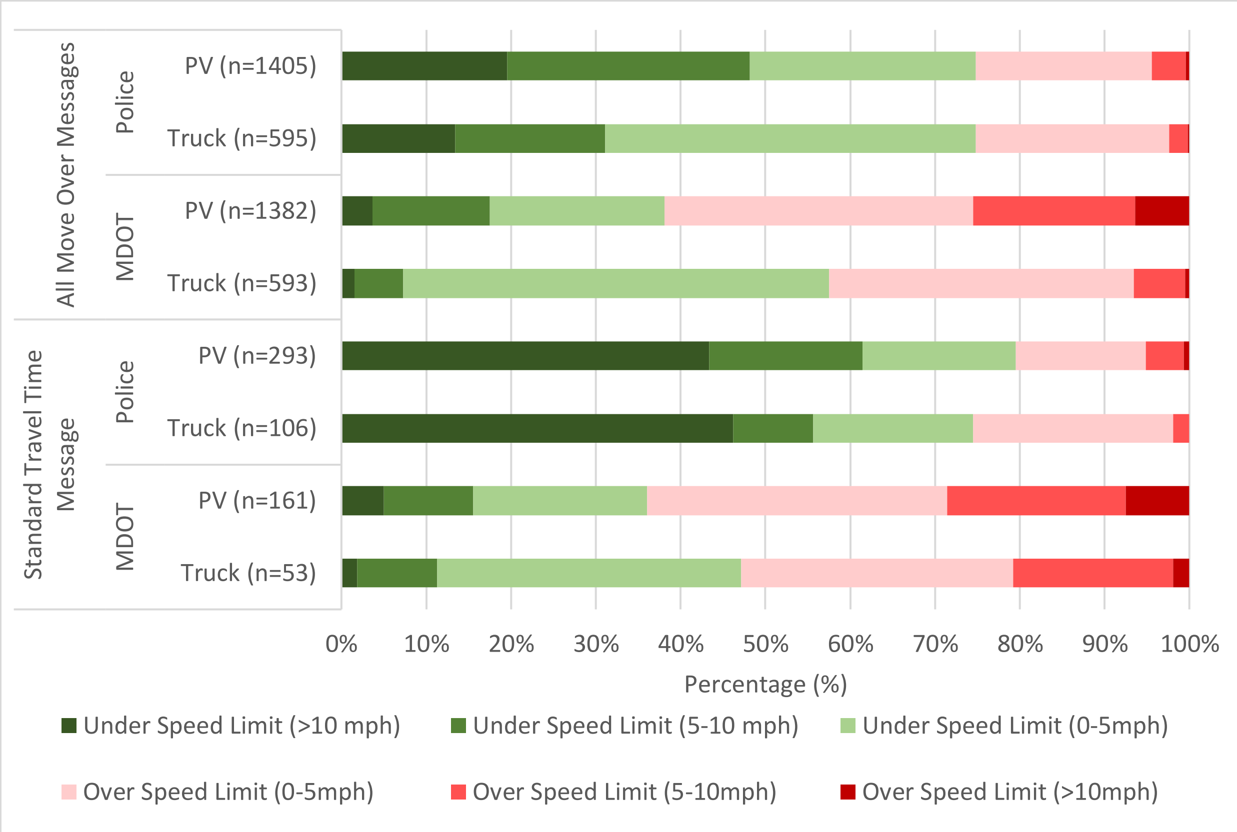


Figure 3-10 Standard Deviation of Speed of Trucks at Upstream and Downstream of DMS

3.3.4 Speed Relative to Speed Limit

Figure 3-11 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.



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

Figure 3-11 Vehicles Driving Over or Under the Speed Limit by Type of Messages and Service Vehicles

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.

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 3-11. 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.

3.3.5 Vehicle Lateral Position

3.3.5.1 Passenger Vehicles

Figure 3-12 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 increases 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 halfway 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.

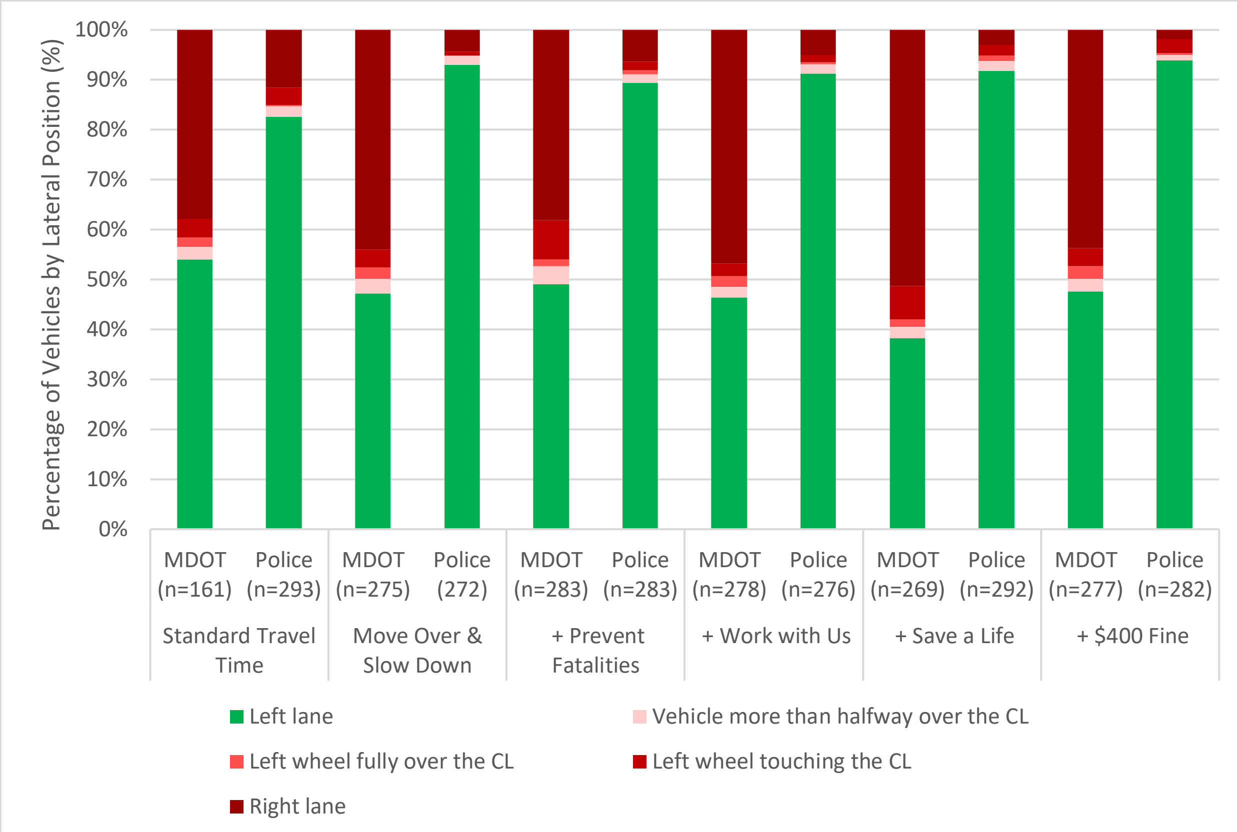


Figure 3-12 Percentage of Downstream Passenger Vehicle Lateral Position by Type of Service Vehicle

3.3.5.2 Trucks

Figure 3-13 demonstrates the position of trucks when passing the MDOT or police vehicles on the shoulder. Like the passenger vehicle from Figure 3-12, 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.

