Human Factors Evaluation of an In-Vehicle Active Traffic and Demand Management (ATDM) System

CVI UTC

CONNECTED VEHICLE/INFRASTRUCTURE UNIVERSITY TRANSPORTATION CENTER (CVI-UTC)

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The mission statement of the Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC) is to conduct research that will advance surface transportation through the application of innovative research and using connected-vehicle and infrastructure technologies to improve safety, state of good repair, economic competitiveness, livable communities, and environmental sustainability.

The goals of the Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC) are:

- Increased understanding and awareness of transportation issues
- Improved body of knowledge
- Improved processes, techniques and skills in addressing transportation issues
- Enlarged pool of trained transportation professionals
- Greater adoption of new technology

Abstract

This research study focused on the development and subsequent evaluation of an in-vehicle Active Traffic and Demand Management (ATDM) system deployed on Interstate 66 in Northern Virginia. The ATDM elements inside the vehicle allowed drivers to remain consistently aware of traffic conditions and roadway requirements even if external signage was inaccessible.

Forty participants were accompanied by a member of the research team and experienced the following in-vehicle device (IVD) features: 1) dynamic speed limits, 2) dynamic lane use/shoulder control, 3) High Occupancy Vehicle (HOV) restrictions, and 4) variable message signs (VMS). This ATDM system was equipped with auditory and visual alerts to notify the driver when relevant information was updated. The research questions addressed distraction, desirability, and driver behavior associated with the system. Participant data was collected from the instrumented vehicle, various surveys, and researcher observation.

Several key findings were uncovered related to each research category: 1) the IVD would not be classified as a distraction according to the National Highway Traffic Safety Association (NHTSA) distraction guidelines, 2) 73% of participants would want the in-vehicle technology in their next vehicle, and 3) the speed limit alert motivated participants to alter their speed (based on both survey results and actual participant speed data).

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Introduction

According to highway statistics from the Fatality Analysis Reporting System (FARS), there were 4,124 motor vehicle fatalities on rural and urban interstates in the U.S. in 2013. These fatalities account for 12.6% of the total number of motor vehicle traffic fatalities in the same year [1].

One area of research that has the potential to reduce interstate crashes (and crashes on other roadway systems) is connected vehicle technology (CVT), which includes vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. This technology could alter the current transportation system by fostering direct communication across vehicles, infrastructure, and/or other communication devices. Connected vehicles (CVs) aim to increase safety, enhance mobility, and lessen transportation's influence on the environment [2].

The overall goal of V2V technology is to avert crashes by providing communication among vehicles traveling along a roadway. This technology is capable of gathering surrounding vehicle data, such as speed, and administering warnings to the driver to prevent an impending crash. Some V2V systems can even take over for the driver in potential crash situations. An August 2014 report from the National Highway Traffic Safety Administration (NHTSA) stated that a fully functioning V2V system could prevent approximately 81% of all non-impaired, light vehicle crashes [3].

V2I technology aims not only to reduce crashes but also to increase mobility along various roadway systems. This technology generates communication between vehicles and roadway infrastructure to provide relevant information to drivers [3]. Applications of this technology include warning drivers of roadway conditions ahead, providing real-time information to drivers, presenting drivers with alternate routes, etc. [2]. One specific application of CVT is via active traffic management systems, which have traditionally used infrastructure-mounted displays to communicate with drivers.

Active Traffic and Demand Management (ATDM) systems serve as an example of real-world CVT. ATDM is designed to increase traffic flow, create more reliable travel time predictions, enhance roadway capacity, and reduce congestion while simultaneously improving safety. Traditionally an infrastructure-centric application, ATDM uses dynamic signs (often on overhead highway signs) to provide relevant regulatory and informational content to drivers (e.g. speed limits, queue warnings, etc.). Instead of simply observing and reacting to traffic issues, ATDM provides the ability to dynamically influence traffic flow and, ultimately, driver behavior before an incident fully manifests [4].

Various Departments of Transportation (DOTs) within the United States have recently initiated ATDM projects; one major project is located in Washington State. The Washington State Department of Transportation (WSDOT) is one of the first state transportation organizations to utilize ATDM strategies. Their system uses overhead gantries to display variable speed limits, lane blockage notifications, and collision/slowdown warnings to drivers [5]. Washington State has shown a downward trend in collisions following the introduction of the ATDM system. However, this downward trend is not yet statistically significant. It will be several years before WSDOT is able to collect enough data to identify a statistically significant trend [6].

WSDOT has reported additional positive effects of the ATDM system regarding emergency response and management throughout the state. Emergency responders have observed a high percentage of drivers complying with the “lane blockage” warnings from the ATDM systems. In addition, WSDOT has successfully utilized the ATDM signage to warn drivers of poor weather conditions. Congestion data has been collected as well; however, a few more years of data are necessary before statistically significant conclusions can be made [5].

Minneapolis, MN has deployed an Active Traffic Management (ATM) system along Interstate 35W known as Smart Lanes. Smart Lanes uses variable speed limits to relieve traffic congestion and increase safety. In addition, Smart Lanes is able to display lane closures, instruct drivers to merge into a different lane, display HOV restrictions, and notify drivers of environmental hazards along the highway [4]. An analysis of before and after speeds was completed to understand how the variable speed limits affected overall traffic congestion. It was determined that the section of I-35 utilizing variable speed limits did have less congestion after deployment, saving 7.6 minutes of travel time for the morning peak hour [7].

With only a few relatively recent ATDM implementations throughout the U.S., research is ongoing to facilitate a strong understanding of the advantages/disadvantages of this new traffic control technology. However, with the positive initial indicators, DOTs are continuing to deploy ATDM systems. One of the newest systems, located along the Interstate 66 (I-66) corridor in Northern Virginia, was undergoing construction at the time of this research. The overhead gantries had been constructed along the test section of the interstate, but the Virginia Department of Transportation (VDOT) had not fully activated the ATDM system (i.e. signage was installed but not activated).

With CVT, the ATDM interface may instead be located inside vehicles with an in-vehicle device (IVD) where messages may be more ubiquitous, salient, and dynamically updated. An example of the IVD used in this study is provided in Figure 1. By placing these ATDM elements inside the vehicle, drivers remain consistently aware of the roadway requirements, even when external signage is not visible or available. This application has the potential to decrease infrastructure cost to road operators as well as road sign clutter along the roadway. Despite the improved information flow between road operators and road users, IVDs may also negatively affect the driver by requiring them to take their eyes off the road, adding distractions, and causing over-reliance on potentially imperfect information and false alerts.

Figure 1. In-Vehicle Device (IVD).

This research study focused on the development and Human Factors evaluation of an in-vehicle ATDM system on the I-66 corridor. The in-vehicle ATDM features in this study included 1) dynamic speed limits, 2) dynamic lane use/shoulder control, 3) High Occupancy Vehicle (HOV) restrictions, and 4) other traveler information through variable message signs (VMS). Various visual and/or auditory alerts were implemented whenever the displayed information was updated to notify the driver. The purpose of this research was to draw inferences from individual subjects to determine if in-vehicle signage, coupled with ATDM, had the potential to successfully manage traffic. The research team sought to accomplish the following during this study: determine whether drivers found the alerts helpful, receive feedback regarding the design of the in-vehicle system, obtain any suggestions for improvement, and ascertain if drivers would like to have this technology incorporated inside their own vehicles.

Research Questions

The complete list of research questions for this study is given below.

1) Distraction:
    a. Does the IVD comply with all NHTSA distraction guidelines?
    b. Did alert type, age group, and/or time of day affect glance durations to the IVD?
    c. Were the IVD alerts perceived as overly distracting and/or annoying?
    d. Did drivers find the IVD gave them relevant, clear information?

2) Desirability:
    a. Would drivers like to have the IVD system in their own vehicles?
    b. What changes would participants make to improve the current system?
    c. How much money would drivers be willing to pay for the IVD?
    d. Which IVD alert approach did drivers prefer, if any?

3) Driver Behavior:
    a. Did the speed limit alert elicit a change in speed?
    b. Did alert type affect glance duration to the instrument cluster?
    c. Did drivers comprehend the Variable Message Signs?

The research questions related to distraction focused on eye glance data (first two questions in the distraction category) and survey responses (last two questions in the distraction category). The eye glance questions were generated based on the 100-Car Naturalistic Driving Study (NDS) conducted by the Virginia Tech Transportation Institute (VTTI), in which the authors concluded that driver distraction encompassed a much broader spectrum than previously theorized. Prior to the 100-Car NDS, researchers believed that driver distraction was caused by fatigue and tasks unrelated to driving. However, the authors of the 100-Car NDS report deemed *driver inattention* to be a more accurate term to describe all forms of driver distraction. By definition, driver inattention includes fatigue and attention to secondary tasks, but it also includes eye glances to non-specific items and driving-related glances away from the forward roadway (i.e., checking mirrors) [8].

In this research study, glances to the IVD are defined as the time spent looking at the IVD and away from the forward roadway. Therefore, IVD glances would be considered "driving-related glances away from the forward roadway." Findings from the 100-Car NDS highlighted the importance of analyzing these glances in order to understand how the system affects the level of distraction/inattention. Furthermore, the specific eye glance measures were selected based on the 100-Car NDS findings. The authors of the 100-Car NDS report concluded that any eye glance away from the forward roadway longer than 2 seconds greatly amplified the probability of a crash [9]. As a result, NHTSA has since created the following distraction guidelines that shaped this study's glance-related research questions [10]:

1) The mean eye glance duration away from the road must be ≤ 2 seconds.
2) 85% of eye glance durations away from the road must be ≤ 2 seconds.
3) The cumulative time spent glancing away from the road per event period must be ≤ 12 seconds. Note: "event period" is the 30 seconds following each in-vehicle alert.

Note that the IVD tested in this study did not require the driver to physically interact with the system. Future IVD designs may involve direct input from the driver, but those interactions cannot be evaluated with the system in this study.

The desirability research questions are all based on participant survey responses. The goal of these questions was simply to target participant opinions of the system and to define future areas of improvement.

The first driver behavior question focused on whether the speed limit alert actually influenced the driver's speed. This question was analyzed by utilizing survey responses as well as speed data collected along each participant trip. Examining this question using two different methods allowed the research team to validate participant survey responses with their corresponding speed data. The second research question allowed further analysis of the speed limit alert by utilizing eye glance durations to the instrument cluster across alert types. The final driver behavior question was included to analyze whether participants understood the displayed messages and whether they followed the IVD instructions presented.

Research Contributions

The results of this study will add to the body of knowledge for the effectiveness of in-vehicle signage and ATDM features by analyzing the IVD from a distraction, desirability, and driver behavior standpoint. Based on the study's findings, recommendations for future studies involving in-vehicle signage and ATDM technology will be discussed along with methods of refining the design of future in-vehicle systems.

Method

Study Participants

Forty participants were recruited from the Northern Virginia/D.C. area and were grouped by age and balanced by gender. The younger age group included those from 18–29 years of age and the older group included those from 50–65 years of age. These age groups were chosen for the following reasons: 1) they represent a sizeable portion of the licensed driver population in D.C., 2) they include those in the younger population who are at a higher risk of involvement in a crash, 3) they contain more than half of all licensed D.C. drivers over fifty years old, and 4) they provide a large enough gap to separate the drivers into two distinct age groups. The sample size was chosen to include enough participants to produce statistically significant results when distributed across the targeted conditions.

The percentage of total licensed drivers by age in D.C. in 2010 was reported by the Federal Highway Administration, and the research team created Figure 2 to visually display the results [11]. The purpose of this diagram was to ensure that the age groups chosen for this study encompassed enough of the licensed driver population in D.C. The two groups of yellow bars represent the older and younger age groups selected, which accounts for about 40% of D.C.'s licensed driver population.

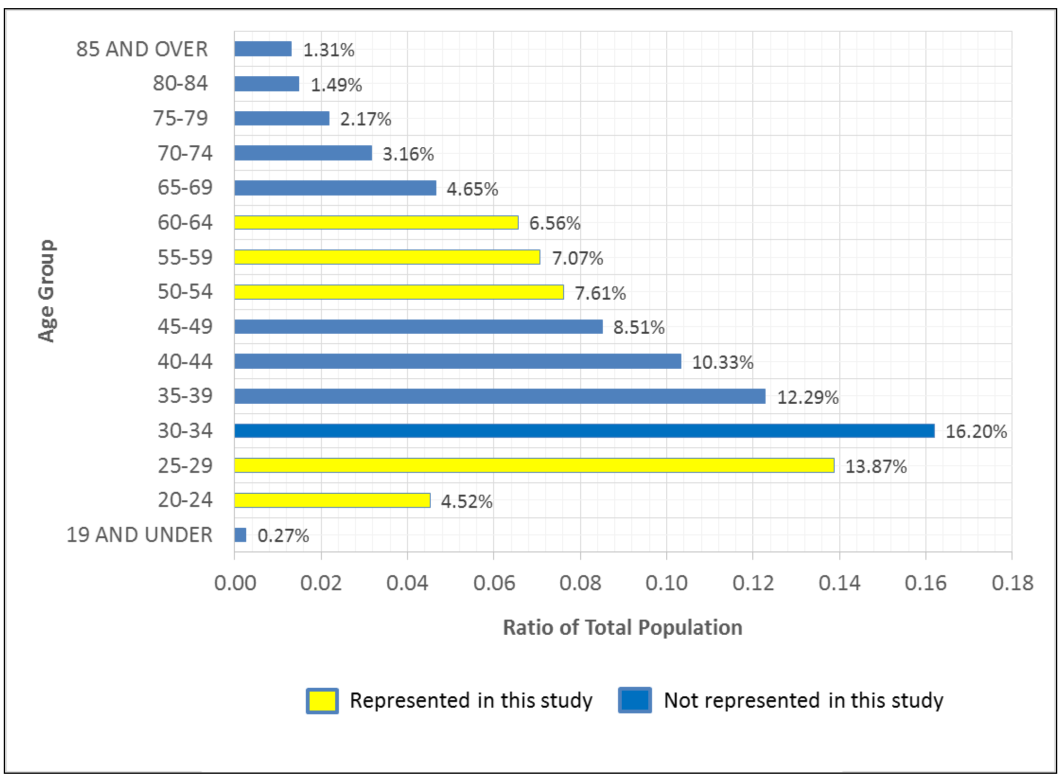

Figure 2. Percentage of total licensed drivers in D.C. by age – 2010.

In addition, the 2008 passenger vehicle driver crashes and fatality rates by driver age were analyzed (Figure 3). The police-reported crash rates were approximately 3.5 times higher for younger than older drivers on average. The fatal crash rates were about 3.2 times greater for younger than older drivers on average. Within each age grouping and type of crash (police-reported crashes for younger drivers, fatal crashes for older drivers, etc.), the crash rates were fairly steady [12].

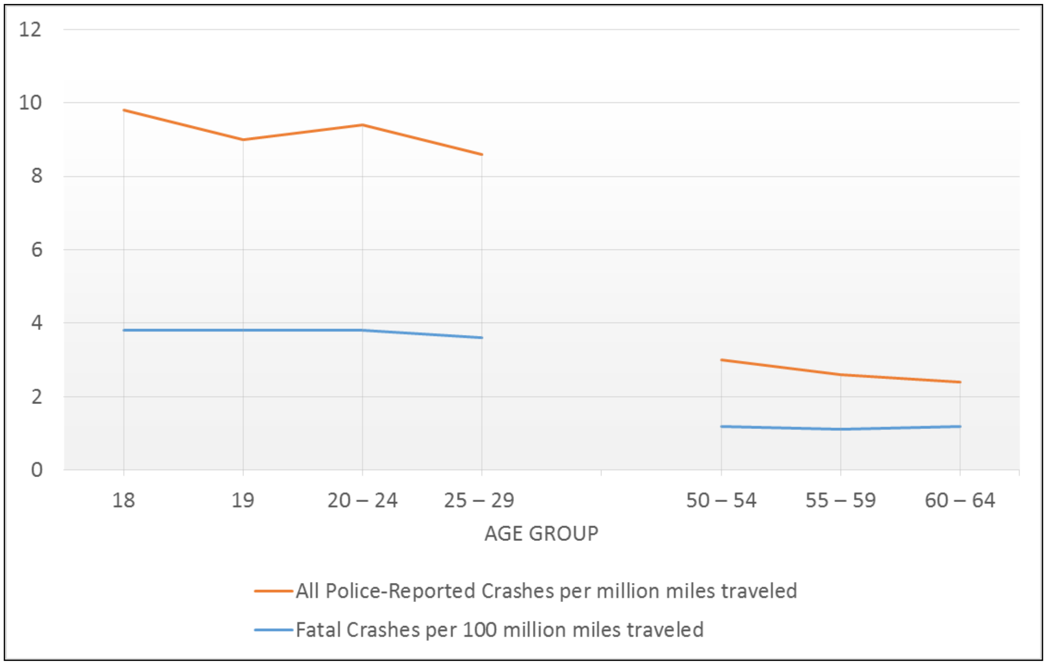

Figure 3. Crash rates by driver age – 2008.

The 2010 motor vehicle fatalities per 100,000 people by age and gender were also examined (Figure 4). Male drivers had a higher number of fatalities than female drivers across both age groups. Younger, male drivers had 1.4 times more crash-related fatalities than older, male drivers on average. Younger, female drivers had 1.5 times more crash-related deaths than older, female drivers. Note that the younger, male age range (18–29) captures a large variation in fatality levels [13].

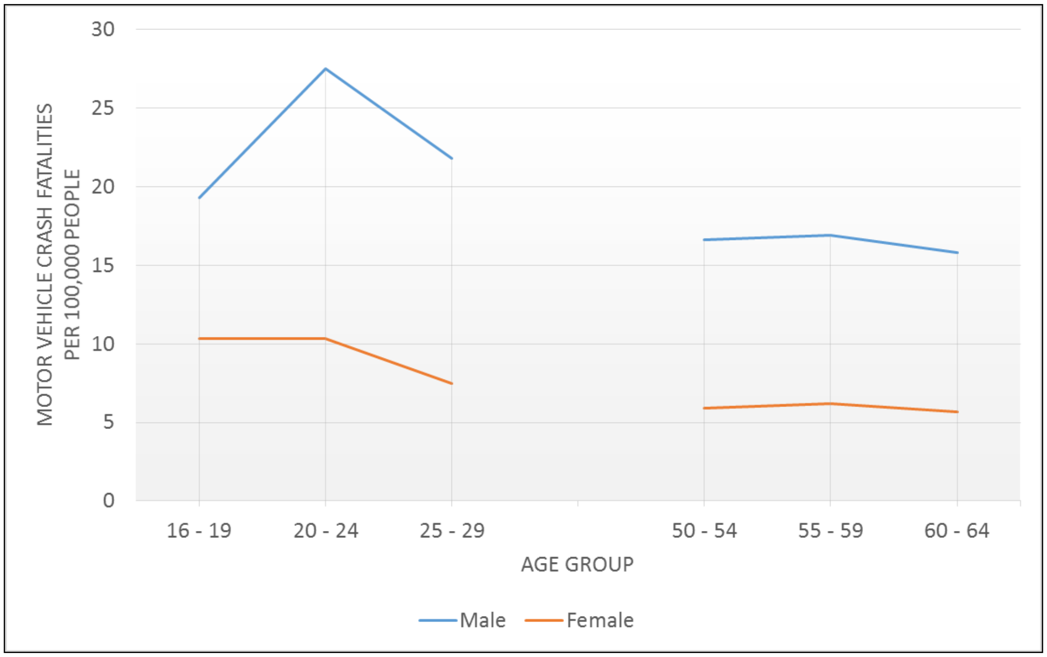

Figure 4. Crash fatalities by age and gender – 2010.

Participant Recruitment

VTTI's participant database was used to recruit 40 participants for the study. This extensive database contains drivers who have either previously participated in studies or who have expressed interest in doing so and have provided contact information. This database is private and only accessible to the recruitment team at VTTI. Participant recruitment was also conducted via flyers (Appendix F), Craigslist (Appendix G), e-mail, and by word-of-mouth.

The recruitment team actively screened for individuals who had previously completed other VTTI studies along the same I-66 corridor to reduce previous participant knowledge of the route. Upon completion of this study, there was only one participant who had previously completed another VTTI study on I-66. This participant was included due to time constraints and difficulty recruiting their particular demographic. All other participant recruitment requirements can be found in Appendix A.

Procedure

Potential participants were screened by telephone by the recruiting team at VTTI in Blacksburg, VA using a prepared script (Appendix A). Those who were interested and eligible were scheduled to come to the Virginia Tech Northern Virginia Center (NVC) in Falls Church, VA and sent a confirmation email (Appendix C). If a potential participant was interested but needed more information about the study, the recruitment team e-mailed them with additional information (Appendix B).

There were 40 participants in the study, divided as equally as possible by age, gender, and time of day (Table 1). Prior to beginning the research study, all participants had to sign an Informed Consent form (Appendices H and I), present their driver's licenses, and pass all required vision and hearing tests (Appendix D). The research team ensured that all steps of the procedure were followed and documented by using a prepared checklist (Appendix E).

Table 1. Participant Demographics

Time of Day	Younger (18 – 29)		Older (50 – 65)		SUM
	Male	Female	Male	Female	
a.m. Peak	3	2	2	3	10
p.m. Peak	2	3	3	2	10
Off-Peak	5	5	5	5	20

After meeting all requirements and giving their consent, each participant completed the pre-drive questionnaire (Appendix J). This survey focused on driver familiarity with connected vehicle and traffic management technology and how frequently the driver utilized HOV lanes, managed lanes, variable message signs, etc.

Once a participant completed the pre-drive questionnaire, the experimenter escorted them to the research vehicle parked in the NVC parking lot, where they were oriented to the research vehicle and shown an example display screen and associated alert to experience the device layout, symbols, and alert system (Appendix D). Then, the participant drove while the experimenter gave directions to the beginning of the I-66 route. Once the participant had successfully merged onto I-66, the participant was told to follow all directions from the in-vehicle system for the rest of the study.

During the driving portion, participants were asked a series of questions regarding each alert from the IVD (Appendices K, L, and M). These questions were geared to capture the driver's opinion of each alert, including its ease of comprehension, usefulness, distraction level, and timing. In addition, participants were asked NASA TLX questions at both the halfway and end points of the route. The goal of these questions was to determine how mentally demanding, temporally demanding, and frustrating each half of the route was due to the in-vehicle alerts in conjunction with surrounding traffic.

At the end of the route, participants were given instructions to return to the NVC office. The participant then completed the post-drive questionnaire (Appendices N and O). This survey aimed to capture participants' impressions of the in-vehicle system, including attributes such as desirability, distractibility, driver behavior, general concerns, and areas of improvement. Each participant then completed a W-9 Form (Appendix P) and a debrief form (Appendix Q) to ensure that they were paid correctly.

Testing Environment

During the driving portion of the study, participants were asked to drive along I-66 in Northern Virginia while following route guidance provided by the IVD. The route extended from Exit 47A (Manassas – Sudley Road) to Exit 66 (Falls Church – Leesburg Pike), both eastbound and westbound directions (Figure 5). The route is about 40 miles total, and the amount of time it took to complete the entire route varied based on the time of day and level of traffic. Participant driving time ranged from 40–90 minutes with an average duration of 1 hour. At least one experimenter was present in the research vehicle with every participant; therefore, all study participants could travel in the HOV-only section of the route. There is a section of the route that is "HOV-only." During certain times of the day, only vehicles with two or more people can use this portion of roadway. All vehicles with only one person must exit I-66 and continue onto Interstate 495.

Figure 5. I-66 participant route.

During the data collection phase of this study, VDOT was constructing overhead gantries along a section of the study route. Excluding the newly constructed overhead gantries, I-66 contains outside infrastructure to communicate information to drivers. The HOV lane on I-66 is the leftmost lane, and access to the lane is restricted to vehicles with two or more passengers during peak hours. The peak hours are displayed with traditional signage at various points along the roadway. The rightmost lane on I-66 is closed and used as a shoulder during off-peak hours; the lane is used as a regular travel lane during peak hours to increase roadway capacity. Lane availability is shown on small display screens with either a red "X" or a green arrow. Large message boards along I-66 are utilized to display various messages to drivers, including congestion, slow-downs, crashes, detours, etc. Because this study was conducted without interference from the newly constructed overhead gantries, this dataset could later be used as a comparison for future studies regarding VDOT's ATDM system once it is fully functional.

Research Vehicle

The research vehicle utilized throughout this study was a white 2006 Cadillac STS (Figure 6), which was equipped with a passenger-side emergency brake, first aid kit, and fire extinguisher for all participant runs.

Figure 6. 2006 Cadillac STS.

There were four separate cameras located inside the vehicle in order to capture the participant's face, the in-vehicle display, an over-the-shoulder view of the participant, and the forward roadway view (Figure 7 and Figure 8). These cameras were carefully installed to be secure and unobtrusive.

Figure 7. Forward and face cameras, IVD, over the shoulder cameras.

Figure 8. Recorded 4-way camera views.

The trunk of the Cadillac housed the necessary study hardware, including the NextGen Data Acquisition System (DAS), the Savari On-Board Equipment (OBE), a USB hub, internet router, and Omnistar Differential GPS (DGPS) (Figure 9).

Figure 9. Study Hardware.

In–Vehicle Device

The device tested was an in-vehicle ATDM device. This device used geofence coordinates in order to display 1) dynamic speed limits, 2) dynamic lane use/shoulder control, 3) HOV restrictions, and 4) other traveler information through variable message signs (VMS). In addition, the system was equipped with various auditory and visual alerts to notify the driver when relevant information was updated. The IVD was located above the vehicle's center console and to the right of the steering wheel (Figure 10). Participants were not asked to physically interact with the IVD (i.e. the IVD was for content display only and did not accept driver inputs).

Figure 10. IVD placement.

Figure 11 shows how the display screen looked inside the vehicle. The top of the display depicted a white diamond for an HOV lane, a green circle for a lane open to all traffic, and a red "X" to indicate a closed lane. This row changed based upon the number of lanes and time of day. The speed limit was located in the bottom left corner of the display and was posted at all times. It changed along the route to reflect the posted speed limits. The rest of the display screen was used for VMS, which was displayed in yellow font. This portion of the screen was only used when necessary.

Figure 11. IVD symbols.

The in-vehicle VMSs did not always reflect actual roadway conditions since there was no connection between the IVD and outside infrastructure; however, participants were instructed to follow all instructions from the IVD for the duration of the study. For example, one of the VMSs notified the drivers of an accident ahead and instructed them to exit at a certain location. This alert was designed to test driver comprehension and distraction while maintaining consistency across participants, regardless of actual roadway conditions. However, in future in-vehicle systems, the device would receive real-time messages regarding roadway conditions and would be able to dynamically warn participants of upcoming lane blockages, accidents ahead, etc.

While the in-vehicle VMS was not always reflective of current conditions, the HOV, lane management, and speed limit in-vehicle information mirrored actual roadway conditions. This level of accuracy was achieved by programming the IVD to abide by the current lane management and HOV hours along I-66 displayed in Table 2 [14]. The locations of posted speed limit signs along I-66 were also programmed into the IVD to maintain accuracy. In a fully deployed system, the information displayed on the IVD would be received from the traffic operating center according to real-time traffic conditions and network optimization algorithms.

Table 2. Current HOV and Lane Management Hours on I-66

IVD Symbol	A.M. Peak Hours (M-F)	P.M. Peak Hours (M-F)
Shoulders Open to General Traffic ("O")	5:30 a.m. – 11:00 a.m.	2:00 p.m. – 8:00 p.m.
HOV Lanes in Effect ("◊")	5:30 a.m. – 9:30 a.m.	3:00 p.m. – 7:00 p.m.
All Lanes are HOV ("◊")	6:30 a.m. – 9:00 a.m.	4:00 p.m. – 6:30 p.m.

Data Collection Hours

In order to finalize the data collection times for this study, current I-66 HOV and lane management hours as well as average I-66 traffic volumes were analyzed. Note that participant data was collected from July–August 2015.

Current HOV and Lane Management Hours

The final driving hours selected needed to include the a.m. peak traffic, middle-of-the-day off-peak traffic, and p.m. peak traffic to incorporate a variety of traffic densities. These hours also had to allow for a balance among the displayed symbols to allow participants to experience as many as possible. This meant that if the leftmost lane was open to all traffic moving one direction, then the leftmost lane should be HOV-only when traveling the opposite direction. This system ensured that participants experienced as many in-vehicle symbols as possible during their participation.

Table 3 shows the approximate participant driving times and the corresponding IVD symbols for that time of the day.

> For example: a.m. peak participants would begin traveling at 7:30 a.m. moving westbound along I-66. They would NOT see a white diamond symbol because the HOV lanes would be open to all traffic at that time. Participants would see a red "X" in the lane management lane, indicating that the lane is closed to all traffic. On the "HOV-only" section of the route, the HOV lanes would be open to all traffic.

Table 3. Symbols Present Based on Time of Day

Time of Day	On-Road Time	Direction	HOV	Lane Management	HOV-only section	SL, VMS
A.M. Peak	7:30 a.m.	WB	O	X	O	All participants experience the same alerts.
	8:00 a.m.	EB - Traffic	◊	O	◊	
Off-Peak	12:00 p.m.	WB	O	X	O	
	12:30 p.m.	EB	O	X	O	
P.M. Peak	6:30 p.m.	WB - Traffic	◊ **until 7 p.m. / O**	O	O	
	7:00 p.m.	EB	O	X	O	

The off-peak hour was determined to start at 12:00 p.m. so that participants would have a green circle in the HOV lane and a red "X" in the managed lanes. In the a.m. and p.m. peak hours, participants experienced different HOV and managed lane symbols depending on the time of day and direction of travel; however, the symbols displayed to off-peak participants were unaffected by time of day and direction of travel. This occurred because HOV lanes are always open and managed lanes are always closed during off-peak hours along I-66.

2009 Traffic Volumes along I-66

When selecting the a.m. peak, p.m. peak, and off-peak data collection hours, average traffic volumes on I-66 during various hours of the day were studied. Figure 12 shows the 2009 weekday hourly traffic volumes moving westbound on I-66 (indicated by a gray line) [15]. The colored boxes represent the data collection hours during the a.m. peak (green box), off-peak (blue box), and p.m. peak (red box).

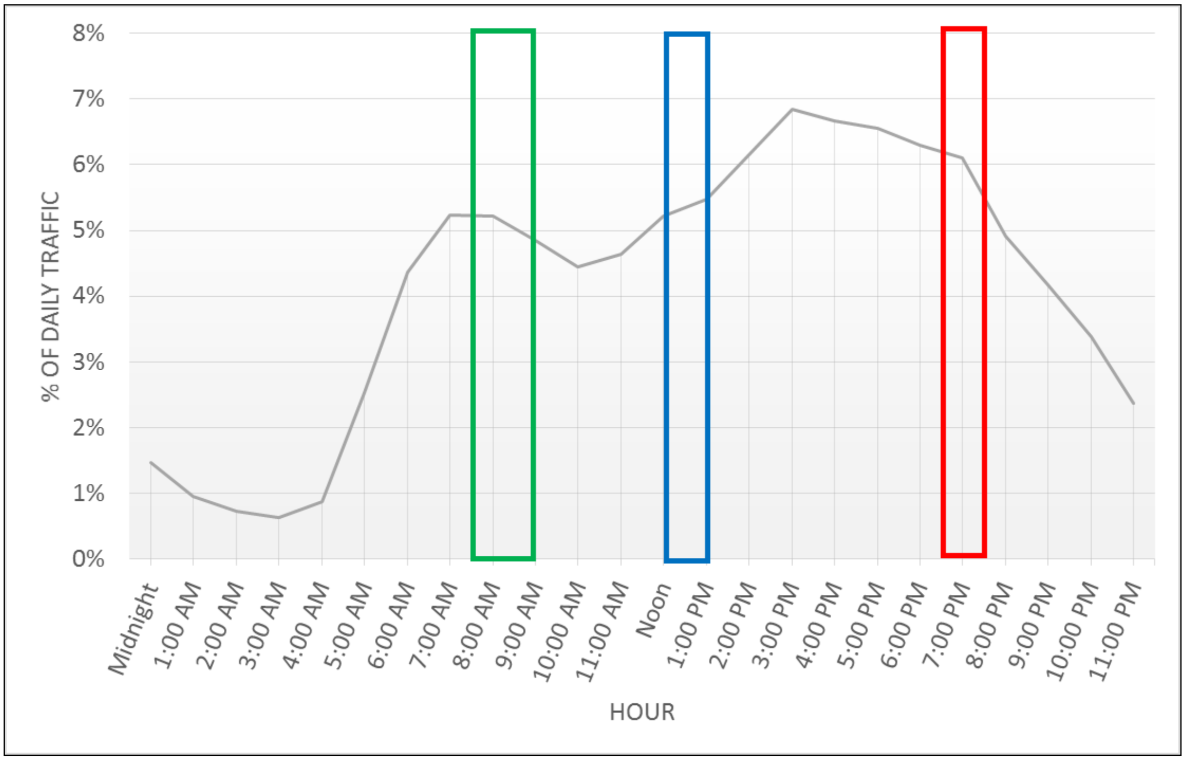

Figure 12. Weekday hourly westbound traffic volumes – 2009.

When comparing the a.m. and p.m. peak hour volumes (Figure 12), it is evident that the average traffic volumes differ; the p.m. peak hour exhibits higher volumes. In addition, there is a sharp decline in traffic volume beginning in the selected p.m. peak hour that is not present in the a.m. peak hour [15]. This decline may be related to the HOV lane restriction that ends at 7:00 p.m. Because of this decline, the a.m. peak hour and the p.m. peak hour were treated as two separate groups.

It was determined that the a.m. peak hour participants would be on the road by 7:30 a.m. after completing the required paperwork. On average, a.m. participants completed their route by 9:00 a.m. According to Figure 12, the a.m. peak hours chosen—from 7:30 a.m.–9:00 a.m. —includes part of the peak in volume during the a.m. hours; therefore, these hours were determined to successfully capture a.m. peak hour traffic volumes [15].

The p.m. peak hour for this study began around 6:30 p.m. This time was selected to provide the closest average traffic volumes to the a.m. peak hour. The p.m. peak hours had to start at 6:30 p.m. so that the p.m. participants would see the HOV diamond symbol, which disappeared at 7:00 p.m. In addition, the sun set around 8:30 p.m., and it was vital that all participants drove during daylight hours for safety reasons. The average p.m. peak hour participant finished the route around 7:30 p.m. According to Figure 12, the p.m. peak hours chosen from 6:30 p.m. – 7:30 p.m. capture the final surge in volume during the p.m. peak hours [15].

The off-peak hour began at 12:00 p.m., with the average participant finishing around 1:00 p.m. During this hour, traffic volumes are lower than the p.m. traffic volumes but similar to the a.m.

traffic volumes. Even so, this time frame is considered the off-peak hour since the HOV lanes are open to all traffic and the managed lanes are closed [15].

In-Vehicle Device Alerts

Alert Features

In-vehicle alerts were utilized in order to notify the driver that new information was available. Descriptions of the alerts and their messages are given in Table 4.

Table 4. Alert Features

Alert Type	Visual	Auditory	Verbal	Verbal Message
HOV	Yes	-	-	-
Lane Management	Yes	Yes	-	-
Speed Limit	Yes	Yes	Yes	"The speed limit is now ____ mph."
Variable Message Signs (VMS)	Yes	Yes	Yes	"Route 29. 6 miles. 15 minutes."
				"Accident ahead. 30 minute delay. Take exit 47A.
				"Stopped traffic. 5 miles."
				"Detour ahead. Take Exit 66."

In an effort to limit the number of potentially distracting tones, no alert was given for updated HOV information; the HOV symbol simply changed on the display to reflect the new HOV lane status. For example, the white diamond would change to a green circle to show that the leftmost lane was now open to all traffic.

The lane management alert sounded when the status of the rightmost lane changed (note that only a section of the route had managed lanes). The lane management alert sounded approximately 5 seconds before the participant entered the lane management section, which equated to about 400 feet assuming the participant was traveling at the speed limit of 55 mph. For example, before the participant entered the lane management section, a green circle would be displayed in the rightmost lane. If the managed lanes were closed at that time of day, then an auditory "ding" would sound 400 feet prior to the start of the lane management section. The green circle would change to a red "X" and blink 5 times at 1 Hz. Once the participant exited the lane management section, the auditory "ding" would sound right at the end of the lane management section. The red "X" would change to a green circle and blink 5 times at 1 Hz. If the managed lanes were open at that time of the day, no alert would sound and a green circle would remain in the rightmost lane for the entire lane management section.

The speed limit alert would deploy when the speed limit changed along the I-66 route. For example: If a participant was traveling along the section of the route that is 55 mph and the speed limit changed to 60 mph, the participant would hear an auditory "ding" followed by a verbal message saying "The speed limit is now 60 mph." The speed limit in the lower left corner of the display would change from 55 mph to 60 mph. According to the 2009 Manual on Uniform Traffic Control Devices (MUTCD), speed limit signs are placed where the old speed limit changes to the new speed limit [16]. It was important to warn participants of the speed limit change prior to reaching the posted sign; therefore, the IVD was coded so that each participant would receive the speed limit alert approximately 5 seconds in advance of the roadway sign. The speed limit alert sounded 400 feet before the posted sign for the westbound route and 440 feet prior to the posted sign for the eastbound route. This calculation gave drivers about a 5 second warning, assuming they were traveling at the posted speed limit (either 55 or 60 mph).

There were four VMSs along the I-66 route. At a pre-designated spot along the route, the participant would hear an auditory "ding" followed by a verbal message. This message would also be displayed to the participant in yellow font. For example, the participant would hear a "ding" following by "Detour ahead, Take Exit 66." The "Route 29, 6 miles, 15 minutes" and the "Stopped traffic, 5 miles" messages were displayed on the screen for 10 seconds. These alerts were pre-positioned to allow enough time for participants to respond to the in-vehicle survey questions given during this time. The aforementioned messages stayed on the display until the participant successfully exited the highway. This enabled the participant to exit at the correct location without having to remember the exit number. Approximately one mile was allotted for both exits to ensure participants had enough time to safely exit the highway.

Alert Design

The design of each alert was based on the importance of the information conveyed. The study was designed with the speed limit and VMS alerts as the highest priorities for user perception. These two alerts have the largest probability of requiring an action from the driver, i.e. lowering speed, changing lanes, etc. Because of the importance of the information, auditory, visual, and verbal alert features were used to create redundancy for the driver. This redundancy is important, especially in an environment like I-66 with high speed variability and heavy traffic. This complex environment can cause an elevated driver workload, increasing the likelihood of missing a single-modality message.

The lane management alert was considered the next highest priority for this study. It is important for drivers to be aware of the status of the managed lane. A driver unaware that the managed lane was closed to traffic could crash into a stopped vehicle using the managed lane as a shoulder. Therefore, auditory and visual components were included in the lane management alert. The flashing symbol was used to quickly grab the driver's attention and reduce their visual search time.

In order to design the lane management alert, standards from the Federal Highway Administration (FHWA) were applied. In the design guidelines for flashing alerts, FHWA states that the optimum flash rate for emergency alerts is 4 Hz [17]. Since the lane management alert cannot be considered an emergency alert, a very low frequency was chosen (1 Hz) [18]. This flash rate was also chosen to reduce the distracting qualities of the alert. With CVT, future IVD designs could further reduce distraction by limiting the alert to only cases where the driver is actually traveling in the closed lane.

The HOV alert was considered the lowest priority for this study. If a driver with no passengers is driving in the HOV lane during HOV hours, they could be stopped by the police; however, no other drivers would be harmed because of that action. Therefore, there was no alert associated with HOV information.

In-Vehicle Questionnaires

While driving, the participants were asked to respond to a series of questions regarding each of the alerts administered along the route (Appendices K, L, and M). The questions and categories were as follows. Note that questions 2–4 were ranked on a scale from 1–5.

1) Comprehension – Regarding the alert last presented, what information was the system trying to give you?
2) Usefulness – How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?
3) Distraction – How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?
4) Timing – How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?

These questions were asked following each in-vehicle alert, including speed limit changes, variable message signs, and lane management updates. The number of alerts the participant experienced was based on the time of day and the direction of travel. The a.m. and p.m. peak hour participants received eight total alerts while the off-peak hour participants experienced 10 total alerts. The experimenter recorded the driver responses as well as any additional comments the participant may have provided.

In addition to the in-vehicle questions, the participants were asked to respond to National Aeronautics and Space Administration (NASA) Tax Load Index (TLX) questions at the halfway and end points of both the Eastbound and Westbound sections of the route. The participants were asked to rate the following NASA TLX categories from 1 – 5 (low to high): mental demand, temporal demand, and frustration. The NASA TLX questions and categories were as follows.

1) Mental Demand – How mentally demanding was this half of the route, where 1 is not at all mentally demanding and 5 is very mentally demanding?
2) Temporal Demand – How hurried or rushed were you, where 1 is not at all hurried and/or rushed and 5 is very hurried and/or rushed?
3) Frustration – How insecure, discouraged, irritated, stressed, and annoyed were you, where 1 is not at all stressed/annoyed, etc. and 5 is very stressed/annoyed, etc.?

The experimenter recorded the driver responses as well as any additional comments participants may have provided.

Results and Discussion

Participant Pre-Drive Survey Results

Prior to the driving portion of the study, participants completed a pre-drive survey to capture background information about each individual. These responses are important because they may help explain how participants responded to post-drive survey questions. Figure 13 displays the years of driving experience for the 40 participants in this study. The “>20” years of driving experience group is the largest bin in Figure 13 due to the age groups represented in this study: 18 – 29 (younger) and 50 – 65 (older). Half of the participants were in the “older” age group and all had at least twenty years of driving experience.

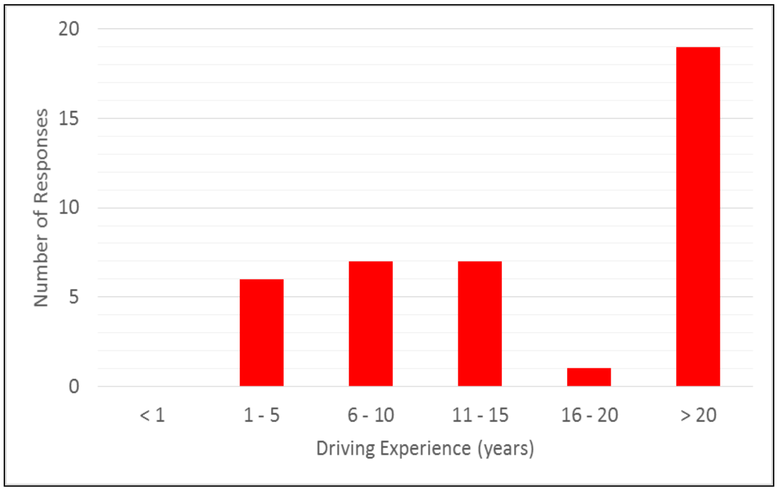

Figure 13. Participant driving experience.

All participants were asked to rank the following statement from 1–5 (not at all to very familiar) on the pre-drive survey: "Are you familiar with vehicle-to-infrastructure and/or vehicle-to-vehicle technology (systems located ***inside*** your vehicle that use various communication technologies to provide information to the driver, such as travel delay, crash warnings, etc.)?" According to Figure 14, it appears that many participants were familiar with V2I and/or V2V technology inside their vehicles (N = 40). Note that some participants may have ranked their familiarity based on GPS systems, such as Google Maps and Waze, which they use for travel delay estimates and crash warnings; it is believed that participants may have assumed these applications were V2I and/or V2V technology.

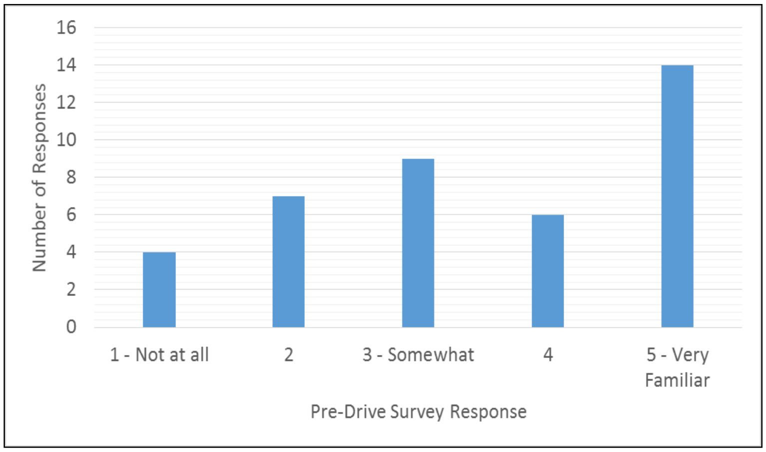

Figure 14. Participant familiarity with V2I and/or V2V.

All participants were also asked to rank the following question from 1–5 (not at all to very familiar) on the pre-drive survey: "Are you familiar with out-of-vehicle traffic management technology (systems located ***outside*** your vehicle that notify drivers of upcoming traffic conditions, provide travel delay estimates, etc.)?" Figure 15 shows that many participants were at least somewhat familiar with out-of-vehicle traffic management technology (N = 40).

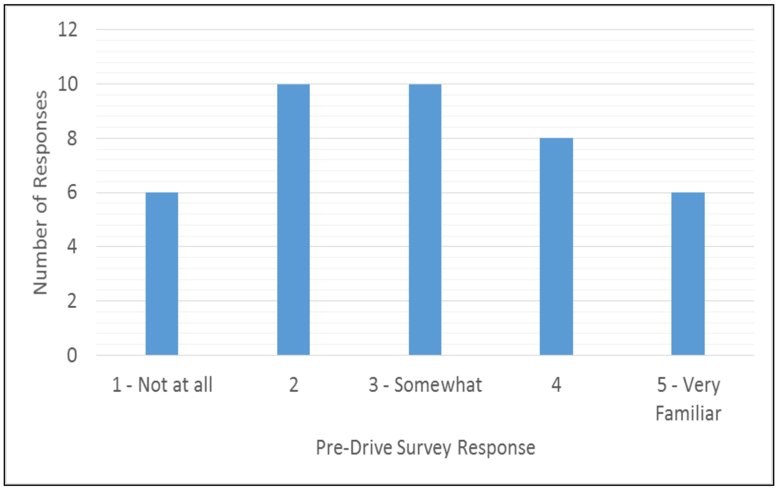

Figure 15. Participant familiarity with out-of-vehicle traffic management technology.