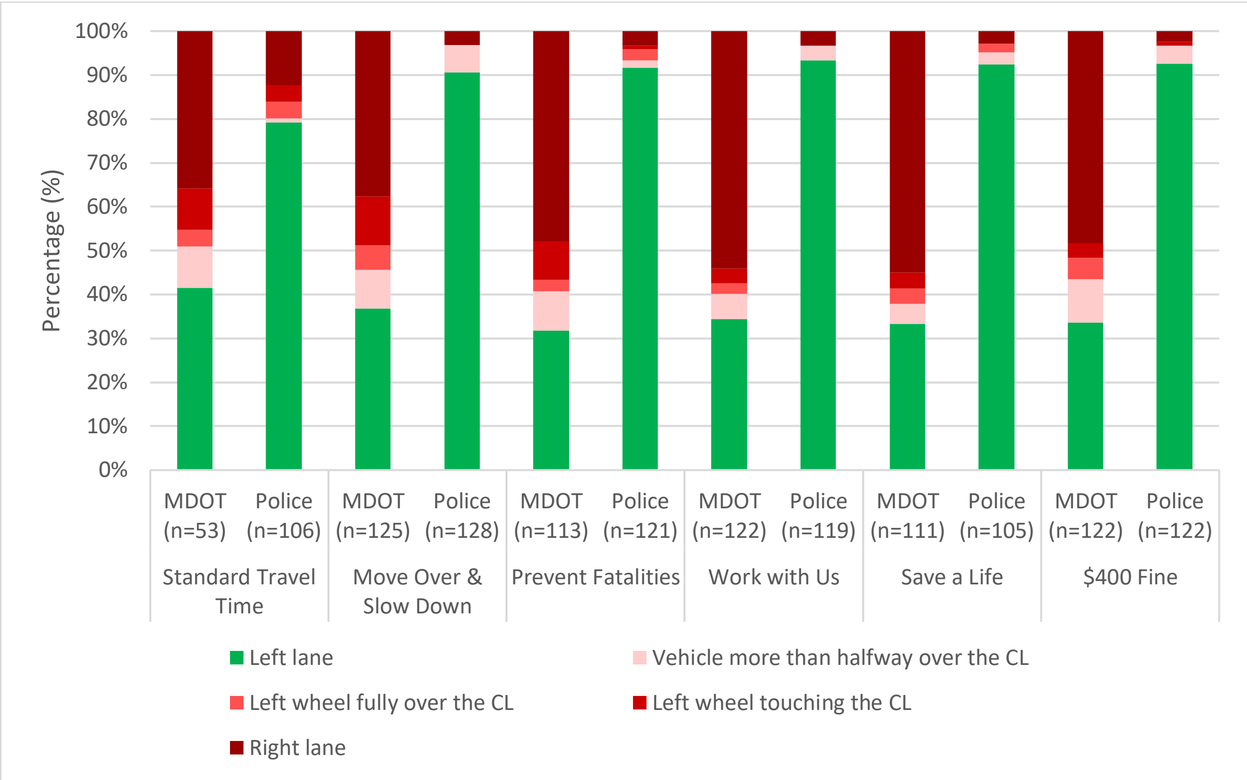


Figure 3-13 Percentage of Downstream Truck Lateral Position by Type of Service Vehicle

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.

3.4 Statistical Methodology

Several aspects related to driving behavior, including speed and lane positions, were analyzed in this study. The effectiveness of DMS displays of MOSD 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.

3.4.1 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:

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \tag{4.1}$$

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. The individual speed of vehicles at the downstream of the DMS were analyzed using this model.

3.4.2 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:

$$Y_i = logit(P_i)ln\left[\frac{P_i}{1-P_i}\right] = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \tag{4.2}$$

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.

3.5 Results and Discussion

3.5.1 Vehicle Speeds Downstream of DMS

Estimation results for the random effects linear regression model for vehicle speed are shown in Table 3-4. 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 3-4, 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.

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.

Table 3-4 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

At the downstream location, speeds were reduced by 1.1 to 4.8 mph when a police car was located on the shoulder. All 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.

3.5.2 Speeding at Downstream Location

Unlike most 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 3-5 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.

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.

Table 3-5 Logistic Regression Results for Downstream Speeding

Variable	Estimate	Standard Error	P-Value	Odds Ratio
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	
Downstream Headway	0.009	0.004	0.024	
Not Speeding Upstream (Baseline)	-	-	-	-
Speeding Upstream	1.399	0.074	<0.001	4.053
I-96 Highway (Baseline)	-	-	-	-
M-6 Highway	1.160	0.109	<0.001	3.191
Police Vehicle on the Shoulder (Baseline)	-	-	-	-
MDOT Vehicle on the Shoulder	1.404	0.073	<0.001	4.073
Passenger Vehicle (Baseline)	-	-	-	-
Single Unit/Heavy Trucks	-0.102	0.136	0.453	0.903
Tractor Trailer/Semi-Truck	0.045	0.090	0.616	1.046
Passenger Vehicle with Trailer	-0.649	0.233	0.005	0.523
Single Unit/Heavy Trucks with Trailer	-0.422	0.396	0.286	0.656
Standard Travel Time Message (Baseline)	-	-	-	-
MOSD Message	-0.412	0.150	0.006	0.662
MOSD Message + $400 Fine	-0.450	0.145	0.002	0.638
MOSD Message + Save a Life	-0.287	0.153	0.060	0.751
MOSD Message + Work with Us	-0.493	0.136	0.001	0.611
MOSD Message + Prevent Fatalities	-0.318	0.138	0.021	0.728

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 3-9 and Figure 3-10), 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.

3.5.3 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 3-12 and Figure 3-13 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 3-6, 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.

Table 3-6 Logistic Regression Results for Move Over Lane Compliance

Variable	Estimate	Standard Error	P-Value	Odds Ratio
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	0.385
Police Vehicle on the Shoulder (Baseline)	-	-	-	-
MDOT Vehicle on the Shoulder	-2.635	0.090	<0.001	0.072
Passenger Vehicle (Baseline)	-	-	-	-
Single Unit/Heavy Trucks	-0.412	0.146	0.005	0.662
Tractor Trailer/Semi-Truck	-0.462	0.095	<0.001	0.630
Passenger Vehicle with Trailer	-0.543	0.224	0.015	0.581
Single Unit/Heavy Trucks with Trailer	-1.108	0.388	0.004	0.330
Standard Travel Time Message (Baseline)	-	-	-	-
MOSD Message	-0.027	0.171	0.874	0.973
MOSD Message + $400 Fine	0.033	0.165	0.844	1.033
MOSD Message + Save a Life	-0.356	0.170	0.037	0.700
MOSD Message + Work with Us	0.047	0.150	0.756	1.048
MOSD Message + Prevent Fatalities	-0.100	0.154	0.515	0.905

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.

3.6 Summary

This study evaluates drive compliance with a move-over and slow down law in consideration of vehicle type and messages displayed on upstream dynamic message signs. Two type of vehicles were staged for the data collection, a police vehicle representing emergency vehicles, and an MDOT pick up truck representing service vehicle. Five variation of move-over messages were displayed on DMS upstream of the staged vehicles. Three models were developed based on two locations where move over data were collected; linear regression model for average vehicle speeds downstream of DMS, logistic regression for downstream speeding, and logistic regression for move over lane compliance.

The findings from the study revealed that compliance with the law, both in terms of speed reduction and move-over behavior, was markedly higher when the police vehicles was parked on the shoulder 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.

CHAPTER 4:EXAMINING ENFORCEMENT AND DYNAMIC MESSAGE SIGN MESSAGING CAMPAIGN ON REDUCING CELL PHONE RELATED DISTRACTED DRIVING

This study aims to assess how the combination of cell phone-focused enforcement activities and the use of targeted safety messages on DMS affect cell phone use while driving. The effects of location type, time of day, driver age, presence of enforcement activity, and type of safety message were studied in two urban areas of Michigan. The results of this study can assist road agencies in better coordinating distracted driving advocacy efforts through evidence-based interventions, in addition to highlighting other areas that warrant further investigation through subsequent research.

4.1 Study Design

Figure 4-1 provides an overview of the study design and the sequence of program activities. Ultimately, data were collected across three time periods, including before, during, and after the enforcement activity. This allowed for an assessment of differences in the rates of distracted driving as they related to the presence of enforcement activities, the utilization of DMS messages, and the combination of these two effects.

The enforcement campaign was conducted in two phases during October 2020 and April 2021. It is important to note that these months coincided with the NSC Distracted Driving Awareness Months during both calendar years. Traditionally, this campaign occurs in April, but the 2020 event was delayed due to the COVID-19 pandemic. Consequently, the enforcement campaigns and use of DMS signs were supplemented through earned media. Press events, news reports, and articles associated with distracted driving were tracked on news sites and social media accounts of relevant agencies in Michigan. For example, the Michigan Office of Highway Safety Planning (OHSP) Twitter account recorded a six-fold increase in distracted driving messages during the campaign months. Similarly, the Michigan State Police Twitter account recorded 10 and 21 distracted driving tweets in October 2020 and April 2021, respectively (no distracted driving related tweets were recorded in other months). This is consistent with a broader review of media records, which showed greater media on distracted driving coverage in April 2021 compared to October 2020.

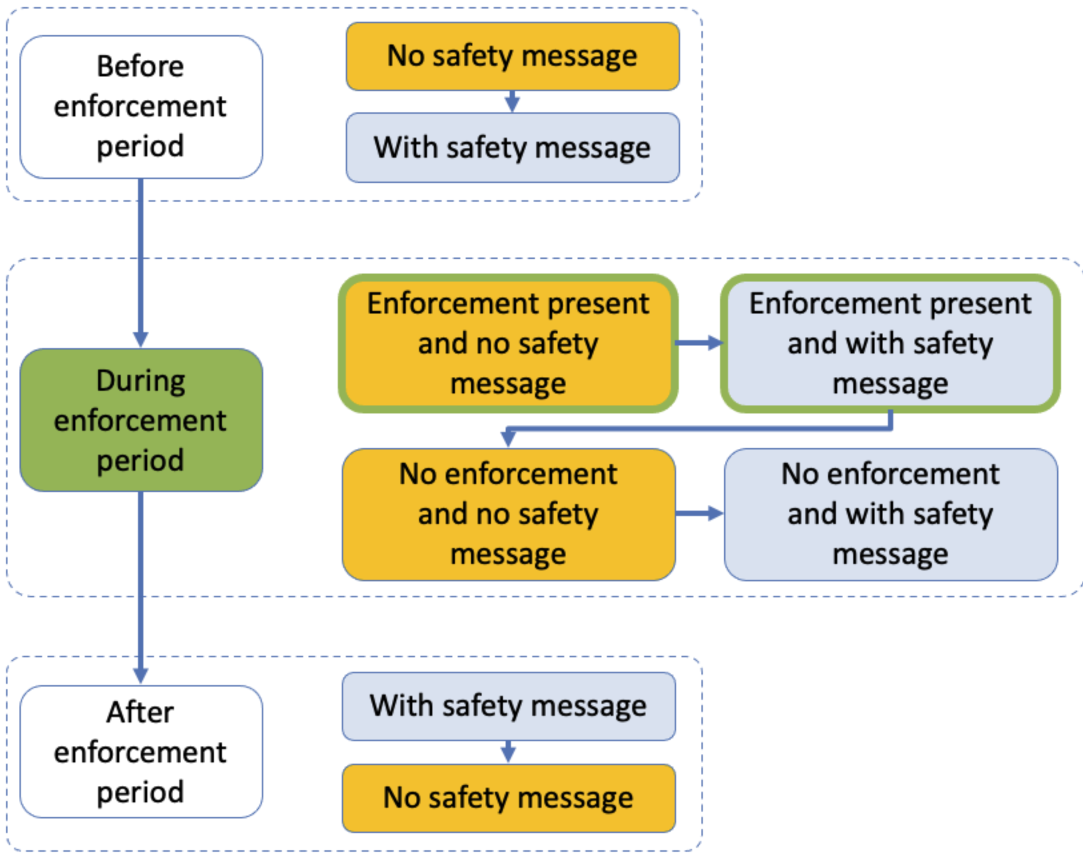


Figure 4-1 Overview of Study Design

At the onset of the study, two weeks of data collection were conducted before the commencement of the enforcement activity. During the first week of data collection, the dynamic message signs (DMS) displayed a default travel time or generic safety message (e.g., annual fatality statistics). This provided data to quantify the baseline level of distraction prior to campaign implementation. During the second week, these default messages were replaced by a series of four targeted messages focused on distracted driving. This allowed for a comparison of any differences in use rates that may be related to the type of DMS messages.