Participants were asked, "How frequently do you travel in HOV lanes per week?" and asked to "check one." Figure 16 shows that many participants (85%) either never use the HOV lanes along their routes or they only use them 1–2 days per week (N = 40).

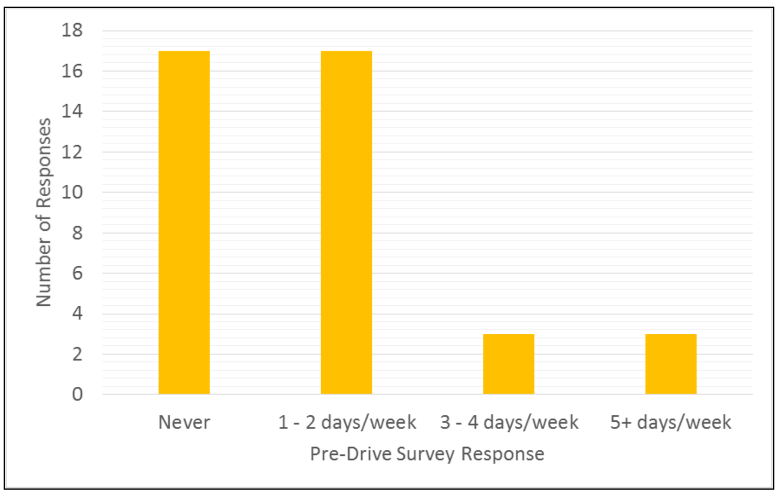

Figure 16. HOV Travel lane frequency.

If the participant stated that they traveled in the HOV lanes at least 1 day/week, they were then asked "When you are driving along routes with HOV lanes, is it easy to determine the status of the HOV lanes?" Participants were instructed to either circle "Yes" or "No." Twenty-three participants responded to this question, with 96% circling "Yes," indicating that they found it easy to determine the status of the HOV lanes using traditional road signs.

Next, each participant was asked, "How frequently do you travel along ***routes*** with a lane management system?" Figure 17 shows that most participants do travel along routes with lane management systems at least once per week (N = 40).

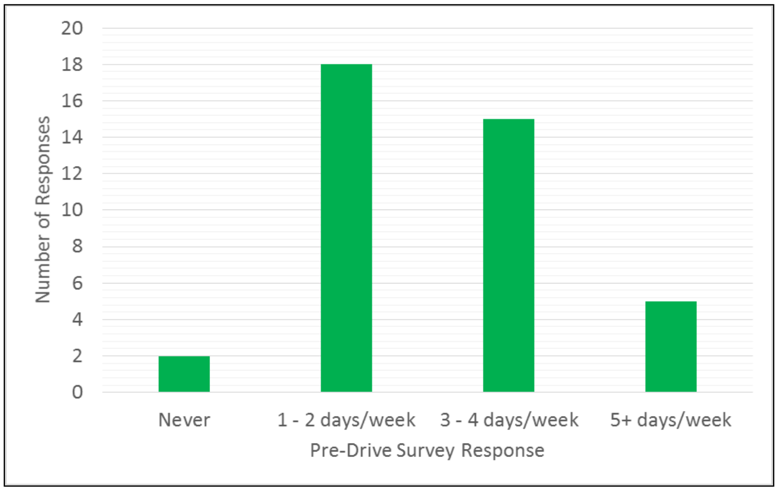

Figure 17. Travel frequency on routes with lane management systems.

Those who had traveled along routes with lane management systems were asked, "How frequently do you travel in the lane management ***lanes*** per week?" This question was meant to understand if participants utilized the managed lanes when they were open to traffic. Figure 18 displays the results, and it appears that many participants used the managed lanes at least once per week; however, there were 10 participants (26%) who never used the managed lanes even though they traveled along routes where they were available (N = 38).

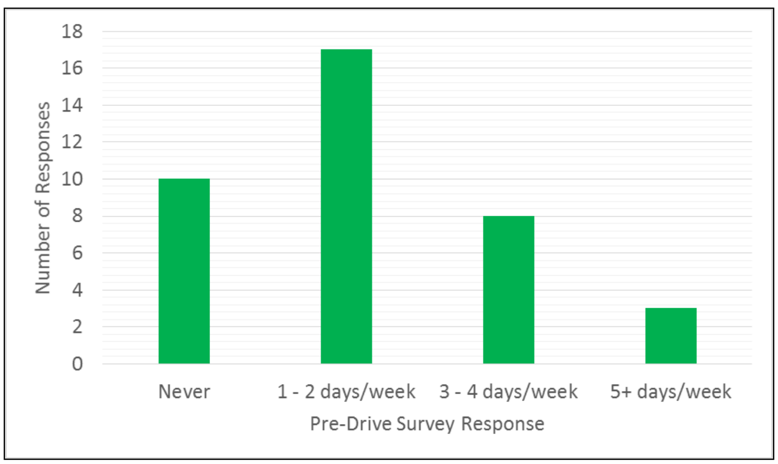

Figure 18. Lane management lane travel frequency.

Again, those who had traveled along routes with lane management systems were asked, "When you are driving along routes with lane management lanes, is it easy to determine the status of the lanes using the traditional system?" Participants were asked to circle either "Yes" or "No." A majority of participants (89%) stated that it was easy to determine the status of the lanes using the traditional system (N = 38).

As part of the pre-drive survey, participants were asked to rank the following statement from 1–5 (strongly disagree to strongly agree): "I am generally aware of the speed limit while driving on the interstate." Participants were instructed to "circle one." Based on Figure 19, a vast majority of the participants (80%) ranked their awareness of the speed limit as a "4" or "5" (N = 40).

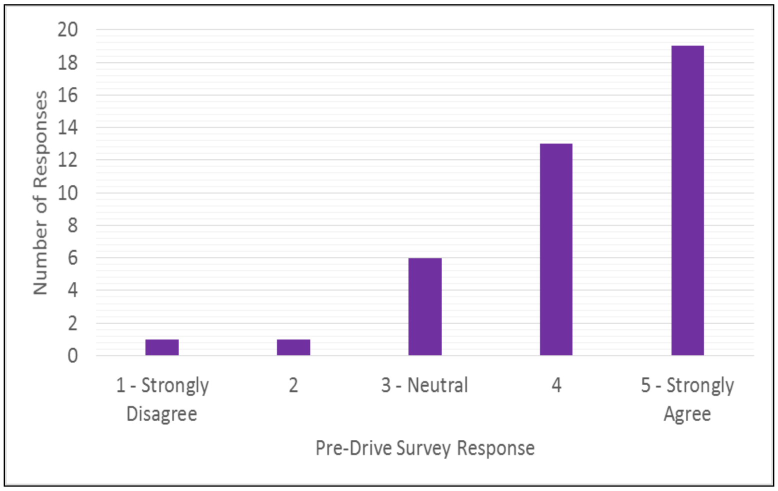

Figure 19. Participant awareness of speed limit.

Next, participants were asked, "How frequently do the Variable Message Signs impact your route decision-making?" Figure 20 shows that most of the participants stated that the VMS either never (33%) or rarely (48%) impacted their route decision-making (N = 40).

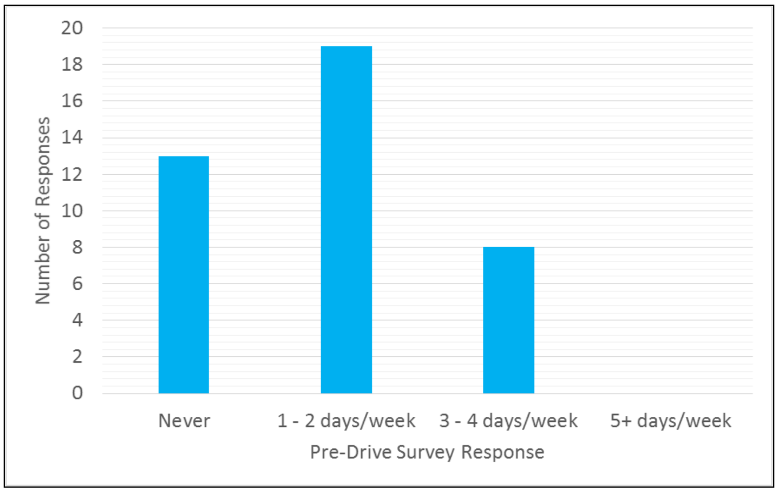

Figure 20. Impact of VMS on route decision-making.

Finally, participants were asked, "How frequently do you travel ***on I-66*** where HOV lanes, lane management systems, and Variable Message Signs are present?" Figure 21 indicates that every participant except one had driven on the sections of I-66 that include HOV lanes, lane management systems, and VMS at least one day per week (N = 40). This result was important to ensure that participants in the study had experienced these information systems throughout their personal travels.

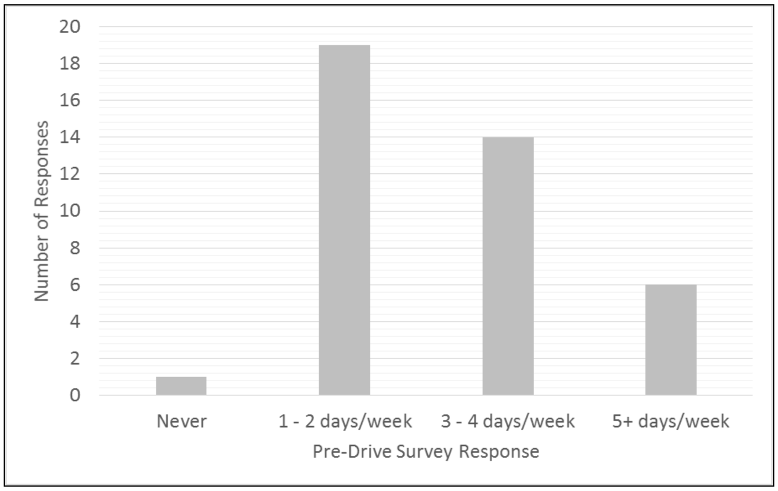

Figure 21. Travel frequency on sections of I-66 with HOV, LM, and VMS.

The following observations summarize the pre-drive survey results:

- All participants had at least one year of driving experience.
- Many participants were familiar with some type of traffic management technology.
- 85% of participants used the HOV lanes either never or only 1–2 days a week.
- A vast majority of participants traveled along routes with managed lanes. Of those participants, 26% never used the managed lanes even though they were available.
- 80% of participants were aware or very aware of the speed limit when traveling on interstates.
- 33% of participants stated that VMS never impacted their route decision-making.
- All participants, except one, had traveled along the sections of I-66 which have HOV lanes, lane management systems, and VMS at least once per week.

The pre-drive survey results suggest that the study participants were an appropriate sample. The amount of driving experience and previous knowledge of the existing infrastructure along the study route (or similar routes) indicate that this sample of participants had the ability to make an informed assessment of the proposed IVD.

Distraction

The following research questions were defined to investigate whether the IVD was a distraction to drivers:

1) Does the IVD comply with all NHTSA distraction guidelines?
2) Did alert type, age group, and/or time of day affect glance durations to the IVD?
3) Were the IVD alerts perceived as overly distracting and/or annoying?
4) Did drivers find the IVD gave them relevant, clear information?

1) Does the IVD comply with all NHTSA distraction guidelines?

Once all participant data had been collected, the research team identified the timestamp of every alert for all participant runs. This information was given to the data reduction team at VTTI along with the participant video files. For 30 seconds following each alert, the data reduction team identified where the participant was looking in each frame of video using the following location variables: IVD, forward, transition, mirrors, instrument cluster, over-the-shoulder, passenger, etc. However, the main focus for the eye glance results were glances to the IVD.

NHTSA has developed eye glance guidelines to help researchers determine if technology is a distraction to drivers. The device would not be considered a distraction if the following guidelines were met. [10].

1) The mean eye glance duration away from the road must be ≤ 2 seconds.
2) 85% of eye glance durations away from the road must be ≤ 2 seconds.
3) The cumulative time spent glancing away from the road per event period must be ≤ 12 seconds. Note: "event period" is the 30 seconds following each in-vehicle alert.

The final eye glance data from the reductionist team was pulled from a secure VTTI server and organized in MATLAB. MATLAB was then used to calculate the following statistics related to eye glance durations to the IVD (Table 5).

Table 5. IVD Eye Glance Reduction Results

In-Vehicle Alert Type	Mean (s)	Median(s)	Standard Deviation (s)	85th Percentile (s)	Average Cumulative Time (s)	Max Cumulative Time (s)
NHTSA Guideline	**≤ 2 sec**	**-**	**-**	**≤ 2 sec**	**≤ 12 sec**	**-**
Lane Management	0.50	0.40	0.34	0.80	1.95	8.88
Speed Limit	0.47	0.40	0.30	0.73	1.64	4.54
VMS	0.66	0.54	0.45	1.07	3.02	8.14

According to these results, the average eye glance duration to the IVD was well below 2 seconds for every alert type, the 85th percentile eye glance duration values were less than 2 seconds per alert type, and the average of the cumulative time spent glancing at the IVD for each 30 second period was less than 12 seconds for every alert. Therefore, all of the NHTSA distraction guidelines were met, which implies that the IVD would not be considered a source of distraction in this context. Future in-vehicle systems that require no or minimal driver interaction should produce similar distraction results based on eye glance behavior. Note that the IVD in this study was located above the center console and to the right of the steering wheel. Should manufacturers integrate future systems into the center stack, eye glance durations may be impacted.

Figure 22 depicts all of the eye glance durations towards the IVD for all participants and alert types. There were 10 total eye glance durations that were greater than the NHTSA guideline of 2 seconds. These glances accounted for 0.7% (10/1,412) of all glance durations towards the IVD for all participants, which means that 99.3% of the eye glances were within the distraction guidelines.

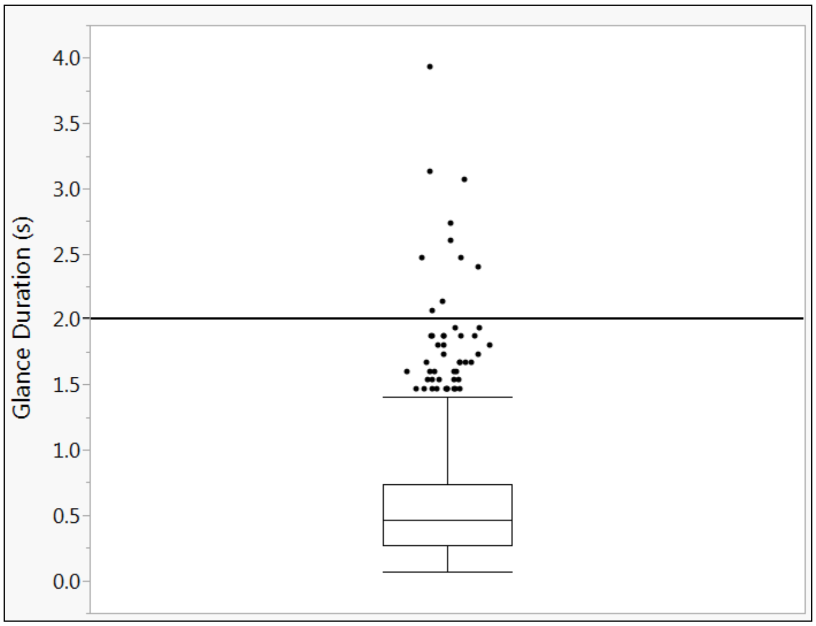

Figure 22. All glance durations towards IVD.

Since the eye glance duration data were skewed, the median duration values were also calculated to ensure that the guidelines were still met. In addition, the maximum cumulative time value over the 30-second interval was determined for each alert type. All of these values were still less than 12 seconds for all alert types.

There were three eye glance durations computed as zero. These glances came from three different alert types: speed limit, lane management, and VMS. The eye glance durations computed as zero for the speed limit and lane management alerts were both very quick glances just before the alert sounded; therefore, these glances were outside the 30-second time window and not included in the computation. The glance duration to the IVD calculated as zero for the VMS alert was rapid but was not complete by the end of the 30-second time window; therefore, this glance was also considered negligible and removed from the analysis.

There were three VMS “stopped traffic” alerts that did not deploy, most likely due to poor GPS reception (once during the a.m. peak, p.m. peak, and off-peak hour); therefore, there was no eye glance duration data for those three alerts.

2) Did alert type, age group, and/or time of day affect glance durations to the IVD?

Because sample size varied across comparison groups, it was difficult to visually determine significance simply based on the side-by-side box plots. As a result, a series of one-way and two-way Analysis of Variance (ANOVA) tests using JMP software were performed across the dataset to determine if alert type, age group, and/or time of day had an effect on participant eye glance durations. The ANOVA test allows the comparison of means across two or more groups (e.g., the effect of alert type on eye glance duration). A two-way ANOVA was applied when two variables were compared to eye glance duration (e.g., the effect of alert type and age group on glance duration) [19].

Before any statistical analysis methods were applied to the data, a log transformation on the IVD glance durations was performed to transform the raw data. The purpose of this log transformation was to stabilize the variances across groups within alert type, age group, and time of day in order to authorize the use of the ANOVA test [19]. Because each participant experienced each alert type along the route, the analysis had to account for repeated measures. Therefore, the participant ID was coded as a random effect in JMP since the research team was not interested in including the person-to-person variability in the significance tests. The random effect was coded slightly differently in JMP for the two-way analysis, which will be discussed in a later section.

Glance Duration vs. Alert Type

A one-way ANOVA test was run in JMP with the log of the duration values as the response variable. Figure 23 shows a boxplot of the glance durations for each alert type. The participant ID was included as a random effect. The following were the hypotheses (where μ_{LM} = mean glance duration to IVD following a lane management alert, μ_{SL} = mean eye glance duration to IVD following a speed limit alert, μ_{VMS} = mean eye glance duration to IVD following a VMS alert):

H_o: $\mu_{LM} = \mu_{SL} = \mu_{VMS}$
H_a: At least one mean glance duration differs across alert type.

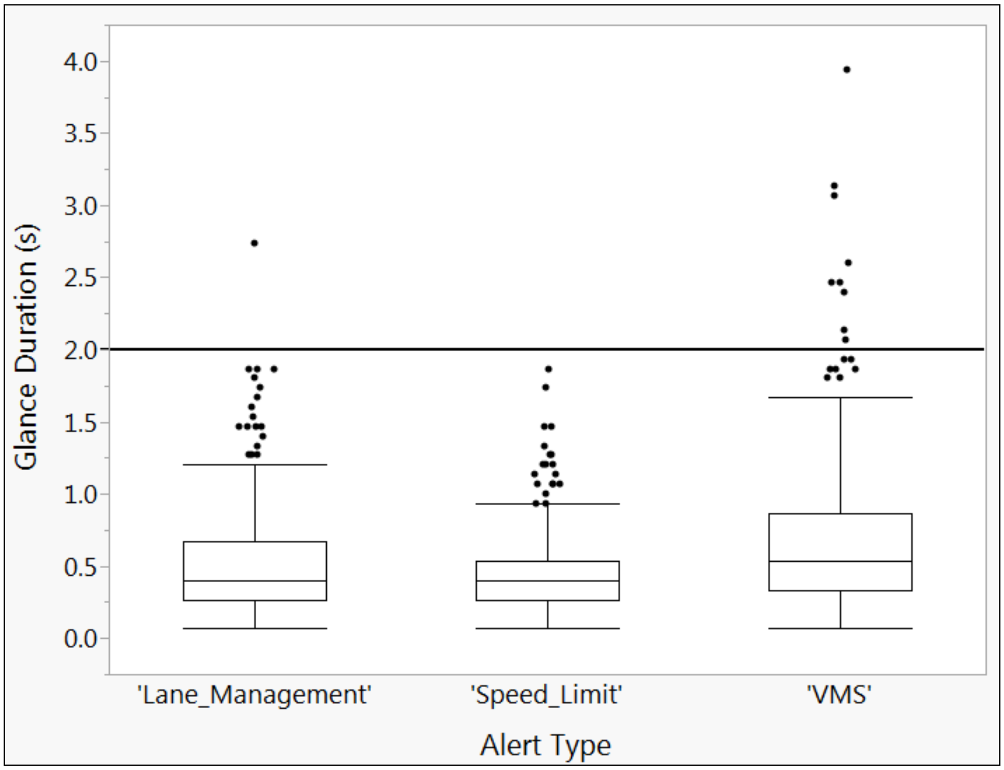

Figure 23. Glance duration vs. alert type.

Since the p-value (< 0.0001) was less than alpha (0.05), the null hypothesis is rejected; therefore, there is sufficient evidence to conclude that at least one mean glance duration differs across alert types.

In order to determine which specific alert grouping was significantly different, a supplemental statistical test, known as the Tukey-Kramer Method (also called Tukey's Honest Significant Difference), was implemented in JMP. This multiple comparison method was chosen since it provides less probability of a Type I error. This means there is less chance that the test will show a significant difference between two groups when there is not a significant difference in reality [19].

The results of the Tukey-Kramer method showed a significant difference in mean eye glance durations between the VMS and LM alerts (p-value < 0.0001) as well as the VMS and SL alerts (p-value < 0.0001). There was no significant difference between the mean eye glance durations between the SL and LM groups (p-value = 0.99). This finding was understandable since the VMS alerts presented various lines of text that turned the driver's attention to the display and caused longer glances. Note that the driver was not required to read the message on the screen as there was a redundant verbal message for all VMS alerts; however, many participants still glanced towards the display upon hearing the alert tone.

Glance Duration vs. Age Group

Another one-way ANOVA test was run in JMP with the log of the duration values as the response variable. Figure 24 displays the glance duration distributions across both age groups. The participant ID was included as a random effect. The following were the hypotheses (where μ_{Older} = mean eye glance duration to the IVD for the older participants, $\mu_{Younger}$ = mean eye glance duration to the IVD among the younger participants):

H_o: $\mu_{Older} = \mu_{Younger}$
H_a: The mean eye glance duration differs across age groups.