The messages that were displayed on the DMS during the campaign were selected from a list of cell phone related messages that had been used historically by the Michigan Department of Transportation. These messages were chosen to stimulate different emotions (i.e., positive, negative, or neutral) and to imply different consequences that drivers would face if they were stopped for using their cell phone while driving. These consequences were either punitive in nature (e.g., ticket or fine) or spoke to personal consequences (e.g., life and death). Table 4-1 provides details of the four safety messages that were displayed during the study period in consideration of these emotions and consequences. Figure 4-2 shows one of the DMS displaying selected cell phone use message during the study period.

Table 4-1 Cell Phone Use Related Messages

Message	**Emotion**	**Consequence**
Arrive Alive Don't Text And Drive	Positive	Punitive and personal
Avoid Cell Phone Use While Driving	Neutral	None
Stop The Texts Stop The Wrecks	Negative	Personal
U Text U Drive U Pay	Negative	Punitive and personal

Enforcement was conducted over the subsequent four-week period, during which these default and targeted messages were alternated across the various DMS. This allowed for an assessment of any potential synergistic effects between enforcement and messaging strategies. During the post-enforcement periods, data collection time varied between one and three weeks depending on the enforcement phase and locality. Table 4-2 provides details of the data collection periods based on the phase of enforcement and the locality in which the program was conducted.

After the enforcement period had concluded, additional data were collected over the subsequent two-week period. This included one week during which the targeted safety messages continued to be displayed, as well as a final week where the DMS reverted to the default (i.e., non-distraction related) messages. Due to scheduling constraints, post-enforcement data were only collected during the first post-enforcement week in the metro Detroit area.

Figure 4-2 Safety Message Displayed on DMS

Table 4-2 Details of Data Collection Period

Enforcement Phase	Locality	Study Period (Relative to Enforcement)	Dates
October 2020	Kent County	Before	09/21/2020 – 10/01/2020
		During	10/05/2020 – 10/30/2020
		After	11/04/2020 – 11/17/2020
	Metro Detroit	Before	09/18/2020 – 09/24/2020
		During	10/05/2020 – 10/30/2020
		After	11/03/2020 – 11/03/2020
April 2021	Kent County	Before	03/25/2021 – 04/01/2021
		During	04/05/2021 – 04/26/2021
		After	05/03/2021 – 05/10/2021
	Metro Detroit	Before	03/25/2021 – 04/01/2021
		During	04/05/2021 – 04/26/2021
		After	05/03/2021 – 05/10/2021

4.2 Site Selection

The Michigan OHSP coordinated enforcement activities, which included a mix of state police and local law enforcement in Kent County and the Detroit metropolitan area. A total of eight agencies participated, with more than 75 location-dates of distracted driving enforcement over both phases. Enforcement was conducted at two general facility types, limited access freeways and surface collector roads. Law enforcement agencies selected locations that were well suited for enforcement activity, with emphases on high-volume roads near to major cross-streets. This information was then used in combination with DMS location information provided by the Michigan Department of Transportation (MDOT), as well as several databases from the Michigan GIS Open Data (e.g., road network, city limit, and county databases). These sources were used to select appropriate locations for the distracted driving data collection. The roads selected for enforcement activity were first identified using GIS software. The DMS database was then overlaid on top of the road network to determine the DMS closest to each road segment. Sites with no DMS near the road segments were removed from the list. For freeway sites, the exit ramp immediately downstream of the DMS (i.e., the intersection between the exit ramp and the crossroad) were selected as data collection location. On collector roads, data were collected as close as possible to the nearest exit ramps as virtually all DMS are located on freeways. Other aspects were also considered when selecting the data collection locations, including adequately high levels of traffic volume, sufficient space to safely stand and collect data on the side of the road, and availability of parking near the site.

Finally, 28 locations were selected for the October 2020 enforcement, with 20 from Kent County and eight from metro Detroit. The Kent County enforcement was conducted by the Grand Rapids Police Department, Kent County Sheriff's Office, Wyoming Department of Public Safety, and MSP Rockford Post. The metro Detroit enforcement involved the MSP 2nd District and the Wayne County Sheriff's Office. Among the 20 locations in Kent County, five of those did not have enforcement present. Meanwhile, for the April 2021 enforcement, 20 sites were selected, with 13 from Kent County and seven from the metro Detroit area.

4.3 Data Collection

Data were collected during one-hour intervals at most sites by a single observer per site. However, some sites with higher traffic volumes involved two observers over a period of 30 minutes. These scenarios generally yielded similar numbers of observations (i.e., on average 170 vehicles/hour/data collector). The observers positioned themselves such that they were inconspicuous to approaching drivers to the extent possible. Observers would stand on the side of the road at 50 to 150 feet upstream of the intersection, where they had an unobstructed view of approaching traffic. Data were recorded from passenger vehicles provided the observers could clearly determine cell phone use and other data collection elements. To reduce variability within and across observers, a two-week training period was conducted prior to the launch of full-scale data collection. This included classroom training, as well as field practice that was conducted in small groups to assess consistency. The subsequent statistical analysis also included a random effect to capture any observer-specific differences in use rates and other variables of interest.

The data were collected using a form developed specifically for this study. The pertinent fields included passenger vehicle type (i.e., van, pickup truck, sedan, sports utility vehicle), demographic characteristics of the driver (i.e., age, race, and gender), whether a passenger was present, whether the driver was belted, and whether the driver was engaged in any type of distracting behavior. Distractions were classified into five discrete categories: cell phone-talking, cell phone-typing, other distractions (e.g., smoking, drinking, reading), no distraction, and unknown. Additional site-specific information was also collected, which included weather conditions (i.e., clear, light rain, and fog), the number of lanes (i.e., at and before the intersection), and the type of study location (i.e., exit ramp or surface street intersection). Ultimately, these data were converted into spreadsheet format for analysis purposes.

4.4 Data Summary

Table 4-3 shows a summary of the enforcement reports by enforcement phase and locality. Over the course of the entire campaign, more than 1400 traffic stops were conducted. These stops resulted in 308 citations, with the most frequent citations involving texting (42.2 percent). A small number of citations were also issued to young drivers who were in the graduated driver's license (GDL) program, as well as to adults who were talking or otherwise manually operating a cell phone. While these latter offenses are not explicitly prohibited, drivers can be stopped and cited if these activities are judged to be reckless by the officer.

Table 4-3 Enforcement Reports based on Enforcement Phase and Locality

Enforcement Phase	**Area**	**Enforcement Hour**	**Count**					
			Traffic Stops	**Texting Citations**	**GDL 1 or 2 using Cell Phone**	**Talking Hands-Free***	**Talking Hand-Held***	**Manual Operation of Cell Phone***
October 2020	Metro Detroit	261	443	50	14	13	23	33
	Kent County	205	274	8	0	3	4	14
April 2021	Metro Detroit	186	309	63	0	4	4	37
	Kent County	262	395	9	1	0	7	21

Note: GDL = graduate driver licensing; GDL 1 = supervised learner's license; GDL 2 = intermediate license with limited passengers and nighttime driving; * = may not have resulted in citation

Table 4-4 shows the descriptive statistics of the data collected for both phases. In total, 108,372 observations were recorded, with 60 percent from the October 2020 enforcement, and 40 percent during the April 2021 enforcement. Approximately one-third of the data were collected during each of the before, during, and after periods during both phases of the program. In terms of the locality, most of the data came from Kent County, which comprised more than 65 percent of the data.

Approximately 14 percent of the drivers were engaged in some sort of observable distraction over the course of the study period. Across the sample, five percent of drivers were found to be typing or manually manipulating their cell phones, four percent were talking on their handheld phone, and five percent were engaged in some other type of distraction. These rates are significantly higher than what is reported in police crash reports, which suggest only 5.8 percent of all crashes involved a distracted driver and less than one percent were related to cell phone use (Michigan Traffic Crash Facts, n.d.). This points the degree to which distraction-related crashes tend to be underreported (Hanley & Sikka, 2012).

The drivers' demographic information is also shown in Table 4-4. Most of the observations were among drivers ages 30 to 59 (61 percent). The driving distribution tends to skew disproportionately towards males, where male drivers comprised 58 percent of the sample. The data also showed that more than 97 percent of drivers were belted, and 17 percent of drivers had at least one passenger in their vehicle. In terms of data collected by location, 27 percent of the observations were recorded at exit ramps (compared to intersections). Default messages (i.e., non-distraction-related) were displayed 29 percent of the time across the sample while the targeted safety messages ranged from 16 to 20 percent of the sample.

Table 4-4 Descriptive Statistics (108,372 Observations)

Variable		Mean	Standard Deviation
Enforcement Phase	October 2020 enforcement	0.60	0.49
	April 2021 enforcement	0.40	0.49
Enforcement Period	Before enforcement week	0.34	0.47
	During enforcement week	0.34	0.47
	After enforcement week	0.32	0.47
Locality	Wayne County	0.35	0.48
	Kent County	0.65	0.48
Type of Distraction	Cell phone – talking	0.04	0.19
	Cell phone - typing	0.05	0.22
	Other distractions	0.05	0.22
	No distraction	0.86	0.35
	Unknown distraction	0.00	0.06
Driver's Age	Age between 16 and 29	0.26	0.44
	Age between 30 and 59	0.61	0.49
	Age above 60	0.13	0.33
	Unknown Age	0.00	0.07
Driver's Gender	Male	0.58	0.49
	Female	0.41	0.49
	Unknown gender	0.01	0.08
Driver's Race	White	0.74	0.44
	African American	0.18	0.38
	Others	0.07	0.25
	Unknown Race	0.01	0.09
Seat Belt Use	Belted	0.97	0.18
	Unbelted	0.01	0.12
	Unknown belted	0.02	0.14
Passenger present	Yes	0.17	0.38
	No	0.83	0.38
Weather Condition	Clear	0.88	0.33
	Fog	0.01	0.11
	Rain	0.11	0.32
Location Type	Exit ramp	0.27	0.44
	Surface street	0.73	0.44
Message Displayed on DMS	Arrive Alive Don't Text and Drive	0.16	0.37
	Avoid Cell Phone Use While Driving	0.18	0.38
	Stop The Texts Stop The Wrecks	0.20	0.40
	U Text U Drive U Pay	0.17	0.38
	Default Messages (Not Distraction Related)	0.29	0.45

4.5 Statistical Methodology

To better understand the relationship between the rate of driver distraction and the presence of enforcement and/or safety messages, a logistic regression model was estimated for cell phone-related distractions (i.e., cell phone-typing or cell phone-talking). The response variable was coded as one in cases where the driver was engaged in cell phone use and zero otherwise. Given the dichotomous nature of the response variable, the data are well suited for analysis through logistic regression. Within the context of this study, the model takes the following form (Equation 3):

$$Y_i = logit(P_i) = ln\left(\frac{P_i}{1-P_i}\right) = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k, \quad (3)$$

$k = 1,2,3,\ldots,K$

where P_i is the probability of driver *i* being engaged in a cell phone-related distraction, X_1 to X_k are a series of predictor variables that are associated with driver distraction (e.g., enforcement presence, use of targeted safety messages, demographic background of drivers, site characteristics, etc.), and β_1 to β_k are a series of estimable parameters.

There are several important methodological concerns as they related to the analysis of these data. First, data were collected over multiple time periods at the same set of sites over the two phases of the program, as well as across the three study periods within each phase. This gives rise to concerns as to correlation due to important, unobserved factors that are unique to each site and cannot be explicitly incorporated into the model (e.g., land use, geometric characteristics). Similarly, there were several observers who conducted repeated measurements within and across locations. Correlation may be expected within observers. For example, some individuals may show systemic differences in use rates or demographic characteristics as compared to other observers. Failure to account for these types of correlations may lead to biased or inefficient parameter estimates. To accommodate this concern, a two-way random effects framework was employed as shown in Equation 4:

$$Y_{ijl} = logit(P_{ijl}) = ln\left(\frac{P_{ijl}}{1 - P_{ijl}}\right) = \beta_o + \beta_1 X_{1jl} + \beta_2 X_{2jl} + \cdots + \beta_k X_{kjl} + u_j + v_l \tag{4}$$

$$u_j \sim N(0, \sigma_u^2); \; v_l \sim N(0, \sigma_v^2)$$

$$j = 1, 2, 3, \ldots, J; \; l = 1, 2, 3, \ldots, L$$

where P_{ijl} is the probability of driver i being engaged in cell phone-related distractions at site j by observer l. The term u_j and v_l are the random effects that capture the unobserved site- and observer-level effects, respectively. These two terms allow the constant term to vary across the sites and observers. The model is estimated using the 'lme4' package in R software (Bates et al., 2021).

4.6 Results and Discussion

After removing cases where any variables of interest were missing or unknown, the final sample size was reduced from 108,372 to 106,668 observations. The results of the two-way random effects logistic regression model for cell phone use are shown in Table 4-5. These results include parameter estimates, along with the associated standard errors, t-statistics, and p-values. Odds ratios are also provided for each parameter. All the predictor variables are discrete in nature and, as such, one category for each variable was excluded from the model and serves as the baseline to which the other categories are compared. For example, young drivers (ages 29 and below) serve as the baseline to which middle aged (ages 30 to 59) and older (ages 60 and above) are compared. When interpreting the results, a positive parameter estimate (and odds ratio greater than one) indicates that the driver was more likely to be distracted under that specific condition or setting as compared to the baseline condition/setting. In contrast, a negative parameter estimate (and odds ratio less than one) is associated with lower rates of cell phone use. As noted previously, the site number and observer identification number were both treated as random effects.