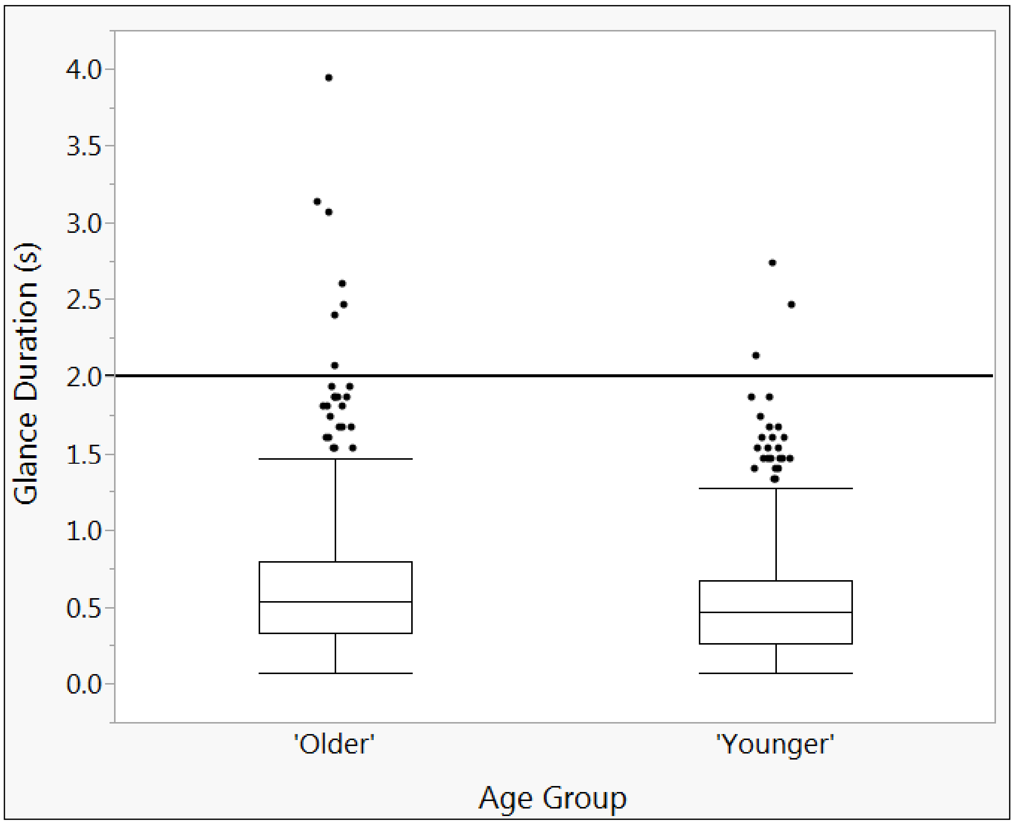

Figure 24. Glance duration vs. age.

Since the p-value (0.32) was greater than alpha (0.05), we fail to reject the null hypothesis; therefore, there is sufficient evidence to conclude that the difference in mean glance duration is not statistically significant between younger and older participants. In other words, participants had relatively the same eye glance durations regardless of their age.

Glance Duration vs. Time of Day

A one-way ANOVA test was run in JMP with the log of the duration values as the response variable. Figure 25 depicts the glance duration distributions across various times of day (a.m. peak, Off-peak, and p.m. peak). The participant ID was included as a random effect. The hypotheses were:

H_o: $\mu_{AM\ Peak} = \mu_{Off\text{-}Peak} = \mu_{PM\ Peak}$
H_a: At least one mean glance duration differs across time of day.

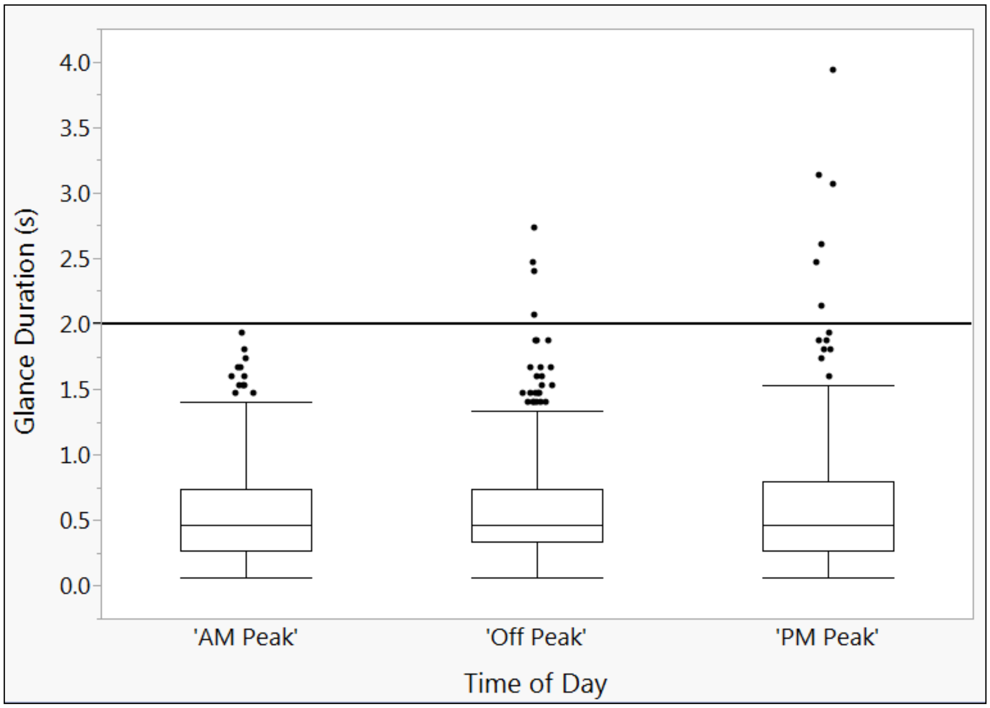

Figure 25. Glance duration vs. time of day.

Since the p-value (0.72) was greater than alpha (0.05), we fail to reject the null hypothesis; therefore, there is sufficient evidence to conclude that the difference in mean glance duration is not statistically significant among times of day. In other words, participant eye glance duration did not vary based on the time of day.

Glance Duration vs. Alert Type & Age Group

A two-way ANOVA test was run in JMP with the log of the duration values as the response variable. The participant ID was included as a nested random effect for all two-way tests, which is implemented differently by JMP than the random effect used previously in the one-way ANOVA tests. In the two-way case, an un-nested random effect would not be sufficient because JMP would not account for the repeated observations due to the crossed factors, denoted as "Alert * Age Group" in the JMP model. Therefore, the nested random effect was utilized so that the participant ID within each alert type as well as within each age group was considered random. This was important since the research team was not interested in variability across individuals in each category.

The hypotheses for the two-way ANOVA test were:

H_o: No interaction exists between alert type and age group
H_a: An interaction exists between alert type and age group

Since the p-value (0.74) was greater than alpha (0.05), we fail to reject the null hypothesis; therefore, there is sufficient evidence to conclude that there is no interaction between alert type and age group. This means that alert type and age group did not significantly affect the eye glance durations to the IVD when analyzed together.

Glance Duration vs. Time of Day & Age Group

A two-way ANOVA test was run in JMP with the log of the duration values as the response variable. The participant ID was included as a nested random effect. This means that the participant ID within each age group and each time of day was considered random since the research team was not interested in variability across individuals in each category. The hypotheses were:

H_o: No interaction exists between time of day and age group
H_a: An interaction exists between time of day and age group

Since the p-value (0.43) was greater than alpha (0.05), we fail to reject the null hypothesis; therefore, there is sufficient evidence to conclude that there is no interaction between time of day and age group. This means that time of day and age group did not significantly affect the eye glance durations to the IVD when analyzed together.

Glance Duration vs. Time of Day & Alert Type

A two-way ANOVA test was run in JMP with the log of the duration values as the response variable. The participant ID was included as a nested random effect. This means that the participant ID within each time of day and each alert type was considered random. The hypotheses were:

H_o: No interaction exists between time of day and alert type
H_a: An interaction exists between time of day and alert type

Since the p-value (0.90) was greater than alpha (0.05), we fail to reject the null hypothesis; therefore, there is sufficient evidence to conclude that there is no interaction between time of day and alert type. This means that time of day and alert type did not significantly affect the eye glance durations to the IVD when analyzed together.

3) Were the IVD alerts perceived as overly distracting and/or annoying?

Along the drive, each participant was presented with various alerts. The alert descriptions are presented in Table 6.

Table 6. IVD Alerts

Category	Type	Tone/Verbal Description
Lane Management (LM)	Onset	"Ding" + Blinking red 'X' symbol
	Offset	"Ding" + Blinking green 'O' symbol
Speed Limit (SL)	Increase	"Ding" + "The speed limit is now 60 mph."
	Decrease	"Ding" + "The speed limit is now 55 mph."
Variable Message Signs (VMS)	#1	"Ding" + "Route 29. 6 miles. 15 minutes."
	#2	"Ding" + "Accident ahead. 30 minute delay. Take Exit 47A."
	#3	"Ding" + "Stopped traffic. 5 miles."
	#4	"Ding" + "Detour ahead. Take Exit 66."

The surveys asked participants to respond to questions and/or statements using a Likert-type Scale from 1–5 (the scale is further explained in later sections). Wilcoxon signed rank tests were run on the dataset using JMP software in order to determine if the alerts were distracting based on various survey responses. This test is the non-parametric version of the t-test and assumes that the underlying population of differences is symmetric about the unknown median (not necessarily normally distributed) [19]. The goal of the Wilcoxon signed rank test is to observe how the sample median compares to a certain value (in this case the value is 3). An alpha value of 0.05 was utilized for all Wilcoxon signed rank tests.

All of the alerts could be considered somewhat distracting since the alerts did remove the driver's attention from the roadway. However, since the alerts provided drivers with relevant information, some participants may have viewed this level of distraction as acceptable. Therefore, participant distraction ratings of "1" (not at all distracting) and "2" (somewhat distracting) were both considered desirable responses.

All Wilcoxon signed rank tests used the following hypotheses (where m = median):

H_o: m >= 3
H_a: m < 3

In-Vehicle Survey Questions

Along the drive, each participant was asked to rank each alert's distraction level from 1–5. The following question was asked after each alert sounded: "How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?"

Table 7 displays all of the statistical test results. All of the p-values (< 0.0001) were less than alpha (0.05); therefore, the null hypotheses were rejected. There is sufficient evidence to conclude that the alerts were not distracting according to participant in-vehicle survey responses.

Table 7. Summary of Wilcoxon Test Results for All In-Vehicle Distraction Survey Questions

Category	Type	Median	Standard Deviation	Sample Size	P-Value	Significant?
Lane Management (LM)	Onset	2.00	0.96	60	< 0.0001	Yes
	Offset	1.00	0.86	60	< 0.0001	Yes
Speed Limit (SL)	Increase	1.00	0.78	40	< 0.0001	Yes
	Decrease	1.00	0.96	40	< 0.0001	Yes
Variable Message Signs (VMS)	#1	2.00	0.96	40	< 0.0001	Yes
	#2	1.00	0.91	40	< 0.0001	Yes
	#3	1.00	0.84	37	< 0.0001	Yes
	#4	1.00	0.67	40	< 0.0001	Yes

Note that there are three missing data points in the VMS #3 category. There were three VMS "stopped traffic" alerts that did not deploy, most likely due to poor GPS reception (once during the a.m. peak, p.m. peak, and off-peak hour); therefore, three participants did not have "distraction" ratings for that particular alert.

Post-Drive Survey: Speed Limit (SL) In-Vehicle Alert

On the post-drive survey, each participant was asked to rank the following statement from 1–5 ("1" = not at all, "3" = moderately, "5" = highly): "How distracting and/or annoying was the in-vehicle speed limit alert?" A Wilcoxon test was performed for all three traffic level conditions, and the speed limit alert was deemed neither distracting nor annoying (m = 1.00, SD = 0.79, p-value = < 0.0001, N = 39). There was one participant who responded with two different rankings for this survey question: "4" and "1." The participant explained they would have ranked the alert as a "4" based on their initial assessment and a "1" based on their final assessment of the alert. This data point was excluded from the analysis since there was no clear-cut value provided by the participant.

The post-drive survey asked each participant to explain which aspect of the alert was distracting and/or annoying only if their response was "3" or higher. The following choices were given on the survey, and participants were instructed to "check all that apply":

- The auditory "ding" prior to the verbal message
- The verbal/voice message
- Other

Of the five participants who responded with "3" or higher distraction and/or annoyance level, three participants attributed it to the auditory "ding" prior to the verbal messages while the remaining two cited the verbal/voice message. The tone of the "ding" as well as the voice can be altered for future systems. Another option could be to provide users with multiple options of "dings" and voices so they could choose the combination that suits them.

Post-Drive Survey: Variable Message Sign (VMS) In-Vehicle Alert

On the post-drive survey, each participant was asked to rank the following statement from 1–5 ("1" = not at all, "3" = moderately, "5" = highly): "How distracting and/or annoying was the in-vehicle Variable Message Sign (VMS) alert?" A Wilcoxon test was performed for all three traffic level conditions, and the VMS alert was deemed neither distracting nor annoying (m = 1.00, SD = 0.68, p-value = < 0.0001, N = 40).

Only two participants ranked the level of distraction of the Variable Message Signs (VMS) alerts as a "3" or higher. The post-drive survey asked each participant to explain which aspect of the alert was distracting and/or annoying only if their response was "3" or higher. The following choices were given on the survey, and participants were instructed to "check all that apply":

- The auditory "ding" prior to the verbal message
- The verbal/voice message
- Other

Those two participants who responded with "3" or higher distraction and/or annoyance level both said it was due to the auditory "ding" prior to the verbal message. Much like the speed limit alerts, the tone of the "ding" and the voice can be altered for future systems. Providing multiple options for the user could also improve the alert system as a whole.

Post-Drive Survey: Lane Management (LM) In-Vehicle Alert

On the post-drive survey, each participant was asked to rank the following statement from 1–5 ("1" = not at all, "3" = moderately, "5" = highly): "How distracting and/or annoying was the in-vehicle lane management alert?" A Wilcoxon test was performed for all three traffic level conditions, and the lane management alert was deemed neither distracting nor annoying (m = 1.00, SD = 0.75, p-value = < 0.0001, N = 40).

Four participants ranked the level of distraction of the Variable Message Signs (VMS) alerts as a "3" or higher. The post-drive survey asked each participant to explain which aspect of the alert was distracting and/or annoying only if their response was "3" or higher. The following choices were given on the survey, and participants were instructed to "check all that apply":

- The auditory "ding" prior to the flashing symbol
- The flashing symbol
- Other

Three out of those four participants who responded with a "3" or higher distraction and/or annoyance level all said it was due to the auditory "ding" prior to the flashing symbol, which can be altered in future models. The remaining participant explained their ranking as "Other." This participant commented that the alert was "not necessarily annoying but not very accurate…the system did not indicate exit lanes or temporary lanes." Currently, the IVD only shows the travel lanes. Indicating exit lanes and temporary lanes along I-66 with additional symbols could be another area of improvement for the system in the future.

Post-Drive Survey: HOV In-Vehicle Alert

On the post-drive survey, the a.m. and p.m. peak hour participants were asked to rank the following statement from 1–5 ("1" = not at all, "3" = moderately, "5" = highly): "How distracting and/or annoying was the presentation of the HOV information?" The off-peak hour participants were not asked this question since they never experienced the in-vehicle HOV symbols due to the time of day. A Wilcoxon test was performed for only the a.m. and p.m. peak traffic level conditions, and the presentation of the HOV information was deemed neither distracting nor annoying (m = 1.00, SD = 0.31, p-value = < 0.0001, N = 20).

Summary of All In-Vehicle Alerts

Based on the Wilcoxon signed rank test results in Table 8, all alerts were deemed neither distracting nor annoying to participants. Figure 26 and Figure 27 visually depict the participant survey responses.

Table 8. Summary of Wilcoxon Results for All In-Vehicle Alerts

In-Vehicle Alert Type	Median	Standard Deviation	Sample Size	P-Value	Significant?
Speed Limit (SL)	1.00	0.79	39	< 0.0001	Yes
Variable Message Signs (VMS)	1.00	0.68	40	< 0.0001	Yes
Lane Management (LM)	1.00	0.75	40	< 0.0001	Yes
HOV	1.00	0.31	20	< 0.0001	Yes

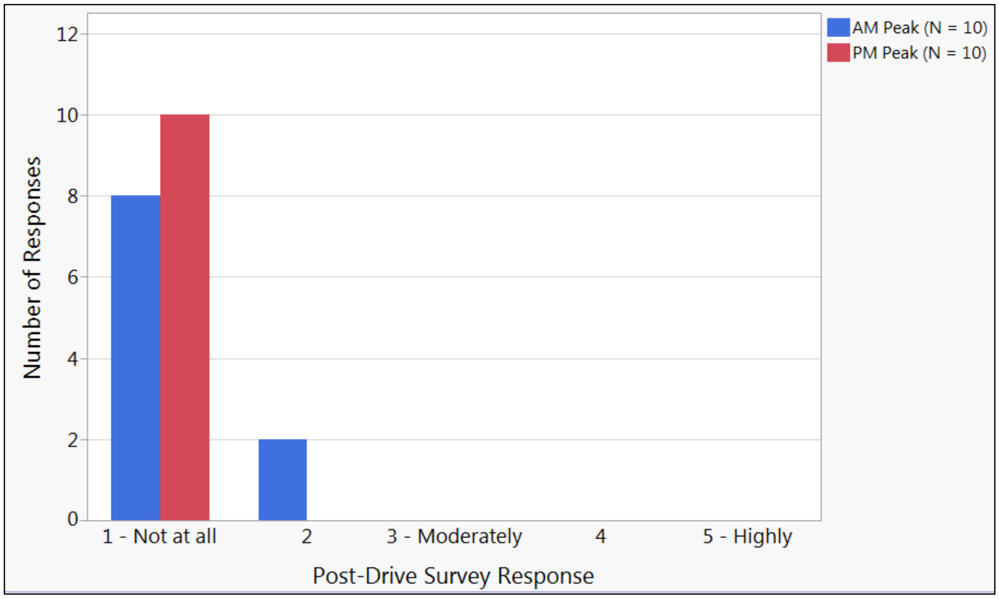

Figure 26. Level of distraction of HOV presentation – survey responses.

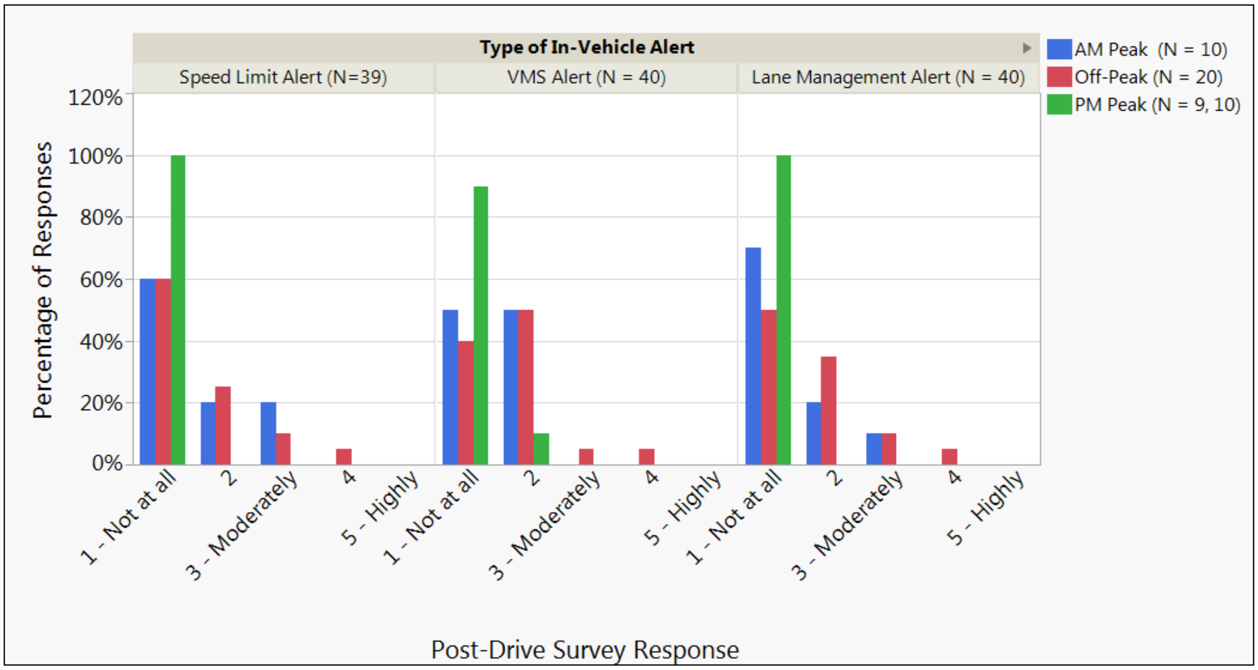

Figure 27. Level of distraction of SL, VMS, LM alerts – survey responses.

4) Did drivers find the IVD gave them relevant, clear information?

Along the drive, each participant was asked to rank each alert's usefulness from 1–5. The following question was asked after each alert sounded: "How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?" A Wilcoxon test was run on each alert to determine significance. The following hypotheses were used for all tests (where m = median):

H_o: m <= 3
H_a: m > 3

Table 9 displays all of the statistical test results. All of the p-values (< 0.0001) were less than alpha (0.05); therefore, the null hypotheses were rejected. There is sufficient evidence to conclude that drivers believed the IVD gave them relevant, clear information.

Table 9. Summary of All Wilcoxon Test Results for In-Vehicle Usefulness Survey Questions

Category	Type	Median	Standard Deviation	Sample Size	P-Value	Significant?
Lane Management (LM)	Onset	5.00	0.50	58	< 0.0001	Yes
	Offset	5.00	0.64	59	< 0.0001	Yes
Speed Limit (SL)	Increase	5.00	0.40	40	< 0.0001	Yes
	Decrease	5.00	0.32	39	< 0.0001	Yes
Variable Message Signs (VMS)	#1	5.00	0.91	39	< 0.0001	Yes
	#2	5.00	0.43	40	< 0.0001	Yes
	#3	5.00	0.54	37	< 0.0001	Yes
	#4	5.00	0.27	40	< 0.0001	Yes

Note that there are three missing data points in the VMS #3 category. There were three VMS "stopped traffic" alerts that did not deploy, most likely due to poor GPS reception (once during the a.m. peak, p.m. peak, and off-peak hour); therefore, three participants did not have "usefulness" ratings for that particular alert. There was one participant who responded with a fraction ("3.5" instead of "3" or "4"). This data point was removed from the analysis. In addition, four participants responded with multiple numbers to the same question ("relevance = 2, clarity = 5"), so these values were excluded as well. In future studies, the research team would ensure that each participant response follows the same rules (no fractions, only one value per ranking, etc.).

Desirability

The following research questions were outlined to determine if the system was desirable to participants and to define any suggestions for improvement:

1) Would drivers like to have the IVD in their own vehicle?
2) What changes would participants make to improve the current system?
3) How much money would drivers be willing to pay for the in-vehicle system?

4) Which IVD alert approach did drivers prefer, if any?

1) Would drivers like to have the IVD in their own vehicle?

All participants were asked to rank the following statement from 1–5 (“1” = strongly disagree, “3” = neutral, “5” = strongly agree) on the post-drive survey: “I would want this in-vehicle technology in my next vehicle.” Participants were instructed to “circle one.”

Seventy-three percent of the participants responded with a “4” or a “5.” Both Table 10 and Figure 28 show that a majority of participants would like to have the IVD in their next vehicle in all three traffic conditions. All but one participant responded with a “3” or higher.