Table 4-5 Two-Level Random Effects Logistic Regression Model Results

Variable	Parameter Estimate	Standard Error	t-stat	p-value	Odds Ratio
Intercept	-1.729	0.109	-15.918	<0.001	0.177
(Baseline: Before enforcement week no SM)	-	-	-	-	-
Before enforcement & SM 1	-0.031	0.060	-0.526	0.599	0.969
Before enforcement & SM 2	-0.087	0.058	-1.498	0.134	0.917
Before enforcement & SM 3	-0.179	0.058	-3.075	0.002	0.836
Before enforcement & SM 4	-0.089	0.059	-1.526	0.127	0.915
During enforcement & no SM	-0.143	0.050	-2.837	0.005	0.867
During enforcement & SM 1	-0.227	0.070	-3.228	0.001	0.797
During enforcement & SM 2	-0.186	0.066	-2.834	0.005	0.830
During enforcement & SM 3	-0.198	0.066	-2.990	0.003	0.820
During enforcement & SM 4	-0.102	0.065	-1.560	0.119	0.903
One week after enforcement & SM 1	-0.275	0.063	-4.346	<0.001	0.760
One week after enforcement & SM 2	-0.285	0.068	-4.170	<0.001	0.752
One week after enforcement & SM 3	-0.272	0.059	-4.626	<0.001	0.762
One week after enforcement & SM 4	-0.298	0.063	-4.726	<0.001	0.742
Two weeks after enforcement & No SM	-0.358	0.060	-5.938	<0.001	0.699
(Baseline: Age below 30)	-	-	-	-	-
Age: 30 - 59	-0.376	0.024	-15.780	<0.001	0.687
Age: 60 and above	-1.497	0.056	-26.662	<0.001	0.224
Gender: Male *(Baseline: Female)*	-0.020	0.022	-0.888	0.375	0.980
(Baseline: Caucasian)	-	-	-	-	-
Race: African American	0.348	0.028	12.454	<0.001	1.416
Race: Others	0.220	0.040	5.440	<0.001	1.246
Exit ramp *(Baseline: Intersection)*	-0.180	0.049	-3.670	<0.001	0.835
Metro Detroit *(Baseline: Kent County)*	0.029	0.050	0.577	0.564	1.029
October 2020 *(Baseline: April 2021)*	0.097	0.027	3.592	<0.001	1.102
Passenger present *(Baseline: No passenger)*	-1.028	0.041	-25.188	<0.001	0.358
(Baseline: Time of day: 8 am to 12pm)	-	-	-	-	-
Time of day: 10am to 12pm	-0.031	0.034	-0.908	0.364	0.969
Time of day: 12pm to 2pm	-0.040	0.035	-1.142	0.253	0.961
Time of day: 2pm to 4pm	-0.065	0.041	-1.576	0.115	0.937

SM 1 = Arrive Alive Don't Text and Drive; SM 2 = Avoid Cell Phone Use While Driving;
SM 3 = Stop the Texts Stop the Wrecks; SM 4 = U Text U Drive U Pay; No SM = No Safety Message

4.6.1 <u>Enforcement Period and Type of Message</u>

Turning to the primary results of interest, the rate of cell phone use was highest prior to enforcement during the first week when no targeted safety message was displayed. (This is the baseline condition in the analysis.) Figure 4-3 provides a graphical comparison of the odds ratios (OR) for each safety message/enforcement period combination, along with the associated 95-percent confidence intervals. For context, an odds ratio of 1.0 represents the rate of distracted driving that was exhibited during the pre-enforcement period when these default messages were displayed on the roadside DMS.

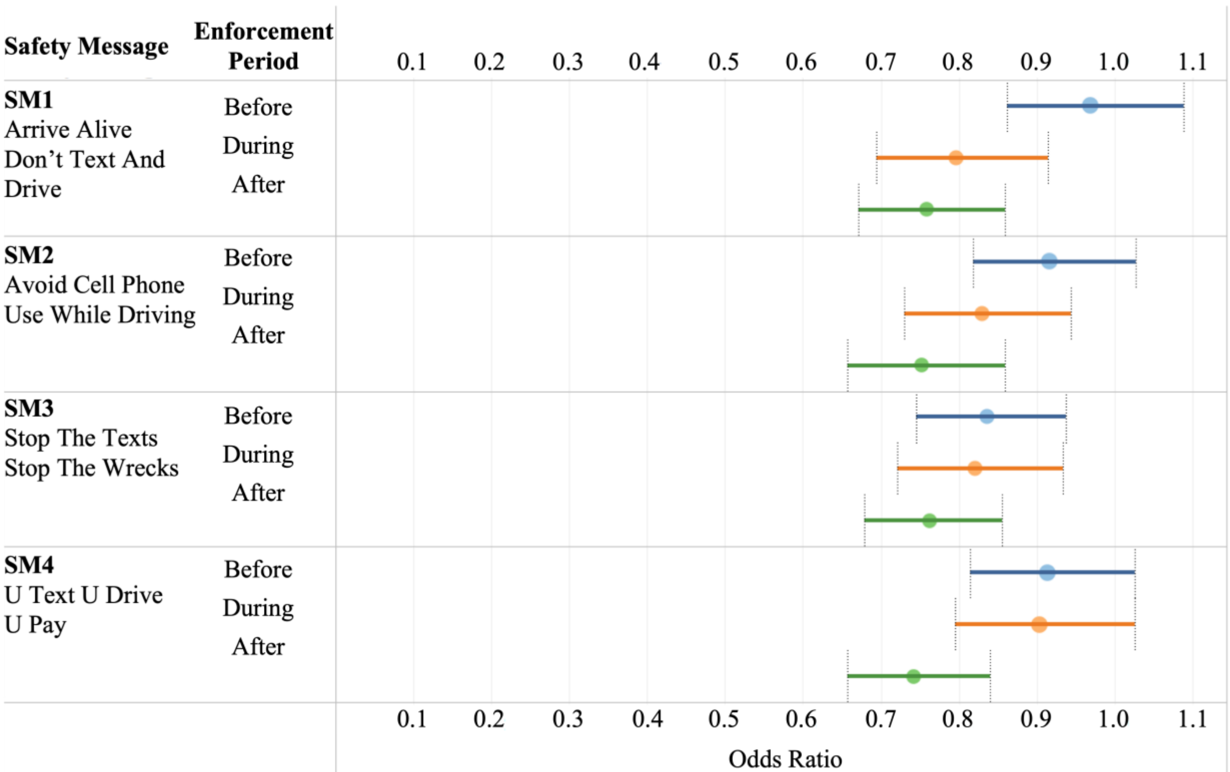


Figure 4-3 Odds Ratios and 95-Percent Confidence Intervals for Driver Cell Phone Use Rates by Study Period and Type of Safety Message

Starting with the type of safety message, the results show that when any of the cell phone specific safety messages were displayed, the odds of use decreased by 4 to 16 percent. At an aggregate level, this reduction is statistically significant, though no consistent trends were observed with respect to any of the four types of targeted messages.

The results show that cell phone use persistently decreased from the before enforcement period, through the during enforcement period, and, subsequently, to the post-enforcement period. This is true for each of the individual safety messages, though again there is not a consistent pattern in terms of which messages were associated with higher or lower use rates overall.

Interestingly, the results show that all rates were significantly lower during the post-enforcement period, with odds ratios ranging from 0.74 to 0.76. However, the results again do not indicate any observable pattern with respect to the specific messages that were displayed on the roadside DMS. Furthermore, the rates were actually lowest two weeks after the enforcement program had concluded when only the generic default messages were displayed. Collectively, these results appear to suggest the program may have sustained effects that last beyond the duration of the actual enforcement activity.

4.6.2 Age Group

Cell phones use rates were also found to vary across demographic groups. For example, the odds of cell phone-based distractions were 31.3 percent lower among those ages 30 to 59 and 77.6 percent lower among those ages 60 and above when compared to the youngest (ages 29 and below) age group. This result supports various prior studies where younger drivers showed significantly higher rates of cell phone use when compared to older age groups (Atchley et al., 2011; Foss & Goodwin, 2014; Rudisill & Zhu, 2015). Additionally, 14 traffic stops during the enforcement phase involved younger drivers with graduate driver licenses, which suggests this youngest group is particularly susceptible to violating Michigan's existing cell phone use law. It is interesting to note that, despite the higher use rates, prior research has shown that the risk of crash involvement among the oldest age groups is almost four times higher when using cell phones, than when cell phones were not in use (Huisingh et al., 2019). Consequently, even these lower use rates among older drivers represent an important public safety concern.

4.6.3 Gender

Gender comparison for cell phone distraction revealed male drivers were less distracted by cell phone use while driving than female drivers. Although the results were not statistically significant (p=0.375), previous studies using roadside observation of handheld use of cell phones also found that female drivers were more likely to be observed using cell phones while driving compared to male drivers (Rudisill & Zhu, 2017; Fakhrmoosavi et al., 2020; Jeihani et al., 2019). Studies have also indicated differing behavior towards the type of distraction between genders. While male participants were significantly less distracted with text messaging compared to female drivers in a simulator-based study in Maryland, external distractions were significantly higher among males compared to females (Jeihani et al., 2019).

4.6.4 Race

Turning to race, African American drivers were more likely to be engaged in cell phone distraction compared to other race categories. The odds of cell phone use among African Americans was 1.42 times higher than white drivers. Other (non-white) races were also more likely to use cell phones (OR = 1.25) while driving. Rudisill and Zhu had also observed higher use of cell phones in a roadside observation among African American drivers (Rudisill & Zhu, 2017). However, in their earlier study among teenage drivers (9th to 12th graders), African Americans and Latinos appeared to text and drive considerably less than white non-Hispanics (Rudisill & Zhu, 2015).

4.6.5 Locality

In terms of the locality, the metro Detroit area experienced slightly higher levels of distraction compared to Kent County, although this difference was not statistically significant. Although based on the enforcement data, the Detroit area showed higher rates of texting citations per every hour of enforcement for both phases. In addition, the number of traffic stops due to cell phone-talking using hand-held and hands-free, and manually operating a cell phone were also higher in metro Detroit.

4.6.6 Study Period

Interestingly, cell phones use was significantly higher during the October 2020 data collection period than during April 2021. This finding may be attributable, at least in part, to the COVID-19 pandemic. An analysis of police-reported crash data showed that the frequency of fatal traffic crashes and associated high-risk behaviors, such as speeding and non-use of seatbelts, was markedly higher in 2020 as compared to prior years (Michigan Traffic Crash Facts, n.d.). As noted previously, the pandemic also resulted in both October 2020 and April 2021 being designated as Distracted Driving Awareness Month by the NSC. However, when comparing online earned media presence, there was significantly less coverage of the distracted driving campaign in October 2020 as compared to April 2021. In hindsight, COVID-19 restrictions in Michigan were lessened gradually beginning early 2021 (Boucher et al., 2021), so it is likely that the driving populations that were observed may have been substantively different between the two phases of the program (Michigan Executive Order No. 2020-192, 2020). The average number of trips per day from October 2020 to April 2021 increased by 38 percent and 40 percent for Wayne and Kent County respectively. Additionally, a study on risk attitude and human mobility during the COVID-19 pandemic revealed that risk-adverse attitudes are more likely to adjust behavioral activity (Chan et al., 2020). Another study on the impact of COVID-19 on road safety found that although the majority of the respondents did not indicate behavior change pre and during the pandemic, a notable proportion indicated that they were likely to engage in more risky driving behaviors during the pandemic, including the use of cell phone while driving (Vanlaar et al., 2021). In relation, Sween et al. found that frequency of text messaging use was greatly associated with greater risk-taking behaviors (Sween et al., 2017).

4.6.7 Roadway Type

Use rates were also found to vary significantly based upon the type of roadway that was observed. The odds of cell phone related distractions among drivers at exit ramp was 17 percent lower when compared to intersections on surface streets. This finding is likely a reflection of several factors, including the familiarity of drivers with the road environment as surface streets are generally associated with shorter trips (e.g., to gas stations, shops, school) as compared to freeways. According to a study that leveraged a naturalistic driving study (NDS) data, distracted driving activities were more prevalent on familiar road as opposed to unfamiliar road (Wu & Xu, 2018).

4.6.8 Time of Day

In terms of time of day, drivers were more likely to be involved in cell phone distractions during early morning (i.e., 8:00 AM to 10:00 AM) when compared to other time periods. This effect diminishes over the course of the day, although the results were not statistically significant. A study by Goodwin et al. (Goodwin et al., 2012) showed similar trends where distracted driving activities decreased over the course of the day.

4.7 Summary

This study assesses the impact of enforcement and dynamic message sign messaging campaign on reducing cell phone related distractions using two-level random effects logistic regression model. The results showed that targeted enforcement activity did lead to reductions in the rate of cell phone use by drivers. The effect was more pronounced in the weeks after enforcement was completed. The findings indicate that the display of traffic safety messages on DMS related to cell phone use was associated with lower observance of drivers talking or typing/browsing on their cell phones during the enforcement period. However, in the after-enforcement period, use rates were lower regardless of what type of message was displayed.

CHAPTER 5: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. Field evaluations were conducted to evaluate immediate impacts of the signs on the behavior of motorists using two surrogate safety measures: 1) examining drive compliance with a move-over and slow down law in consideration of vehicle type and messages displayed on upstream dynamic message signs, and 2) examining enforcement and DMS messaging campaign on reducing cell phone related distracted driving. The documented findings presented in the preceding chapters can help contribute to enhancing traffic safety countermeasures.