Table 10. Statistics for IVD Desirability - Time of Day

Condition	Mean Rating	Median Rating	Standard Deviation	Sample Size
a.m. Peak	4.00	4.00	1.05	10
Off-Peak	4.10	4.00	0.85	20
p.m. Peak	4.10	4.00	0.74	10

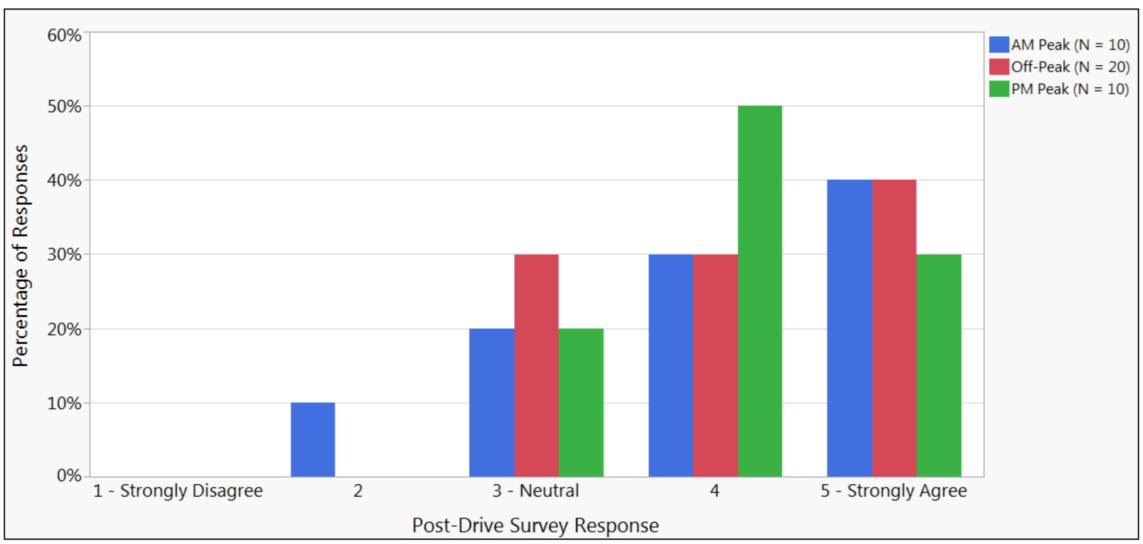

Figure 28. I would want this in-vehicle technology in my next vehicle - time of day.

Table 11 and Figure 29 show participant ratings based on age group. The younger age group had a slightly higher rating (mean = 4.15) than the older age group (mean = 4.00). However, it seems that the participants would like to have the IVD in their next vehicle regardless of their age group. All but one, older, participant responded with a “3” or higher.

Table 11. Statistics for IVD Desirability - Age Group

Condition	Mean Rating	Median Rating	Standard Deviation	Sample Size
Younger	4.15	4.00	0.81	20
Older	4.00	4.00	0.92	20

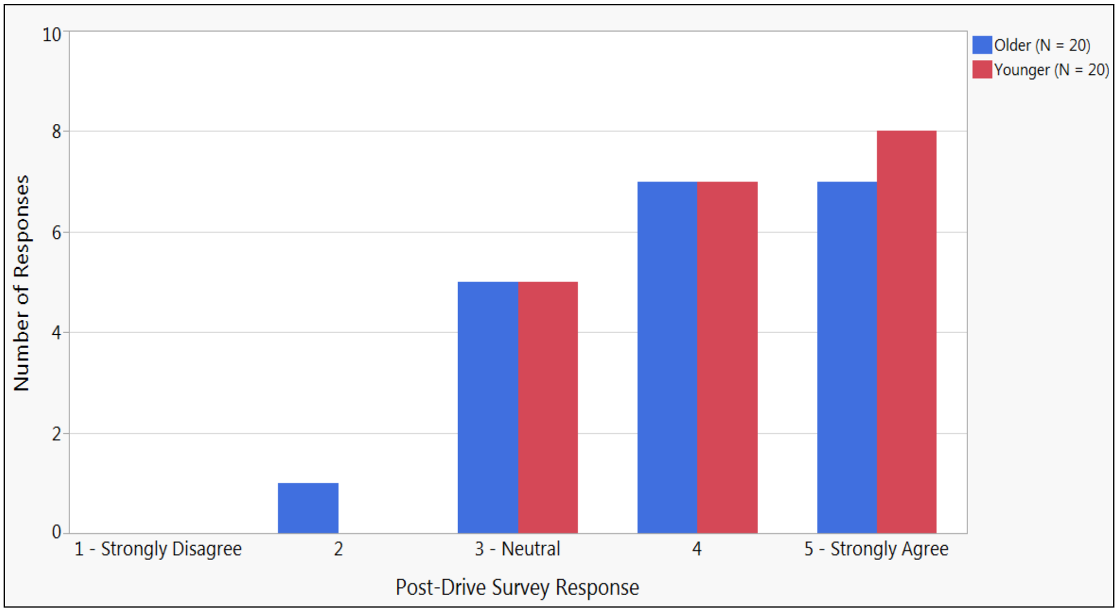

Figure 29. I would want this in-vehicle technology in my next vehicle - age group.

All participants who responded with a "3 or lower" rating were asked which of the following explained their rating (participants were instructed to "check all that apply"):

- The system as a whole was distracting
- The information was not clear and concise
- The system did not provide information that is important to me
- Other

According to Figure 30, 61% of responses from participants with ratings of "3 or lower" cited another reason for their response. Many of the "other" responses said they would want to see the system integrated with another navigational device. Several mentioned other applications such as Google Maps and Waze that already provide similar information. Thirty-one percent of responses indicated that the system did not provide information that was important to participants (or not every piece of information from the IVD was important to them).

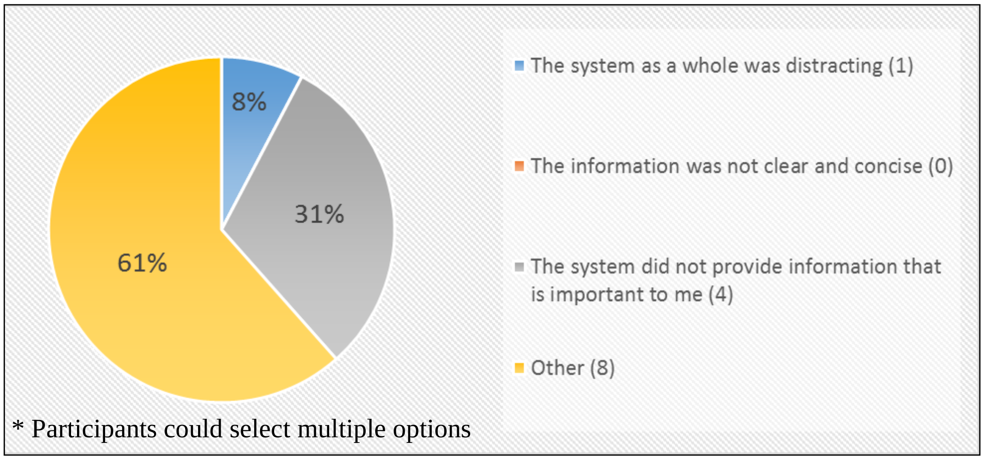

Figure 30. I would want the IVD in my next vehicle - responses of "3 or lower."

Another question on the post-drive survey asked all participants to rank the following statement from 1–5 (“1” = strongly disagree, “3” = neutral, and “5” = strongly agree): “The in-vehicle system gave me information that I am interested in.” Participants were told to “circle one.” Both Figure 31 and

Table **12** shows that most participants believed that the in-vehicle system gave them information that they were interested in. All but one participant responded with a “3” or higher.

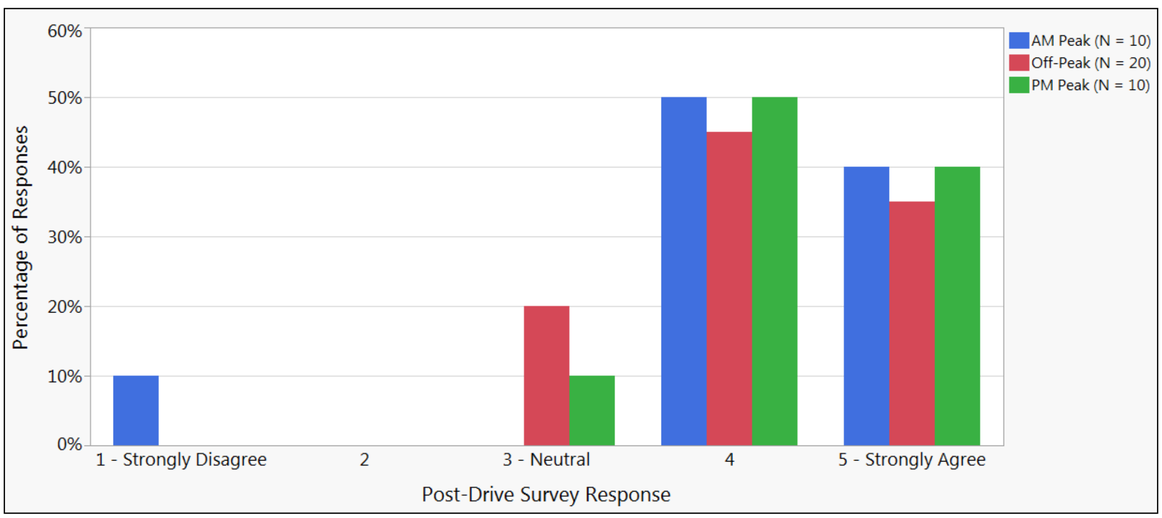

Figure 31. The in-vehicle system gave me information that I am interested in.

Table 12. Statistics for Desirability of IVD Information

Condition	Mean Rating	Median Rating	Standard Deviation	Sample Size
a.m. Peak	4.10	4.00	1.20	10
Off-Peak	4.15	4.00	0.75	20
p.m. Peak	4.30	4.00	0.67	10

Participants who responded with a “3 or lower” rating were asked which aspects of the in-vehicle system they were not interested in and to “check all that apply.” The a.m./p.m. peak hour participants had the following four options:

- Speed Limit
- Variable Message Signs
- Lane Management
- HOV

The off-peak participants only had three options since there was no HOV information throughout their route:

- Speed Limit
- Variable Message Signs
- Lane Management

There were only two a.m./p.m. peak hour participants who responded with “3 or lower.” The a.m. peak hour participant was not interested in the speed limit information; the p.m. peak hour participant was not interested in HOV information.

There were only four off-peak hour participants who responded with “3 or lower.” One participant said they were not interested in the speed limit information and three were not interested in the lane management information. Note that none of the participants said they were not interested in the Variable Message Sign information. Table 13 summarizes the results.

Table 13. The IVD Gave Me Information That I Am Interested In - Responses of "3 or Lower"

Condition	Speed Limit	VMS	Lane Management	HOV
a.m. Peak	1	-	-	-
Off-Peak	1	-	3	-
p.m. Peak	-	-	-	1

Each participant was asked to respond to the following question on both the pre-drive and post-drive questionnaires: “If an in-vehicle system existed that would give you information on HOV hours, lane management, speed limit, and variable message signs, would you use it?” Participants were instructed to circle either “yes” or “no” and then explain their response in their own words (i.e. no answer choices were provided). Due to the nature of free response questions, participant comments varied. During the analysis stage, all similar participant responses were grouped together in cases where participants provided comparable comments. The response variation was not necessarily related to the participant’s experiences throughout the study.

On the pre-drive survey, 39 out of 40 participants replied with "yes" while one participant said "maybe," which shows that there was great interest in the potential for the IVD prior to the beginning of the experiment. Participants believed the IVD could:

- Provide decision-making information in advance (15)
- Help to avoid accidents and/or have detour information (6)
- Have accurate/updated information (5)
- Simplify the driving experience (2)
- Assist in unfamiliar areas (2)
- Remind drivers to follow roadway regulations (2)
- Deliver information better than overhead signs (2)

On the post-drive survey, 39 out of 40 participants said "yes." One participant responded with "maybe" (different than the participant who responded with "maybe" in the pre-drive survey), stating that the system had high potential but still needed some work. These results show that participants were still interested in using the IVD after experiencing the system along the study route. Participants would utilize the in-vehicle system because it could:

- Provide decision-making information in advance (4)
- Help to avoid accidents and/or have detour information (6)
- Have accurate/updated information (6)
- Simplify the driving experience (3)
- Assist in unfamiliar areas (4)
- Remind drivers to follow roadway regulations (2)
- Be incorporated with a GPS system (5)
- Cause less distraction (2)

2) What changes would participants make to improve the current system?

HOV In-Vehicle Alert

On the post-drive survey, all a.m. and p.m. peak hour participants were asked, "Is there anything you would change about the HOV information and/or how it was presented?" The following choices were given and participants were instructed to "check all that apply":

- I would not change anything about the current system
- Add an auditory "ding" when the system updates
- Add a verbal/voice alert when the system updates
- Have the HOV symbol flash when the system updates
- I would rather NOT have HOV information
- Other

Based on Figure 32, 26% of participant responses showed that they would add an auditory "ding" when the system updates. Another 26% of responses indicated that participants would have the HOV symbol flash when the system updates. In 22% of responses, participants said they would not change anything about the current system. This spread of opinions further supports the claim that adding flexibility to the alert system would be important. Allowing users to choose the alert type and tone could draw more users to the system and provide an incentive for the continued use of the system.

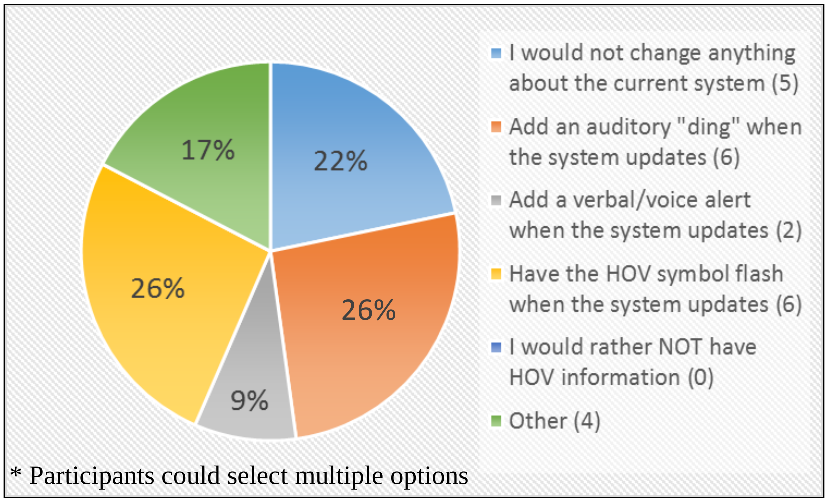

Figure 32. Changes to the display of HOV information.

In-Vehicle Alert System

On the post-drive survey, all participants were asked the following question: "Is there anything you would change about the in-vehicle alert system?" The following options were given, and participants were instructed to "check all that apply":

- I would not change anything about the current system
- I would alter the speed limit alert
- I would alter the Variable Message Sign alert
- I would alter the lane management alert
- Other

According to Figure 33, 31% of participant responses indicated that they were satisfied with the way the alert system was programmed during the study and would not change anything. However, approximately 60% of responses suggested that participants would change something about the speed limit, VMS, and/or lane management alerts.

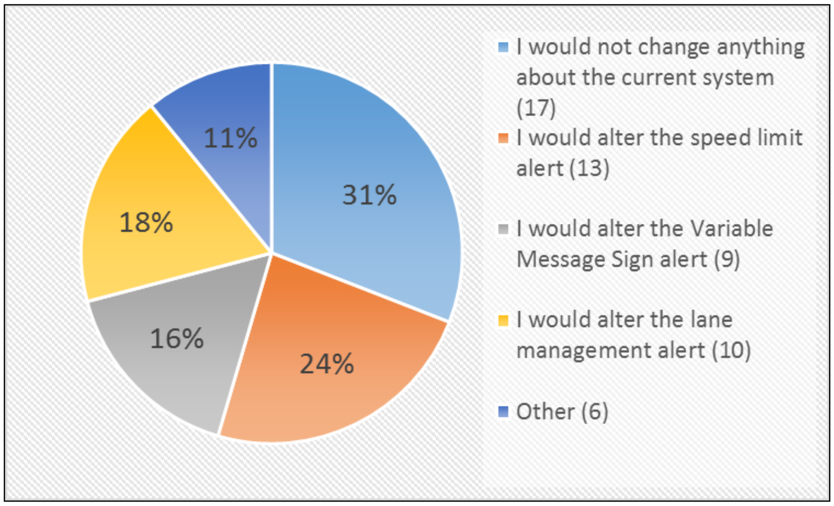

Figure 33. Changes to the in-vehicle alert system.

Participants who would alter one or more alerts were asked to explain their responses further. A common response for all three alert types was to utilize a less abrupt alert tone and/or allow the user to remove the "ding" completely or choose their own tone. One participant recommended providing tones that are unique to each alert type. For example, all the speed limit alerts would have their own tone and all the VMS alerts would have a different tone, etc.

Participants gave various suggestions for improving the speed limit alert specifically. The most popular comment was to provide the warning sooner to allow more time to absorb and react to the new information. Another suggestion was to display the participant's current speed along with the speed limit. A couple of participants mentioned including color changes on the speed limit sign (red = speeding, etc.).

Ideas for improving the VMS alerts included adding more details to the messages (how many miles until exit, congestion due to roadwork, etc.) and allowing messages to remain on the display longer. One participant suggested adding a verbal message to the lane management alert. For example, when the rightmost lane status changes from "closed" to "open," the system would deliver a verbal message such as "Rightmost lane is now open."

Entire In-Vehicle System

Additionally, all participants were asked the following question on the post-drive survey: "Is there anything you would change about the entire in-vehicle system?" This question was open-ended. Forty-two percent of participants said they would not change anything about the entire in-vehicle system. Approximately 13% of participants mentioned incorporating the IVD with an existing GPS system to provide navigation as an additional tool. Another 10% of participants would like more information displayed in the Variable Message Signs. For example: number of miles to the exit, congestion ahead due to accident/roadwork/volume, etc.

The remaining participants suggested the following ways to further develop the current system:

- Less abrupt alert tone
- Provide warnings sooner
- Change location of the system in the vehicle
- Add ability to adjust volume of system
- Haptic alert instead of "ding"
- Add more verbal messages
- Provide unique tones for each alert

3) How much money would drivers be willing to pay for the in-vehicle system?

On the post drive survey, each participant was asked to rate the following statement from 1–5 ("1" = strongly disagree, "3" = neutral, and "5" = strongly agree): "I would want this in-vehicle technology in my next vehicle." Only the participants who rated this question with a "4 or higher" were then asked to answer the following question: "Approximately how much money would you be willing to pay for this in-vehicle technology?"

Based on Figure 34, 27 participants gave price ranges for how much money they would be willing to pay for the in-vehicle system. Note that two participants did not provide a dollar range, so their responses could not be included in this evaluation. Out of the 27 participant responses, 48% were willing to pay $100–$500 for the in-vehicle system. This provides some assurance that the general population would be willing to pay for the information that this in-vehicle system offers.

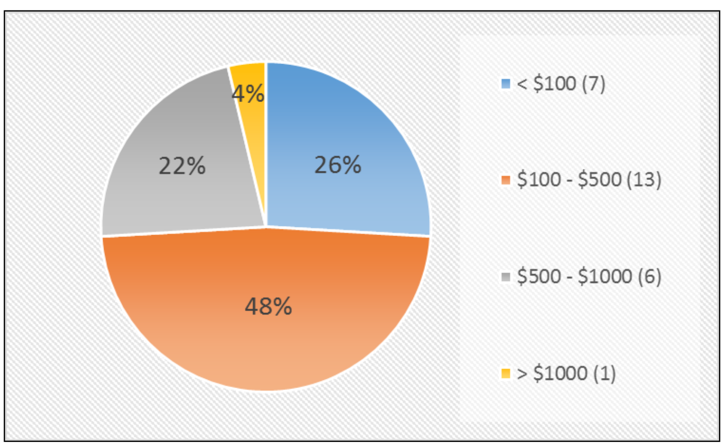

Figure 34. How much money participants are willing to pay for system.

4) Which IVD alert approach did drivers prefer, if any?

On the post-drive survey, the a.m. and p.m. peak hour participants were asked the following question: "Which notification style did you prefer?" The following options were given on the survey (participants were instructed to "check one"):

- Ding + Voice
- Ding + Flashing Symbol
- No Alert

There were three VMS "stopped traffic" alerts that did not sound, which were classified in the "Ding + Voice" category. However, all VMS and speed limit alerts had the "Ding + Voice" feature; therefore, it is unlikely that these missing alerts would have a large impact on the final notification style preferences.

According to the bar chart in Figure 35, the preferred alert among the a.m. and p.m. peak hour participants was the "Ding + Voice" alert (13/20 = 65%). Note that alert presentation varied across alert type; however, the "Ding + Voice" alert was preferred overall.

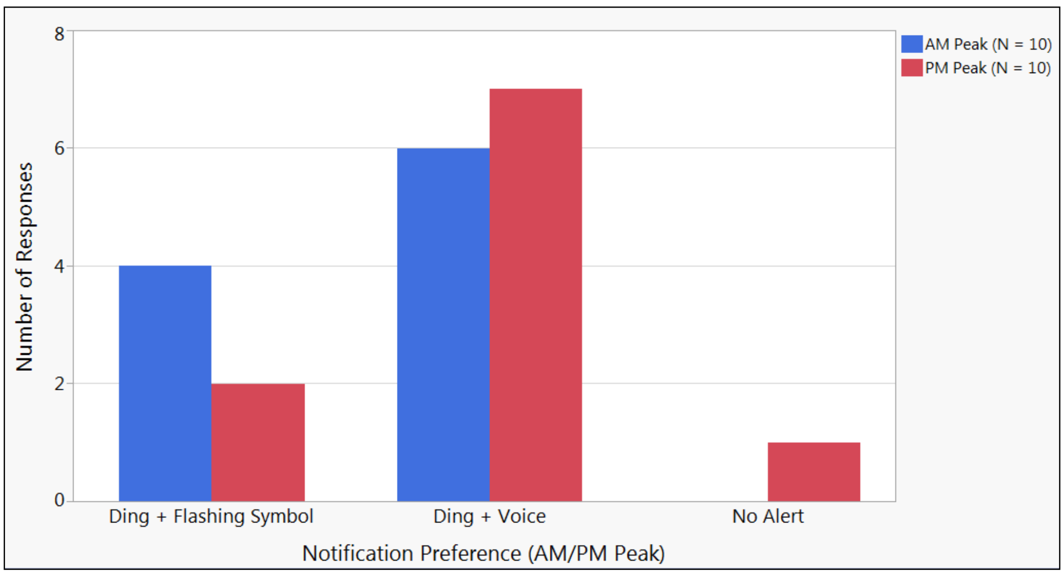

Figure 35. Alert style preference a.m./p.m. peak hour participants.

On the post-drive survey, the off-peak hour participants were asked the same question: "Which notification style did you prefer?" However, the response options were different since the off-peak hour participants never experienced the presentation of HOV information (no alert). Therefore, only two options were given (participants were instructed to "check one"):

- Ding + Voice
- Ding + Flashing Symbol

The bar chart in Figure 36 shows that the off-peak participants also preferred the “Ding + Voice” alert style (14/19 = 74%). The speed limit and the VMS alerts displayed this alert style. Note that alert presentation varied across alert type; however, the “Ding + Voice” alert was preferred overall.

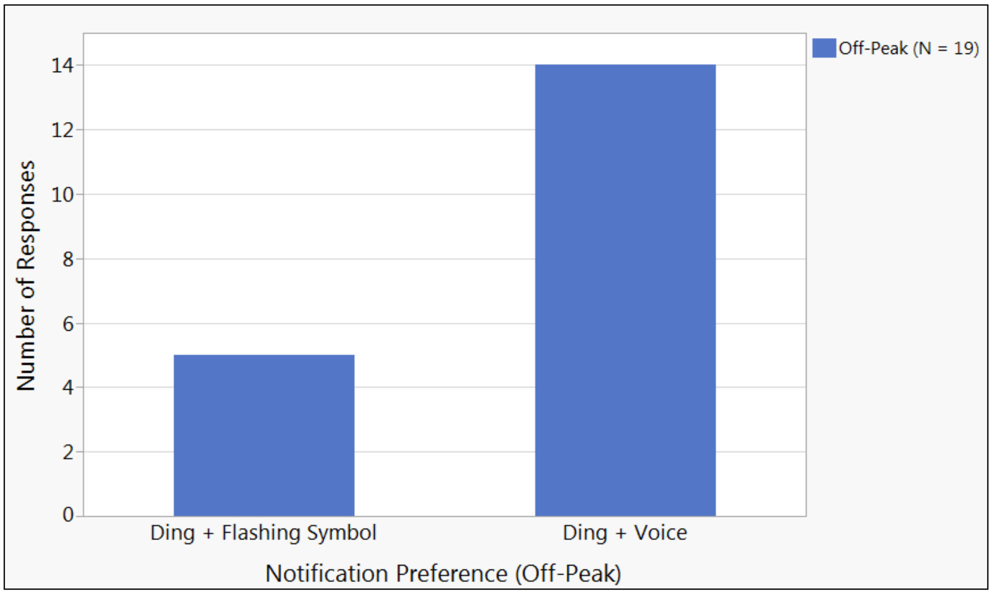

Figure 36. Alert style preference for off-peak hour participants.

Note that there was one participant missing from the data analysis results (N = 19). This participant stated that they would prefer that the “ding” was removed and only the voice remained. This option was not given on the post-drive questionnaire, so this response was excluded from the analysis.

Another question on the post-drive survey asked a.m. and p.m. participants to, “Rank the following alerts from ‘most useful’ to ‘least useful.’ (Rank from 1–4, where 1 is the least useful and 4 is the most useful).” The following alerts were ranked:

- Speed Limit
- Variable Message Signs
- Lane Management
- HOV

Figure 37 and Table 14 display the alert type preference results for peak hour participants. The a.m. peak hour participants seemed to favor the speed limit alert, as 60% of the respondents ranked it as the most useful when compared against the other alerts. In contrast, 65% of the p.m. peak hour participants ranked the speed limit alert as the *least* useful among all the alerts presented. In addition, approximately half of the p.m. peak hour participants found the VMS alerts to be the most useful.

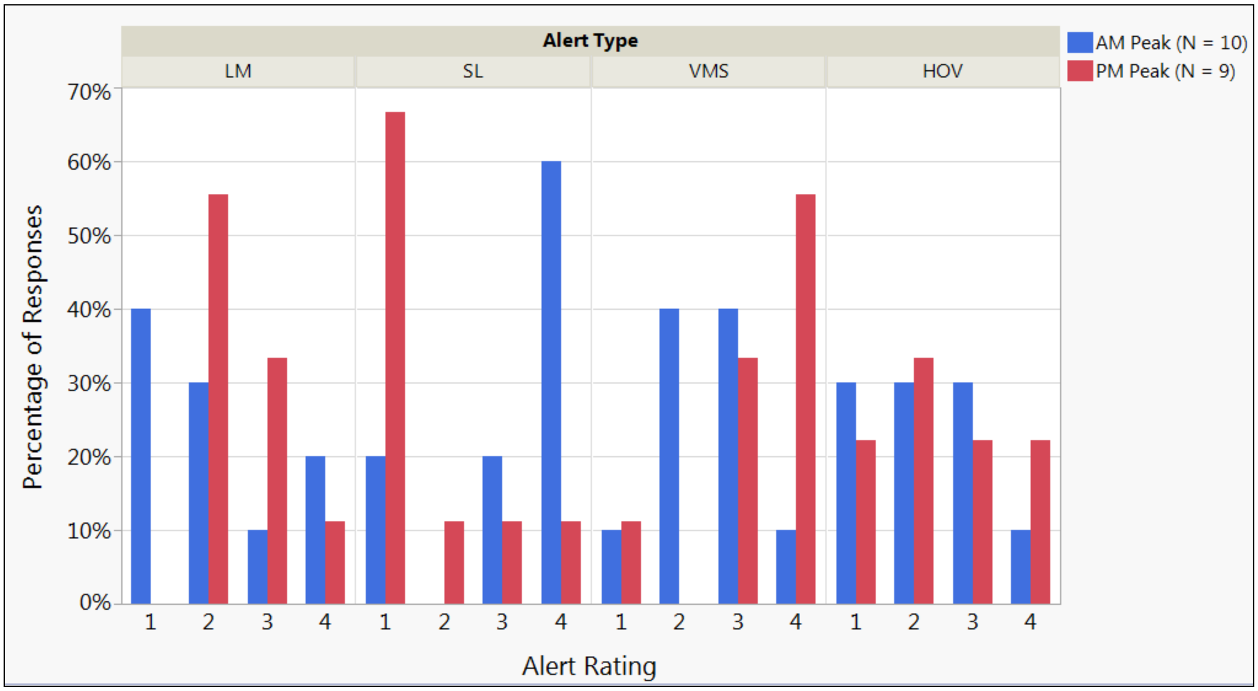

Figure 37. Alert type preference for a.m./p.m. peak hour participants.

Table 14. Statistics for Alert Type Preference (a.m./p.m. Peak)

In-Vehicle Alert Type	Condition	Mean Alert Rating	Standard Deviation	Sample Size
Lane Management (LM)	a.m. Peak	2.10	1.20	10
	p.m. Peak	2.56	0.73	9
Speed Limit (SL)	a.m. Peak	3.20	1.23	10
	p.m. Peak	1.67	1.12	9
Variable Message Signs (VMS)	a.m. Peak	2.50	0.85	10
	p.m. Peak	3.33	1.00	9
High Occupancy Vehicle (HOV)	a.m. Peak	2.20	1.03	10
	p.m. Peak	2.44	1.13	9

Note that there is one participant missing from the p.m. peak hour data (N = 9). This participant's data was excluded from the analysis because their response was invalid. The participant ranked the speed limit alert a "5" and the other three alerts a "4." In the future, the research team would ensure that the survey instructions were clearer to indicate that all four numbers between 1 and 4 should be used once.

Off-peak participants were also asked to, "Rank the following alerts from 'most useful' to 'least useful.' (Rank from 1–3, where 1 is the least useful and 3 is the most useful)." Since the off-peak participants were never presented with HOV information, only the following alerts were ranked:

- Speed Limit
- Variable Message Signs
- Lane Management

Figure 38 and Table 15 present the alert type preference responses for off-peak hour participants. The off-peak hour participants provided mixed results on whether the VMS alerts were the most or least important. The lane management alert tended to be the least useful while the speed limit alert seemed to be more important.

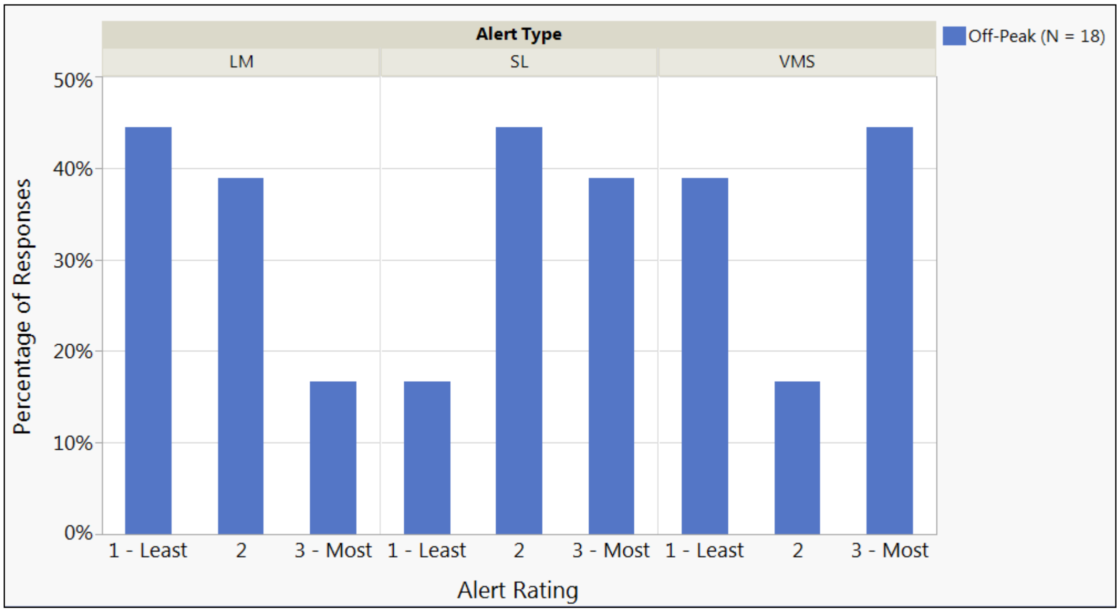

Figure 38. Alert type preference for off-peak hour participants.

Table 15. Statistics for Alert Type Preference (Off-Peak)

In-Vehicle Alert Type	Mean Alert Rating	Standard Deviation	Sample Size
Lane Management (LM)	1.72	0.75	18
Speed Limit (SL)	2.22	0.73	18
Variable Message Signs (VMS)	2.06	0.94	18

Note that there were two participants missing from the off-peak hour data (N = 18). These participants' data was excluded from the analysis because their responses were invalid. The participants ranked the speed limit and VMS alerts a "3" and the lane management alert a "2." In the future, the research team would ensure that the survey instructions were clearer to indicate that all three numbers between 1 and 3 should be used once.

Driver Behavior

The following research questions were designed to understand how the IVD affected driver behavior:

1) Did the speed limit alert elicit a change in speed?
2) Did alert type affect glance duration to the instrument cluster?
3) Did drivers comprehend the Variable Message Signs?

1) Did the speed limit alert elicit a change in speed?

Post-Drive Survey

On the post-drive survey, each participant was asked to rank the following statement from 1–5 ("1" = strongly disagree, "3" = neutral, and "5" = strongly agree): "The speed limit alert system motivated me to change my speed." The following hypotheses were used for this analysis:

H_o: m <= 3
H_a: m > 3

A Wilcoxon test was performed for all three traffic level conditions, and the speed limit alert significantly motivated the participants to change their speed (*m* = 3.00, SD = 1.28, p-value = 0.023). Figure 39 displays the results across times of day.

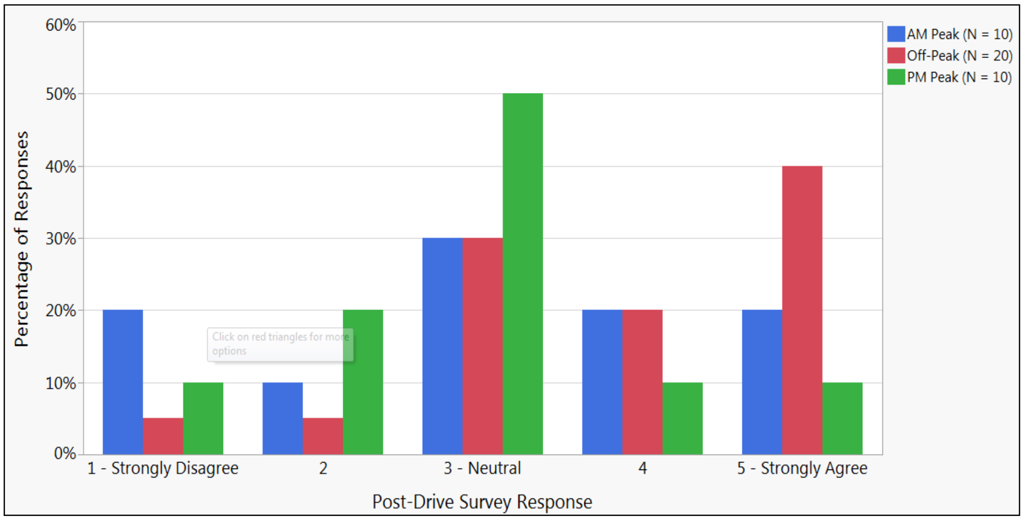

Figure 39. The speed limit alert system motivated me to change my speed.

Twenty-two participants ranked their motivation to change their speed as “3” or lower. The post-drive survey asked each participant to explain their response only if their ranking was “3” or lower. The following choices were given on the survey (participants were instructed to “check all that apply”):

- ☐ I was already going the speed limit
- ☐ I was not traveling much faster than the speed limit
- ☐ I alter my speed based on surrounding vehicle speeds, not the speed limit
- ☐ Other

According to Figure 40, 44% of participant responses explained that they alter their speed based on surrounding vehicles’ speeds, not the speed limit. Thirty percent of the responses said participants were not very motivated to change their speed after the in-vehicle alert because they were not traveling much faster than the speed limit.

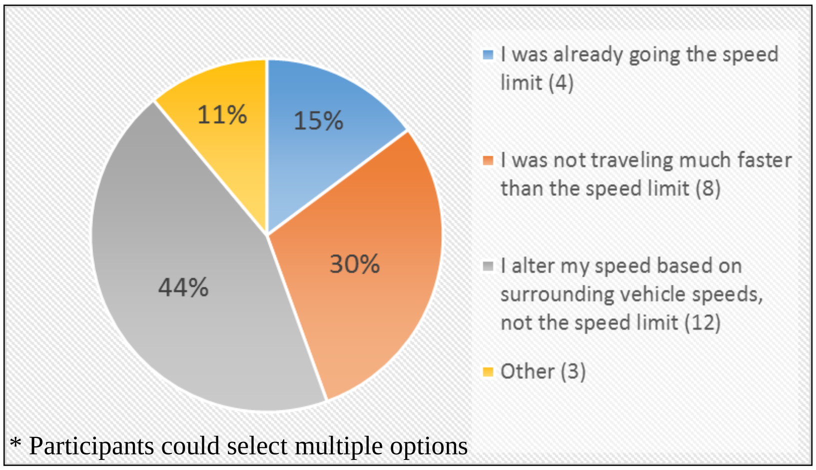

Figure 40. Explanations for speed limit alert "3 or lower."

Currently, the IVD is programmed to deliver a speed limit alert prior to reaching the outside speed limit sign, regardless of the driver’s present speed. A possible improvement for the system would be to deliver the speed limit alert only if the driver is traveling too far under or over the posted speed limit. This could help drivers become more regularly aware of their speed. Determining the proper speed thresholds would be an important step and could be an extension of this study.

During the study, the IVD continuously displayed the posted speed limit to participants. Another way to increase the salience of the driver’s speed is to display the current driver speed along with the posted speed limit on the device itself. This design could prevent drivers from watching both their speedometer and the in-vehicle display for speed information.

Speed from Data Acquisition System

Based on the survey results alone, it appears that the speed limit alert significantly motivated participants to alter their speed. In order to further analyze the effect of the speed limit alert on participants, the speed data collected by the DAS for each participant was examined. The overall goal of this analysis was to determine the effect of the speed limit alert on the participants' resulting speed.

The first speed limit alert, which verbally notified participants that the "speed limit is now 60 mph," occurred on the westbound portion of the route. The original speed limit was 55 mph, so this speed limit alert marked the 5 mph increase in speed along the highway.

There were two possible analysis scenarios: 1) determine whether participants traveling slower than the new speed limit (60 mph) sped up, and 2) examine whether participants traveling faster than the new speed limit (60 mph) slowed down. There were only nine participants who were traveling slower than 60 mph when the alert sounded. This is a small sample size, and it is difficult to determine whether these participants were traveling slower than 60 mph due to outside influences, such as traffic level. In addition, 95% of participants were already traveling faster than the original 55 mph speed limit when the new speed limit alert deployed. Therefore, the second scenario (decreasing speed) was chosen for analysis by the research team.

The research team wanted to determine if the participants traveling faster than 60 mph chose to slow down after the speed limit alert sounded to obey the new speed limit. In order to test the validity of this statement, participant speed data from the DAS was organized in MATLAB. Two separate speed data points were selected from the raw data set: 1) participant speed when the alert sounded and 2) participant speed 10 seconds after the alert deployed. The difference in the two speeds was then calculated for each participant (Speed After – Speed at Alert). The positive or negative sign of the difference indicated whether the participant sped up or slowed down (positive difference = participant sped up; negative difference = participant slowed down). Once the speed differences were calculated, the values were transferred to JMP software for statistical analysis.

A Wilcoxon signed rank test was conducted utilizing JMP to determine if participants traveling at least 60 mph slowed down due to the speed limit alert (N = 31). An alpha value of 0.05 was utilized, and it was assumed that the underlying population of differences is symmetric about the unknown median (not necessarily normally distributed) [19].

The following hypotheses were used for the Wilcoxon signed rank test (where s_{10} = participant speed 10 seconds after alert and s_0 = participant speed at the alert):

H_o: $s_{10} - s_0 = 0$
H_a: $s_{10} - s_0 < 0$

Since the p-value (< 0.0001) was less than alpha (0.05), the null hypotheses was rejected. There is sufficient evidence to conclude that participants who were traveling faster than 60 mph were traveling at a reduced speed 10 seconds after the 60 mph speed alert sounded.
The second speed limit alert occurred along the eastbound part of the route. This alert verbally informed participants that the "speed limit is now 55 mph." The original speed limit was 60 mph, so this alert marked the 5 mph decrease in speed limit.

Again, there were two possible analysis scenarios: 1) assess whether participants traveling less than the new speed limit (55 mph) increased their speed, and 2) test whether participants driving faster than the new speed limit (55 mph) slowed down. There were only 10 participants who were driving less than the new speed limit, and it is difficult to determine whether their speed was due to the surrounding traffic or other influences. Therefore, the second scenario was analyzed.

The research team wanted to determine if the participants traveling at least 55 mph chose to slow down after the speed limit alert sounded to obey the new speed limit (N = 30). Again, participant speed data was organized in MATLAB and the two speed data points were selected: 1) participant speed when the alert sounded and 2) participant speed 10 seconds after the alert deployed. The speed differences were computed (Speed After – Speed at Alert).

JMP was utilized to run the Wilcoxon signed rank test on the speed differences to determine if participants traveling at least 55 mph slowed down due to the speed limit alert. An alpha value of 0.05 was used and the same assumption was made: The underlying population of differences is symmetric about the unknown median (not necessarily normally distributed) [19].

The same hypotheses were used for the Wilcoxon signed rank test (where s_{10} = participant speed 10 seconds after alert and s_0 = participant speed at alert):

H_o: $s_{10} - s_0 = 0$
H_a: $s_{10} - s_0 < 0$

Since the p-value (0.0007) was less than alpha (0.05), the null hypotheses was rejected. There is sufficient evidence to conclude that participants who were traveling faster than 55 mph were traveling at a reduced speed ten seconds after the 55 mph speed alert sounded. It is important to note that none of the participants in this analysis were traveling less than the new speed limit 10 seconds after the alert. Table 16 displays the statistical results of the DAS speed data for both speed limit alerts.

Table 16. Statistics for Participant DAS Speed Data

Speed Alert	Mean Speed At Alert (mph)	Mean Speed After Alert (mph)	Mean Speed Difference ($s_{10} - s_0$) (mph)	Standard Deviation of Speed Difference (mph)	Sample Size	P-Value
Increase (55 → 60)	66.39	64.40	-1.98	2.39	31	< 0.0001
Decrease (60 → 55)	62.86	60.75	-2.11	3.44	30	0.0007

To summarize, participants who were traveling above the new speed limit at the time of the alert were found to be traveling at a reduced speed 10 seconds after the alert. This behavior was observed regardless of whether the speed limit was increasing or decreasing. This data validates the participant survey results, which determined that the speed limit alert significantly motivated participants to alter their speed. However, in both scenarios, participants were still traveling an average of 5 mph faster than the new speed limit 10 seconds after the alert. This result suggested that participants were still influenced by the flow of traffic.

2) Did alert type affect glance duration to the instrument cluster?

Another analysis method was chosen in order to evaluate participant eye glance behavior towards the instrument cluster following various alert types. For this analysis, the eye glance data provided by the VTTI reductionist team was utilized again; however, this time, participant glances towards the instrument cluster were extracted.

A one-way ANOVA test was run in JMP using the log of the glance durations towards the instrument cluster. Similar to the analysis of the IVD glance durations, the log transformation was used to stabilize the variances across alert type in order to authorize the use of the ANOVA test. Figure 41 depicts the glance durations per alert type. The participant ID was included in the analysis as a random effect to eliminate person-to-person variability. The following were the hypotheses (where μ_{LM} = mean glance duration to instrument cluster following a lane management alert, μ_{SL} = mean eye glance duration to instrument cluster following a speed limit alert, μ_{VMS} = mean eye glance duration to instrument cluster following a VMS alert):

H_o: $\mu_{LM} = \mu_{SL} = \mu_{VMS}$
H_a: At least one mean glance duration differs across alert type.

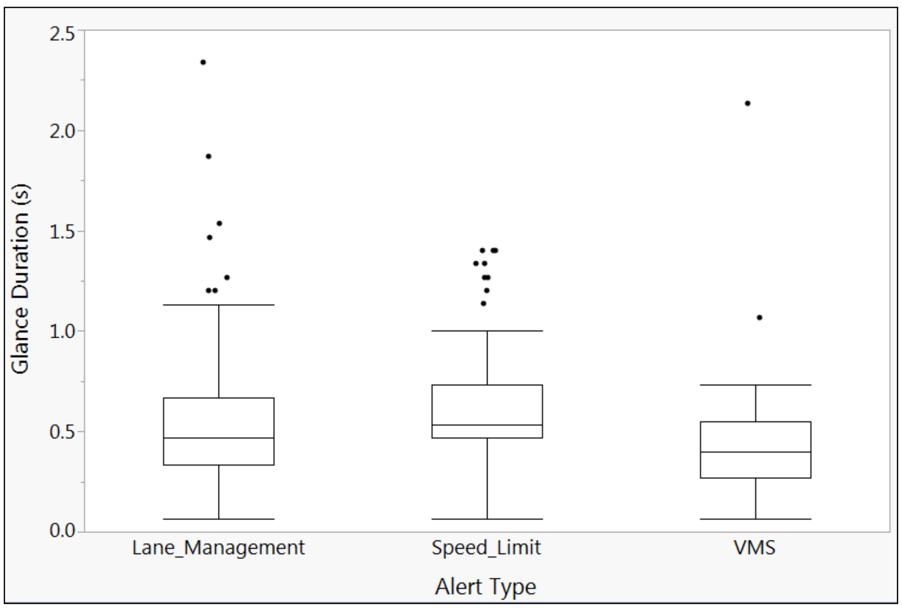

Figure 41. Instrument cluster glance duration vs. alert type.

Since the p-value (0.0003) was less than alpha (0.05), the null hypothesis is rejected; therefore, there is sufficient evidence to conclude that at least one mean glance duration differs across alert types.