5.1 Examining Drive Compliance with a Move-Over and Slow Down Law in Consideration of Vehicle Type and Messages Displayed on Upstream Dynamic Message Signs

5.1.1 Conclusion

This study provides important insights as to the efficacy of move-over laws using data from a staged field experiment. Move-over laws are intended to enhance the safety of road agency and law enforcement personnel who are working on or near the roadway. Revisions to the move-over law in Michigan now require drivers to move over if possible, and reduce their speeds, for both emergency (police, fire, and ambulance) and service (DOT, tow trucks, maintenance vehicles) vehicles.

This study examines driver behavior through a series of field studies where these types of vehicles are located on the outside shoulder of a freeway with their lights activated. The study also evaluates the use of upstream dynamic message sign (DMS) to discern whether targeted safety messages have any impact on behavior under this scenario. Upstream and downstream speed and lane position data are collected from vehicles originally traveling in the rightmost lane upstream of the DMS and emergency or service vehicle at two locations in Michigan.

Logistic regression models are estimated to assess driver compliance with the law while considering important contextual factors, such as the type of vehicle on the shoulder and the message displayed on the DMS. Ultimately, 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, & 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.

A few important limitations should be noted. First, this 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.

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. Thus, this aspect warrants careful consideration when implementing and enforcing move-over laws. The Michigan Office of Highway Safety Planning does indicate within their public dissemination information materials when move over is not possible due to traffic, weather, or road conditions. Drivers are advised to slow down 10mph below the posted speed limit and pass with caution allowing the authorized vehicle as much space as possible.

5.1.2 Recommendations and Future Research

Targeted enforcement or public awareness campaigns are warranted to improve driver knowledge of, and compliance with, the move-over law. Prior research has shown that some road safety campaigns had no independent effect by themselves, but are reinforced with the presence of enforcement, producing an interactive effect (Tay, 2005). Future research is also suggested to investigate compliance with different types and sizes of service vehicles (e.g., snowplows, large maintenance vehicles).

The study also provides some insights as to the efficacy of using of dynamic message signs to display traffic safety messages. However, there were minimal differences observed between travel time messages and targeted move-over/slow-down messages. The one exception was when considering vehicle speeds with respect to the posted limit, where the targeted messages provided improved behavior as compared to generic travel time messages. Additional research may consider the use of DMS as a potential measure to address other problem behaviors such as speeding and distracted driving.

5.2 Examining Enforcement and Dynamic Message Sign Messaging Campaign on Reducing Cell Phone Related Distracted Driving

5.2.1 Conclusion

Cell phone use has increased significantly in the United States and 97 percent of residents now own some type of cell phone. The ubiquity of cell phones has introduced concerns with respect to traffic safety as cell phone related distractions have been shown to affect driving ability and increase crash risk. Various countermeasures have been implemented to address this issue, including public outreach campaigns and targeted enforcement activities. However, the efficacy of such strategies has been the subject of limited research.

This study provides important insights into the efficacy of cell phone enforcement campaigns. In addition to targeted enforcement, this campaign leveraged media content associated with Distracted Driving Awareness Month, along with displaying strategic messages on roadside dynamic message signs (DMS). Ultimately, empirical evidence from this study shows that targeted enforcement did lead to reductions in the rate of cell phone use by drivers. While the enforcement was in effect, rates were reduced by 16 percent on average and these reductions increased to 25 percent in the weeks after enforcement was completed. As indicated by Tay, road safety campaigns accompanied by enforcement efforts can improve overall campaign effort (Tay, 2005). However, the no blanket ban on cell phone use while driving does pose difficulty in the enforcement of cell phone use. Drivers persist in using their cell phones while driving (Ortiz et al., 2018; Oviedo, 2018; Atchley et al., 2011), sometimes more precarious as they resort to hiding their use to avoid detection (Gauld et al., 2014). Similar instances were observed during data location when observers could view drivers from a higher angle; some drivers were found to continue using their cell phones below the dashboard or nearer to their laps while driving.

It was interesting to observe that cell phone use rates were significantly lower during the second phase of the enforcement campaign, which was conducted six months after the first phase. There are several potential explanations for this result, including a potential cumulative effect (i.e., lower user rates) over time, though it should be noted that rates of distraction rebounded somewhat prior to the second phase of the campaign (i.e., between the conclusion of the first phase and launch of the second phase). Traffic volumes were also generally higher during the second phase, and, with enhanced media coverage, it is possible that public information and outreach had further reach during this phase. A potential confounding factor relates to differences in the driving population between fall 2020 and spring 2021 because of the COVID-19 pandemic. In any case, further study is warranted to further investigate temporal effects and the degree to which reductions in cell phone use may be sustained over time.

The findings showed that displaying traffic safety messages on DMS was associated with marginally lower rates of cell phone use as compared to typical travel time messages during the enforcement period. However, in the after-enforcement period, use rates were lower regardless of what type of message was displayed. In fact, rates were lowest two weeks after the program had concluded and after all of the targeted messaging had ceased. It is important to note that it is uncertain how many drivers read and understood these messages. This is particularly true for sites that are located on collector roads since all DMS were installed on freeways. This may also explain, in part, why cell phone use rates were lower on traffic approaching from freeway exit ramps.

There are also a few important limitations to be aware of. First, these data were collected on exit ramps and the approach to other signalized and stop-controlled intersections. The data were collected upstream, but nonetheless, it is unclear how representative these data are of other areas of the transportation system. Next, although observers were trained in the observation techniques to reduce intra-observation variability, data such as drivers age, gender, and race may still be subjected to certain variability between different observers. Furthermore, while the data collectors recorded observations covertly at most of the locations, there may be locations where their presence may have had some impact on driver behavior and the resultant rates of distraction. Future study related to roadside observation may be conducted using video cameras to improve this limitation. Finally, it is unclear how many drivers were impacted by both the targeted enforcement, as well as the roadside messages and other media strategies that were leveraged. However, the results of this project serve as a promising model for similar programs to be implemented at other locations.

5.2.2 Recommendations and Future Research

This study also provides support for continuing discussions as to the use of DMS for displaying safety message. A January 2021 FHWA memorandum notes that safety messages should be of limited nature, in this case to coincide with targeted enforcement activity; coincide with national safety initiatives; and messages should be relevant to the roadway type (Kehrli, 2021).

Moving forward, addressing cell phone use while driving is likely to continue to be a challenge. Enforcing non-compliance with cell phone use laws is plagued by several challenges, including difficulties in identifying violations visually from the roadside. This is particularly true in states such as Michigan, where the only statewide laws ban texting while driving among all drivers, as well as all cell phone use by those on level 1 or level 2 in the graduated drivers licensing program. Given these factors, it would be interesting to consider how these results translate to other states, particularly those with full handheld phone bans.

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