The Tukey-Kramer Method was again necessary to conclude which specific alert grouping was significantly different. The results of the Tukey-Kramer Method indicated a significant difference in the mean glance duration to the instrument cluster following a speed limit alert and following a VMS alert (p-value = 0.0002). No significant differences were discovered between the remaining two pairings: lane management vs. VMS (p-value = 0.072) nor speed limit vs. lane management (p-value = 0.300). These results denote that significantly longer instrument cluster glances occurred after speed limit alerts than after VMS alerts, on average. This result was expected since the purpose of the speed limit alert is to influence the driver to alter their speed, if necessary. However, the instrument cluster glance durations after a speed limit alert and after a lane management alert were similar, on average. Table 17 displays the average and median eye glance durations to the instrument cluster and variability in glance durations per alert type.

Table 17. Instrument Cluster Eye Glance Reduction Results

In-Vehicle Alert Type	Mean (s)	Median(s)	Standard Deviation (s)
Lane Management	0.58	0.47	0.45
Speed Limit	0.61	0.53	0.29
VMS	0.45	0.40	0.32

Note that even though the Tukey-Kramer Method found a significant difference in the mean glance durations to the instrument cluster after a speed limit vs. a VMS alert, the mean magnitudes were only 0.16 seconds apart (0.61 sec – 0.45 sec = 0.16 sec). In addition, the average glance durations to the instrument cluster were still well below the NHTSA distraction guideline of 2 seconds [10]. Therefore, even though a significant difference was found, this difference may not result in an increased driver crash risk following a speed limit alert vs. a VMS alert.

3) Did drivers comprehend the Variable Message Signs?

On the pre-drive survey, all participants were asked to rank the following statement from 1–5 (“1” = strongly disagree, “3” = neutral, and “5” = strongly agree): “I believe the Variable Message Signs are clear and concise.” The purpose of this question was to gauge participant opinions regarding traditional VMS messages they have seen while driving on various roadways. A Wilcoxon test was performed for all traffic level conditions with the following hypotheses:

H_o: m <= 3
H_a: m > 3

Participants significantly indicated that traditional VMS messages were clear and concise (*m* = 4.00, SD = 0.98, p-value = < 0.0001). Thirty-three out of 40 responses were rankings of either “4” or “5” (83%). The results are visually displayed in Figure 42.

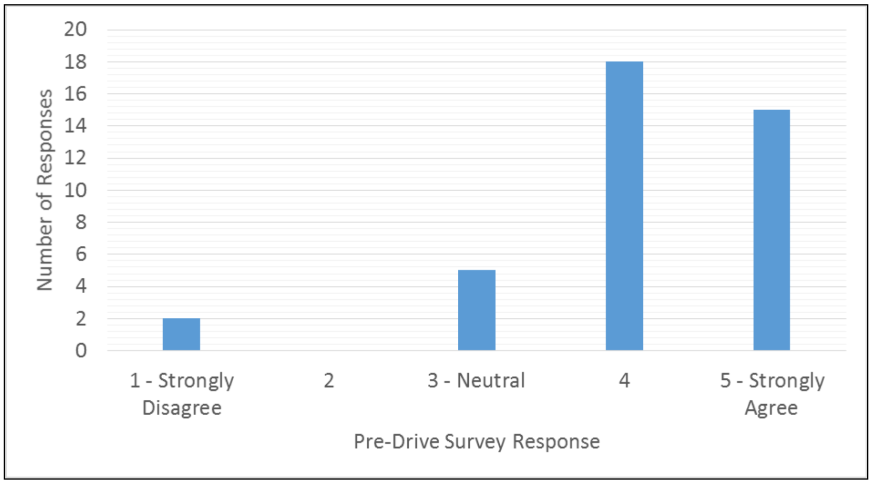

Figure 42. I believe the VMS are clear and concise.

On the post-drive survey, all participants were asked to rank the following statement from 1–5 ("1" = strongly disagree, "3" = neutral, and "5" = strongly agree): "The Variable Message Signs (VMS) messages were clear and concise." A Wilcoxon test was performed for all traffic level conditions with the following hypotheses:

H_o: m <= 3
H_a: m > 3

Participants significantly rated that the in-vehicle VMS messages were clear and concise (*m* = 5.00, SD = 0.67, p-value = < 0.0001). Thirty-eight out of 40 participant responses were "4" or "5" (95%). One participant ranked the VMS messages as a "2" and explained that the exit directions were too vague. Another participant ranked the VMS messages as a "3," and they stated that the messages did not provide enough specific information about the current traffic situation. Figure 43 summarizes the pre-drive and post-drive responses.

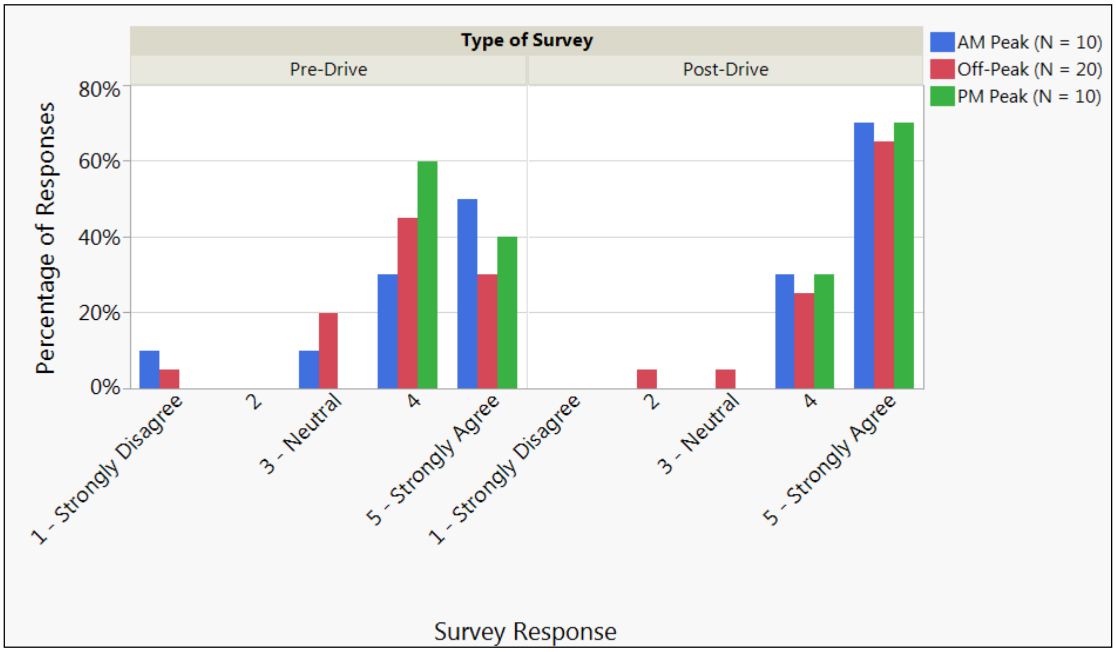

Figure 43. Comprehension of VMS for pre-drive vs. post-drive responses.

Note that there were three VMS "stopped traffic" alerts that did not sound (once during the a.m. peak, p.m. peak, and off-peak hour); therefore, three participants did not hear this particular alert. However, there were three other VMS alerts that deployed correctly, so those three participants could still rank the messages.

Although a vast majority of participants agreed that the VMS from the IVD were clear and concise, the participants' behavior may not have been altered as a result of the information presented. At least one member of the research team rode in the vehicle with each participant to give them directions to the start of the route and ask questions along the drive; however, participants were instructed to follow all directions from the IVD once they reached I-66. There were two VMSs that told participants to exit at a certain point along the route, and the research team tracked the number of participants that needed to be reminded that the IVD directions should be followed (including instructions to exit the highway). The researcher chose to remind the participant to exit I-66 under one or both of the following conditions: 1) the participant asked for confirmation about the exit directions from the IVD, and/or 2) the participant's behavior implied that they were not planning to exit (not changing lanes on time, etc.). Under these conditions, the research team recorded confirming/reminding 27 out of 40 participants (67.5%) to follow the IVD exit instructions for at least one of the two required exits.

The high percentage may be due to several variables: 1) participants did not trust the information presented on the IVD since the VMS did not always reflect actual roadway conditions and, as a result, needed to be reminded to follow the instructions, 2) participants were part of the study and wanted to follow the study protocol, so they asked for confirmation, and/or 3) the researcher could not always tell whether the participant intended to exit or not, so participants were reminded to make sure the exit was not missed. Future studies surrounding IVD systems could further study this phenomenon to understand the extent to which a driver's behavior is affected by the information presented, specifically when the system asks the driver to take a certain exit. In order to truly capture the driver's behavior, a naturalistic driving study would most likely be necessary.

Conclusions and Recommendations

CVT, including V2V and V2I, has the potential to greatly reduce roadway crashes by providing direct communication among vehicles, roadway infrastructure, and/or other communication devices [2]. One real-world application of CVT is ATDM systems, which were introduced to improve traffic flow, decrease congestion, generate dependable travel time estimations, and augment roadway capacity, all while increasing safety. This technology can achieve these goals by providing dynamic, real-time traffic information to drivers [4].

This study focused on a human factors evaluation of an in-vehicle ATDM device that delivered HOV, lane management, speed limit, and VMS information to drivers traveling on a portion of I-66. By displaying these ATDM features inside the vehicle, drivers were constantly aware of the roadway conditions, regardless of the location of the traditional roadway signage. Besides decreasing the number of roadway crashes, these in-vehicle systems could greatly reduce the budget necessary for traditional roadside infrastructure and help control road sign clutter.

Key Findings

As a result of this research effort, fundamental questions were answered surrounding the IVD deployed on I-66 in the following three categories: 1) Distraction, 2) Desirability, and 3) Driver Behavior. The following discussion includes the key findings within each research category.

Distraction

According to the eye glance reduction analysis, all of the NHTSA distraction guidelines were met; therefore, the IVD would not be considered a distraction to drivers. Similar distraction results based on eye glance behavior would be expected from future in-vehicle systems that require no or minimal driver interaction. The IVD in this study was located above the center console and to the right of the steering wheel. If future systems were integrated as part of the center stack, distraction results related to eye glance data may be impacted.

There was no significant difference in eye glance durations between the speed limit and lane management alerts; however, there was a significant difference when comparing the VMS alerts to both the speed limit and lane management alerts. This result was reasonable since the VMS alerts imposed more processing time and resulted in longer glances. Even though participants were not required to read the text on the display due to the redundant verbal message, many participants still glanced at the IVD after the VMS alerts deployed.

Though a significant difference was discovered among alert types, participant eye glance duration was independent of age group and time of day. No interactions related to eye glance duration existed between any of the three groups: age group, time of day, and alert type.

Overall, participants did not feel the in-vehicle alerts were distracting or annoying based on in-vehicle and post-drive survey responses. In addition, participants believed that the IVD gave them relevant, clear information based on the in-vehicle questionnaire.

Desirability

The vast majority of participants were excited about the potential advantages related to this new in-vehicle technology, both before and after the study. When asked if they would use an in-vehicle device that provided HOV, lane management, speed limit, and VMS if such system existed, 98% of participants said they would use the device on both the pre-drive and post-drive surveys.

Furthermore, 73% of participants indicated they would want the in-vehicle technology in their next vehicle while 25% signified a "neutral" feeling towards the IVD. These findings were independent of the participants' age group. There were some participants who were not interested in some of the information presented by the IVD; however, none of the participants indicated that they were not interested in the VMS feature. The preferred alert type among all the participants was the "Ding + Voice" alert, which was utilized in all speed limit and VMS alerts.

In addition to capturing relative interest in the IVD, it was also interesting to determine how much money participants were willing to pay for such a system. Of the 27 participants who provided price ranges, 48% were willing to pay $100–$500 for the IVD.

Driver Behavior

Based on post-drive survey responses, participants indicated that the speed limit alert significantly motivated them to alter their speed. In order to further validate this finding, the actual participant speed data recorded by the DAS during data collection was examined. According to the speed data, participants who were traveling above the new speed limit at the time of the alert were found to be traveling at a reduced speed 10 seconds after the alert, regardless of whether the speed limit was increasing or decreasing. It is important to note that in both scenarios, the participants who were already traveling above the speed limit were still driving an average of 5 mph faster than the new speed limit 10 seconds after the alert. This conclusion suggested that the alerts did motivate participants to alter their speed; however, perhaps participants were still influenced by the flow of traffic.

On average, significantly longer glances to the instrument cluster occurred following speed limit alerts when compared against VMS alerts. This result was plausible because the goal of the speed limit alert is to remind the driver of their speed. However, participant glance durations towards the instrument cluster following a speed limit alert were similar to those following a lane management alert, on average. Further studies are recommended to determine if alert type truly affects glance duration to the instrument cluster in practice.

A vast majority of participants found the in-vehicle VMS to be clear and concise based on post-drive survey responses (95%). Because participants in this study were directed to follow the VMS instructions, it is impossible to know how the displayed messages would affect their normal driving behavior (i.e. exiting at suggested locations, following re-routing options). In order to truly understand how drivers react to in-vehicle VMSs, a naturalistic driving study is recommended.

Limitations

One of the main limitations of this study involved the VMS alerts. Since the IVD alerts were triggered by pre-programmed GPS points and not by outside infrastructure, the in-vehicle VMS alerts did not always reflect actual roadway conditions. However, in future in-vehicle systems, the device would receive real-time messages regarding roadway conditions either from other vehicles or roadside infrastructure and would be able to dynamically warn participants of upcoming lane blockages, accidents ahead, etc. The latest overhead gantry system along I-66 activated after this research was completed is already displaying variable speed limits and lane management symbols.

Since the in-vehicle system relied on GPS points, there were some issues related to poor GPS reception. There were three VMS "stopped traffic" alerts that did not sound (once during the a.m. peak, p.m. peak, and off-peak hour); therefore, three participants were unable to experience this alert and their data for that particular alert was not included in the analyses. In addition, there were some "false" alerts that sounded, especially when the vehicle was moving very slowly. None of these glitches are expected to have caused a measurable impact on the final study results.

Another limitation was due to the simple nature of the study. This type of study required at least one member of the research team to be present in the vehicle with the participant for the entire data collection process. It is probable that the presence of the researcher caused participants to alter their typical driving behaviors.

Recommendations

A naturalistic driving study is recommended in order to capture participants' true responses to the information displayed by the IVD, as this type of study does not require a member of the research team to be present in the vehicle with the participant. A naturalistic driving study would also capture a longer period of time, thereby eliminating potential novelty and experimental demand bias. A naturalistic driving study would be especially helpful in order to understand how a driver's behavior is influenced by VMS and whether or not drivers follow the instructions given by the VMS alerts. This could prove to be an interesting future study since 33% of participants stated that VMS never impacts their route decision-making on the pre-drive survey.

There are a few changes that could improve the design of future in-vehicle systems. It would be advantageous to alter the tone of the "ding" and the voice to make the alerts less obtrusive. The best way to satisfy all users may be to provide various tone and alert options to allow the user to customize their alerts. Additionally, the IVD system used in this study did not indicate exit lanes and temporary lanes along the roadway. This might be an important feature that future systems could incorporate to increase mobility and accurately reflect roadway design. Based on the open-ended participant responses, the IVD systems would be even more helpful if they were also integrated with existing GPS applications, such as Google Maps or Waze.

Another participant recommendation for future systems was to add more details to the VMS alerts, including how many miles until the exit, the reason for the congestion (roadwork vs. accident), etc. This could be something to improve upon in later models; however, designers should be careful when constructing these messages to ensure that the alerts do not become a distraction to drivers due to excess details or a high frequency of delivery.

The speed limit alerts could possibly be improved by only triggering if the driver is traveling too far under or over the posted speed limit. Future designers of the system would need to review past literature to determine the appropriate speed thresholds for deploying the alert. In addition, the driver's current speed could be displayed on the IVD to prevent drivers from needing to examine their odometer and the display for speed information. The lane management alert could further reduce driver distraction levels by limiting the alert to only cases where the driver is actually traveling in the closed lane.

The alert timing could also be altered to improve future systems. The IVD tested in this study gave drivers a 5 second warning before all speed limit and lane management alerts based on the assumption that drivers were traveling close to the speed limit. In addition, participants were notified to exit the highway 1 mile before the required exit through VMS. In future IVDs, it would be beneficial to generate alert timings based on vehicle speed instead of a static distance. This would ensure that drivers would have enough time to perceive the information presented no matter their speed.

This study represented the first test of ATDM technology inside the vehicle and provided insight into the future of IVDs based on the analysis of driver distraction, desirability, and behavior related to the in-vehicle system. While there is room for improvement, this study showed that an in-vehicle system could safely and dynamically provide information to drivers. Based on participant responses, it seems that these devices could be highly desired when correctly designed and implemented. In-vehicle ATDM devices have the potential to transform the current transportation system into a safer and cost-effective environment in the future.

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Appendix/Appendices

Appendix A – Phone Screening

"Roadrunner" Screening Questionnaire (ATDM)

Note:
Initial contact between participants and researchers may take place over the phone. If this is the case, read the following Introductory Statement, followed by the questionnaire. Regardless of how contact is made, this questionnaire must be administered verbally before a decision is made regarding suitability for this study.

Introductory Statement:
After prospective participant calls or you call them, use the following script as a guideline in the screening interview.

Hello. My name is _____ and I'm with the Virginia Tech Transportation Institute. We are currently recruiting people to participate in a research study in the Northern Virginia area. This study involves participating in one session lasting approximately 2-3 hours during daytime hours. The length of the study will vary based on the time of day you participate (peak vs. non-peak hours). The purpose of this research is to assess an in-vehicle traffic management system. This in-vehicle system can send messages to drivers, lower road costs, and reduce sign clutter. You will be asked to provide feedback on these systems while you are driving our research vehicle on the public roads in the Fairfax, Virginia area.

This study has several steps. First, we would need you to come to our office located in Falls Church to fill out a short demographic questionnaire and pass a simple vision and hearing test. The second part of the study involves driving our research vehicle around a pre-planned route, mostly on I-66. While driving along I-66, you will experience various messages and alerts from an in-vehicle device. These messages will include information regarding HOV lanes, lane management, speed limit, and will inform you of traffic conditions ahead. An experimenter will be in the vehicle with you during the drive. The research vehicle is instrumented with data collection equipment, including video cameras which will record you while you drive.

Participants will be paid either $60 or $75 for full participation with a MasterCard from Virginia Tech University. Non-peak hour participants will be paid $60, and peak hour participants will be paid $75. This payment includes $5 to cover parking. In the event a session ends early, a $30/hour rate will apply with a minimum of $30. Note that if the session runs longer than expected, the pay rate is the same - $60 for non-peak hour and $75 for peak hour.

Any questions yet?

If you are interested in possibly participating, I need to go over some screening questions to see if you meet all the eligibility requirements of this study. Any information given to us will be kept secure and confidential.

Do I have your consent to ask the screening questions? [If yes, continue with the questions. If no, then thank him/her for their time and end the phone call.]

Participant Eligibility Questions:

1. Do you currently hold, a valid U.S. driver's license, which you can present at the time of the study? YES _____ NO _____ If yes, how long have you held a U.S. license? _______________ *Criterion: they are ineligible to participate if unable to present a VALID U.S. driver's license at their appointment and they must be an experienced driver (at least 2 years).* *NOTE: They will be reminded they must present a driver's license at their appointment if scheduled.*
2. On average how many days a week do you drive? _______________ *Criterion: Must drive, on average, at least 3 days per week.*
3. What is your current age? ________________ YOB__________ *Criterion: Must be 18-29 or 50-65 years old to participate.*
4. Are you a U.S. Citizen or permanent resident with a valid green card? YES _____NO _____ **Note: participant will need to bring their SS # to the study for W-9 paperwork for payment. (the card is not needed if they have their ss# memorized) *Must be a U.S. citizen or permanent resident (green card holder).*
5. If selected to participate in this study, will you provide your SSN or VT ID number, at the time of participation? *(for payment documentation and tax recording purposes Va Tech will require them to complete a W-9)* YES _____ NO _____ *Must be willing to provide SSN or VT ID number for payment purposes.*
6. Do you normally drive on Interstate 66, US 29, US 50 or I-495? YES _____NO _____ If yes, how often, on average, per week? ______________________________ *Criterion: Must drive, on average, at least 2 days/week on Interstate 66, US 29, US 50 or I-495.* We are running some participants during peak hours and others during non-peak hours. Are you available and would you feel comfortable driving on I-66 for our study… a. During peak hours in the morning Mon-Fri? YES _____NO _____ b. During peak hours in the evening Mon-Fri? YES _____NO _____ c. During non-peak hours in the middle of the day Mon-Fri? YES _____NO _____ Notes:____ *Criterion: Must be comfortable with and able to participate during one of these time slots*

7. Are you comfortable reading, writing, and speaking English?

YES _____ NO _____

NOTE: If the screener finds during the phone interview, the caller is struggling with their ability to communicate fluently in English or has a severe speech impediment (i.e. stuttering) that may affect their ability to participate in the tasks, the screener may determine the caller as ineligible.

8. Have you participated in any experiments for Virginia Tech Transportation Institute?

YES _____ NO _____

If yes, describe the study: ____

Criterion: Ineligible if in a previous study that used the NoVa testbed. Participants who have driven in studies at VTTI in Blacksburg are eligible. (cannot have participated in Delta study)

We need to ask a few questions about your medical history…

Do you have a history of any of the following medical conditions? If yes, please explain.

9. Any history of neck or back conditions, or injury to those areas, which still limit your ability to participate in certain activities?

YES _____ NO _____

If yes, please explain:____

Cannot have a history of neck or back conditions which still limit their ability to participate in certain activities.

10. Any Head Injury, Stroke, or illness or disease affecting the Brain?

YES _____ NO _____

If yes, please explain:____

Cannot have a history of brain damage from stroke, tumor, head injury, recent concussion, or disease or infection of the brain. (Conditions, such as MS would be considered a disease of the brain)

11. Current heart condition which limits your ability to participate in certain activities?

YES _____ NO _____

If yes, please explain:____

Cannot have a current heart condition which limits their ability to participate in certain activities.

12. Current respiratory disorder/disease or any condition which requires oxygen?

YES _____ NO _____ Notes:____

Cannot have current respiratory disorder/disease or disorder/disease requiring oxygen.

13. Any epileptic seizures or lapses of consciousness within the past twelve months?

YES _____ NO _____ Notes:____

Cannot have had an epileptic seizure or lapse of consciousness within the past 12 months.

14. Chronic migraines or tension headaches? YES _____ NO _____
If yes, do they occur more than once a month on average? YES _____ NO _____
Notes: ____

Cannot have, on average, more than one migraine or severe headache per month during the past yr.

15. Current problems with motion sickness, inner ear problems, dizziness, vertigo, or balance problems? YES _____ NO _____

Cannot have current problems with motion sickness, inner ear problems, dizziness, vertigo, or balance problems.

16. Do you have diabetes which requires insulin? YES _____ NO _____
If yes, please explain:____

Cannot have uncontrolled diabetes (have they been recently diagnosed or have they been hospitalized for this condition, or any changes in their insulin prescription during the past 3 months)

17. Have you had any major surgery within the past six months, including any eye procedures?
YES _____ NO _____

Must not have had any major surgery within the past 6 months (including eye procedures).

18. Are you currently taking any medicines or substances that may cause drowsiness or impair your driving ability?
YES _____ NO _____

Cannot currently be taking any substances that may interfere with driving ability (cause drowsiness or impair motor abilities)

19. (*Females only*) Are you currently pregnant? (*If "yes," politely inform the participant:* while being pregnant does not disqualify you from participating in this study, you are encouraged to talk to your physician about your participation to make sure that you both feel it is safe. **We will send you a copy of the consent form to discuss with your physician**. *Answer any questions*)
YES _____ NO _____
(Can still participate, but encourage them to speak with their doctor first)

20. Do you have normal, or corrected to normal, vision in both eyes?
YES _____ NO _____

Criterion: Must have normal or corrected to normal vision in both eyes.

21. You will be asked to drive without sunglasses. Will this present a problem should you be eligible to participate? Yes _______ No ______
Do you wear eyeglasses that tint or darken in the sunlight while sitting inside a vehicle?
Yes _______ No _______

Criterion: Must be able to drive without sunglasses or w/o lenses that darken while inside a vehicle.

22. Do you have normal, or corrected to normal, hearing?

YES _____ NO _____

Criterion: Must be able to hear and follow researcher's verbal directions while driving. Must have normal or corrected to normal hearing.

23. Have you had any moving violations in the past 3 years? If so, please explain.

YES _____ NO _____

Criterion: Must not have been convicted of more than two driving violations in the past 3 years.

24. Have you been involved in any automobile accidents in the past 3 years?

YES _____ NO _____ If so, please explain

____

Criterion: Must not have been convicted of an injurious accident (driving violation) in the past 3 years.

25. Are you able to drive an automatic transmission without assistive devices or special equipment? YES_____NO________

Criterion: Must be able to drive an automatic transmission without assistive devices/special equipment.

Before Assigning a Time Slot to the Participant:

We also want to make sure you are aware that the traffic levels are unpredictable on I-66. Because of this, it is best to choose a time slot where you do not have a prior commitment directly following your participation. Is this alright with you?

Time Slots Available for Participants:

	Time to be at VT-Northern VA Center
AM PEAK	7:00 AM – 10:00 AM (M-F)
NON-PEAK	11:30 AM – 1:30 PM (M-F)
PM PEAK	6:00 PM – 9:00 PM (M-F)

Address of the VT Northern Virginia Center:

7054 Haycock Road

Falls Church, VA 22043

How did you hear about this project? ______________________________________

Recruiting Others:

Do you know anyone else that may be interested in hearing about this study?
If yes, may we send you the information so you can forward it to them? (Or they can provide our phone #, email, website address to others; we will be happy to speak to anyone interested in hearing more)
Do you prefer we send you the info by Email: _________________________ or USPS mail (address):____

If Eligible:

Availability: ____

Scheduled on (date & time):____

Name: ___________________________

Home Phone #: ______________________ Cell#________________ Work #______________

We encourage you to read a copy of the Informed Consent prior to coming in for your scheduled appointment. Please review it ahead of time and contact us with any questions or concerns. You will be asked to read & sign a copy of this document upon arrival at VTTI prior to participating. Do not bring this document with you to the appointment; we simply ask for you to review the document ahead of time and to let us know you received it. Do you prefer we send the study information, appointment confirmation, and directions as an email (with IC as an attachment) or by USPS?
E-mail or mailing address: ____

It is important to note that we will not be able to conduct the study in inclement weather conditions. If there is rain or some other reason we need to reschedule, we will do our best to inform you in a timely manner. Therefore:

Town or city you live in & approximate travel time to the Falls Church Office is needed:

____

Would you like to be contacted for future studies? Yes: _____No: _____

If yes, collect the following:

Last Name: ___________________________ First Name: ___________________________
Y.O.B. _______________________
Home Phone #: ______________________ Cell#________________ Work #______________
Town or city: ______________________ State: _______

Specialty Driver's License____
If CDL, endorsements/restrictions____
Make and Model of Primary Vehicle (light) ____

<u>Upon Completion of Scheduling</u>:

Thank you for signing up to participate in the Roadrunner study! We will send you a copy of the informed consent form, a confirmation letter with the time/date of your appointment, our contact information, and directions to the Virginia Tech Northern Virginia Center. Here is our phone # in case you don't receive the confirmation letter or have any questions: XXX-XXX-XXXX. Please remember to reference the Roadrunner Study with any messages, as we have multiple studies running simultaneously.

Appendix B – More Information Email

Hello ______________________

Thank you for your interest in our research study, named 'Roadrunner'! This project is recruiting drivers, ages 18-29 or 50-65 years old. Participants must be a U.S. citizen or have a green card and hold a valid U.S. driver's license. Student visa's or international driver's license cannot be accepted.

If you meet these criteria and would like to know more about the 'Roadrunner' Study, please continue reading this entire page.

If you would like to sign-up to be on our contact list for future studies, please visit this link, https://surveys.vtti.vt.edu/index.php?sid=53296&lang=en, and complete the short survey. Please note that, by completing the form, you are not agreeing to participate in any particular study. You are simply submitting your name and information for contact by a VTTI researcher when recruiting for a study in the Northern VA area. Any information you provide will remain confidential and will not be shared with others outside of VTTI. Completion of this survey does NOT qualify you for the 'Roadrunner' Study, please continue reading.

ROADRUNNER: We are currently recruiting people to participate in a research study in the Northern Virginia area. This study involves participating in one session lasting approximately 2-3 hours during daytime hours. The length of the study will vary based on the time of day you participate (peak vs. non-peak hours). You will be asked to provide feedback on an in-vehicle traffic information device while you are driving our research vehicle on the public roads in the Fairfax, Virginia area.

First, we would need you to come to our office located in Falls Church to fill out a short demographic questionnaire and pass simple vision and hearing tests. The second part of the study involves driving our research vehicle around a pre-planned route, mostly on I-66. While driving along I-66, you will experience various messages and alerts from an in-vehicle device. These messages will include information regarding HOV lanes, lane management, speed limit, and will inform you of traffic conditions ahead. An experimenter will be in the vehicle with you during the drive. The research vehicle is instrumented with data collection equipment, including video cameras which will record you while you drive.

Participants will be paid either $60 or 75 for full participation with a MasterCard from Virginia Tech University. Non-peak hour participants will be paid $60, and peak hour participants will be paid $75. This payment includes $5 to cover parking. In the event a session ends early, a $30/hour rate will apply with a minimum of $30. Note that if the session runs longer than expected, the pay rate is the same - $60 for non-peak hour and $75 for peak hour.

If you are interested in learning more, the first step to becoming enrolled in this study is to determine eligibility by answering some screening questions. Any information given to us will be kept secure and confidential.

Please call us at 540-231-2125 to go through the telephone screening, which will take approximately 15 minutes. Or you may send an email to ___________________________________with your phone #, time and date, that is best for us to call and we will be happy to contact you.

Please let me know if you have any questions. Please reference the 'Roadrunner' study in the subject of your messages.

Sincerely, _______________________

Project Assistant

Virginia Tech transportation Institute

3500 Transportation Research Plaza

Blacksburg, VA 24061

Email: ______________________________

Work: ______________________________

Please note that VTTI holds normal business hours. Any correspondence received after 5:00pm will be attended to on the next business day.

Confidentiality Notice: The preceding e-mail message (including any attachments) contains information that may be confidential, protected by applicable legal privileges, or constitute non-public information. It is intended to be conveyed only to the designated recipient(s). If you are not an intended recipient of this message, please notify the sender by replying to this message and then delete it from your system. Use, dissemination, distribution or reproduction of this message by unintended recipients is not authorized and may be unlawful.

Appendix C – Confirmation Email

Dear __________,

Please respond to this e-mail to let us know that you received it.

We have you scheduled to drive with us in the **"Roadrunner Study"** on ***Thursday 10/16/14 at 9:00 am***. Please remember to wear closed toe shoes, bring your U.S. driver's license and reading glasses with you if needed. Appointments will have to be rescheduled if there is inclement weather. If this occurs, the researcher will call you in ample time before your scheduled appointment time.

If you have any questions, please don't hesitate to give us a call. You may reach the recruiting staff, at 540-231-2125, if during regular office hours (M-F). Or, if you need to reach the researcher, who is meeting you at the site, call Kayla at 571-455-1270.

Directions: Virginia Tech Northern Virginia Center, 7054 Haycock Road, Falls Church, VA 22043.

Going northbound on the Capital beltway (I-495 inner loop)

- Take Exit 49B to I-66 East. HOV restrictions may apply to I-66.
- From I-66, take Exit 66 to Route 7 East (Leesburg Pike).
- Turn left at the first light onto Haycock Road. The Virginia Tech Northern Virginia Center is on your left next to the George Mason High School.
- At the second left turning lane at the first light, in front of the Virginia Tech Northern Virginia Center, turn left into the West Falls Church Metro Station Parking Area. After the stop sign, the center's parking is available at the next left.

Going southbound on the Capital Beltway (I-495 outer loop)

- Take Exit 47B to Route 7 East (Leesburg Pike).
- Remain on Route 7 for approximately 2.5 miles, passing under Interstate 66.
- Turn left at the next light onto Haycock Road. The Virginia Tech Northern Virginia Center will be on your left.
- At the second left turning lane at the first light, in front of the Virginia Tech Northern Virginia Center, turn left onto the West Falls Church Metro Station Parking Area. After the stop sign, the center's parking is available at the next left.

Parking

- Park in the NVC parking lot.
- Reimbursement for the parking fee will be included within your participate payment ($5)

Metro

- Take the Orange Line to the West Falls Church Metro Station.
- The Virginia Tech Northern Virginia Center is located 100 yards southwest of the Metro station across the parking lot.

Metrobus

- Take Route 3B, 3F, 3W, 3Z, 28A, or 28B to the West Falls Church Metro Station.
- The Virginia Tech Northern Virginia Center is located across the parking lot, southwest of the Metro station.
- For specific information about Metro bus scheduling, call (202) 637-7000.

Fairfax Connector Bus

- Take Route 5S to the West Falls Church Metro Station.
- The Virginia Tech Northern Virginia Center is located southwest of the Metro station, across the parking lot.
- For specific information on bus scheduling, call Fairfax Connector at (703) 339-7200

All participants are required to check in at the security desk at the main entrance to VT NVC. Tell them you are here for the VTTI "**Roadrunner**" driving study and they will call the appropriate persons to come meet you.

If you have any questions, need to change your appointment, or have difficulty finding the office, please call (do not email), using the phone numbers listed at the beginning of this letter.

Have a great day,

Appendix D – Participant Scripts

A. Snellen Vision Test

<The experimenter should administer the Snellen Vision Test and make sure the participant has normal to corrected-normal vision, which is at least 20/40>.

With both eyes open, please read the smallest line you are able to see.

<The experimenter will determine the participant's vision based on the smallest line of letters the participant is able to read without error>.

B. Ishihara Color Vision Test

<The experimenter should administer the Ishihara Color Vision Test. The results of this test is for data collection purposes only and will not disqualify participants from the study>.

Please rest the pole against your chin, and tell me what you see on each card.

C. Hearing Test

<The experimenter will have the participant repeat 4 sentences to make sure they can understand commands from the experimenter>.

Please look straight ahead and repeat the following 4 sentences:

1) Move over to the left lane.
2) Watch your speed.
3) Please take the next exit.
4) The right lane is closed in 5 miles.

D. Pre-Drive Questionnaire

<The experimenter should administer the pre-drive questionnaire and answer any participant questions. Once the participant has completed the pre-drive questionnaire, the experimenter will escort the participant to the research vehicle located in the Virginia Tech Northern Virginia Center parking lot>.

E. Overview of Instrumented Vehicle

Before we continue with a brief overview of the in-vehicle device, you may adjust your seat to a comfortable position. Next, you may adjust your steering wheel to an appropriate height, if needed. You can now adjust your side and rear-view mirrors. It is also important to wear your seatbelt for the entire duration of the study.

This is the vehicle we will be using to travel along I-66. The purpose of this research is to assess an in-vehicle traffic management system (ATDM). This system can send messages to drivers that show up on a display inside the vehicle, and we are looking for feedback from drivers about these systems. For the driving portion of this study, we will be traveling along a section of I-66. We will start on I-66 WB, turn around, and come back on I-66 EB. The device you will be using today is a prototype. A digital video recording will be captured and will include your face, the in-vehicle display, and the forward roadway view.

Do you have any questions?

F. Overview of In-Vehicle Device

In-Vehicle Device

> *Note: The figure referenced in this script (displayed below) was shown to each participant as a hard copy. The experimenter discussed the figure with the participant using the following script.*

HOV/ Lane Management:
The figure shows how the display screen will look inside the vehicle. The top of the display will depict a white diamond for an HOV lane, a green circle for a lane open to all traffic, and a red "X" to indicate a closed lane. This row will change based upon the number of lanes and time of day.

Speed Limit:
The speed limit will be located in the bottom left corner of the display and will be posted at all times. It changes along the route to reflect the posted speed limits.

Variable Message Signs:
The rest of the display screen will be utilized for VMS, which will be displayed in yellow font. These signs include information regarding crashes ahead, lane closings, detours, etc. This portion of the screen will only be used when necessary.

Alerts:

The in-vehicle signage device will not only display information in the vehicle, but it will also include an auditory and/or visual alert. The goal will be to inform you when the information is updated.

→ HOV:	There will be no alert for HOV-designated lanes; however, this information will always be available and accurate on the display.
→ Speed Limit:	You will be given an alert if the speed limit changes along your route.
→Lane Management:	An alert will be given regarding lane management based on the time of day, letting you know if a particular lane is closed or is open for all traffic.
→Variable Message Signs:	Any necessary VMS will be displayed along with an alert. An example message would be "Stopped traffic, 2 miles."

<The experimenter will play an example alert for the participant, which includes a "ding + voice" to make sure the participant is able to understand the information from the in-vehicle device>.

NOTE: It is important to note that there will be structures and/or signage that are displaying similar information outside the vehicle along the I-66 route. However, for the entire duration of the study, please follow all directions from the in-vehicle system. For example: if the in-vehicle device told you to change lanes, you would want to follow that instruction. The HOV, lane management, and speed limit in-vehicle information will all be accurate. However, the Variable Message Signs may not reflect actual roadway conditions because there is no connection between this in-vehicle device and the outside infrastructure. While this is true, the research team asks that you follow all instructions from the in-vehicle system.

Do you have any questions?

G. Overview of In-Vehicle Questionnaires/Rating Scales

Questions During the Drive

I will be asking you a series of questions at various points while you are driving. These questions will relate to the alerts presented by the in-vehicle device. The following are the categories for each set of questions: Comprehension, Usefulness, Distraction, and Timing. You will rank these categories on a scale from 1-5, where 1 is low and 5 is high. I will repeat this scale after each question for clarity.

Questions at Halfway/End Points

In addition, I will ask you questions at the halfway and end points of the route. These questions will be related to the following categories: Mental Demand, Temporal Demand, and Frustration level for each half of the route. Again, you will rate the categories on a scale from 1 – 5, where 1 is low and 5 is high. I will repeat this scale after each question for clarity.

It is important to note that there are no tasks that require physically interacting with the system; rather, the questions are simply asking about the demands of driving while receiving information from the in-vehicle device.

Do you have any questions?

H. Final Thoughts

For the duration of the study, it is important to remember the following:

1) While driving, please do not wear sunglasses, hats, or any other accessories that may block the camera's view of your face. You may use the visor as long as it does not block the camera.
2) While on I-66, you may drive in whichever lane you feel comfortable in. Please drive as you normally would while on the interstate.
3) While on I-66, you should maintain a speed that is safe and consistent with the flow of traffic throughout the session.
4) Remember that the in-vehicle system is being evaluated, not you or your performance.
5) While driving along the route, feel free to make comments regarding the in-vehicle device (likes, dislikes, etc.). You may ask questions as well.

Now that we have reviewed all of the equipment and in-vehicle survey questions, do you have any questions?

<Right before the participant begins driving, the experimenter will remind the participant of the following>.

> I will be giving you instructions to the start of the route. Once you are on I-66, you should follow all instructions from the in-vehicle device.

<Once the participant has successfully merged onto I-66, the experimenter will remind the participant of the following>.

> From this point forward, you should follow all instructions from the in-vehicle device.

Appendix E – Experimental Procedure Checklist

*** Experimenter Reminder: Check the traffic along I-66 route prior to heading out on the road**

- ☐ **Informed Consent Form**
- ☐ **Valid Driver's License**
- ☐ **Snellen Vision Test (20/40):**
    - ____________________
- ☐ **Ishihara Color Vision Test**
    - ____________________
- ☐ **Hearing Test:**
    - ____________________
- ☐ **Pre-Drive Questionnaire**
- ☐ **Overview of Instrumented Vehicle/In-Vehicle Device**

- ☐ **In-Vehicle Questions:**
    - **Modified NASA TLX (halfway and end points)**
    - **Specific Alerts**
- ☐ **Post-Drive Questionnaire**
- ☐ **W-9 Form**
- ☐ **Time In and Out Form/Participant Receipt**
- ☐ **Pay Participant**

Appendix F – Sample Recruitment Flyer

Participants Needed for a Driving Study

Are you <18-29> or <50-65> years old?

Do you have a valid U.S. driver's license?

If yes to both of these questions, please

call VTTI @ 540-231-2125 or

e-mail: NOVAdrivers@vtti.vt.edu

- Mention the **"Roadrunner"** project as the subject of your message
- Drive our Research Vehicle on Public roads around the Fairfax area
- Estimated participation time: 1 visit, during the daytime, lasting 2-3 hrs
- This research project pays <$60 for full participation during non-peak hours> or <$75 for full participation during peak-hours>.

Virginia Tech Transportation Institute

VTTI Roadrunner Driving Study	VTTI Roadrunner Driving Study	VTTI Roadrunner Driving Study	VTTI Roadrunner Driving Study	VTTI Roadrunner Driving Study	VTTI Roadrunner Driving Study	VTTI Roadrunner Driving Study	VTTI Roadrunner Driving Study	VTTI Roadrunner Driving Study

Appendix G – Sample Social Media Ad

Wanted for Research Study

The Virginia Tech Transportation Institute (VTTI) is seeking individuals in Northern VA who:

- Are in the following age ranges: <18-29> or <50-65> years old
- Have a valid U.S. driver's license
- Drive on I-66, or similar roadway in Northern VA, on a regular basis

- Drive our Research Vehicle on Public roads around the Fairfax, VA area
- Estimated participation time: 1 visit, during the daytime, lasting about 2-3 hours
- This research project pays <$60 for full participation during non-peak hours> or <$75 for full participation during peak-hours>
- Your data will be kept strictly confidential

If you are interested in learning more,

Please contact us at: 540-231-2125 or email, NOVAdrivers@vtti.vt.edu
Reference "the Roadrunner Study" in your message
All inquiries welcome!

Virginia Tech Transportation Institute

www.vtti.vt.edu

<u>Appendix H – Peak Hour Informed Consent Form</u>

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants of Investigative Projects

<u>PEAK HOUR</u>

Title of Project:

HUMAN FACTORS EVALUATION OF AN IN-VEHICLE ACTIVE TRAFFIC AND DEMAND MANAGEMENT (ATDM) SYSTEM

Investigators: Kayla Sykes, Tom Dingus, Pamela Murray-Tuite

THE PURPOSE OF THIS RESEARCH PROJECT

The purpose of this research is to test an in-vehicle traffic management system (ATDM). This system can send messages to drivers that show up on a display inside the vehicle. These messages inform the driver about traffic conditions ahead and include the same type of information currently seen on roadway signs. Before this type of system can be used by the general public, it is important that we obtain feedback from drivers. The system you will be using today is a prototype system.

PROCEDURES

During the course of this experiment, you will be asked to perform the following tasks:

1) Read this Informed Consent Form and sign it if you agree to participate.
2) Show the experimenter your valid driver's license.
3) Complete a general vision and a color vision test as well as an informal hearing test.
4) Drive along a portion of I-66 with the researcher present in the vehicle. Not every message you receive will be reflective of real traffic conditions; however, you should still follow instructions provided by the in-vehicle display. You will not need to operate the device or touch the display.
5) Complete pre and post-drive surveys to capture your opinions of the in-vehicle device.
6) Verbally respond to user satisfaction questions during the drive.

It is important for you to understand that we are not evaluating you or your performance in any way. You are helping us to evaluate in-vehicle technology and its implications while driving. The opinions you have will help us determine appropriate guidelines for new in-vehicle interfaces. The information and feedback that you provide is very important to this project. Today's total experiment time will be approximately 3 hours, depending upon traffic conditions and time of day.

The vehicle you will be driving is instrumented with small cameras that will be recording the exterior and the interior of the vehicle. The video recording of the interior will include your face.

RISKS

The tasks described here are believed to pose no more than minimal risk to your health or wellbeing. The risks of driving the test vehicle along I-66 for this experiment are similar to that of driving an unfamiliar vehicle during daylight hours while using unfamiliar technology in peak traffic conditions.

While the risk of participation in this study is considered to be no more than that encountered in everyday driving, if you are pregnant you should talk to your physician and discuss this consent form with them before making a decision about participation.

Please be aware that events such as equipment failure, accidents along I-66, stray or wild animals entering the road, and weather changes may require you to respond accordingly. If at any point in the session the experimenter believes that continuing the session would endanger you or the equipment, he/she will stop the testing.

The following precautions will be taken to ensure minimal risk to you:

1. An experimenter will be with you at all times to monitor your driving and will ask you to stop if he/she feels the risks are too great to continue. The experimenter will also provide you with directions along the route. There may be a second experimenter in the back seat.
2. You may take a break at the half-way point of the route if you would like.
3. You may decide not to participate at any time.
4. You will be required to adhere to a speed that is safe and consistent with the flow of traffic along I-66 throughout the session.
5. An experimenter will be present while you are driving; however, as long as you are driving the research vehicle, it remains your responsibility to drive in a safe and legal manner.
6. You will be required to wear your lap and shoulder belt restraint system while in the car. The vehicle is equipped with a driver's side and passenger's side airbag supplemental restraint system, fire extinguisher, first aid kit, and a passenger-side brake. The experimenter will also have a cell phone.
7. In the event of a medical emergency, or at your request, VTTI staff will arrange medical transportation to a nearby hospital emergency room. You may elect to undergo examination by medical personnel in the emergency room.
8. All data collection equipment is mounted such that, to the greatest extent possible, it does not pose a hazard to you in any foreseeable case.
9. Testing will be cancelled in the event of poor weather resulting in the use of windshield wipers beyond an intermittent speed or if the pavement is or becomes icy.
10. You do not have any medical condition that would put you at a greater risk, including but not restricted to history of neck/spine injury, epilepsy, balance disorders, lingering effects of head injuries and stroke, and advanced osteoporosis.

In the event of an accident or injury in an automobile owned or leased by Virginia Tech, the automobile liability coverage for property damage and personal injury is provided. The total policy amount per occurrence is $2,000,000. This coverage (unless the other party was at fault, which would mean all expense would go to the insurer of the other party's vehicle) would apply in case of an accident for all volunteers and would cover medical expenses up to the policy limit. For example, if you were injured in an automobile owned or leased by Virginia Tech, the cost of transportation to the hospital emergency room would be covered by this policy.

Participants in a study are considered volunteers, regardless of whether they receive payment for their participation; under Commonwealth of Virginia law, worker's compensation does not apply to volunteers; therefore, if not in the automobile, the participants are responsible for their own medical insurance for bodily injury. Appropriate health insurance is strongly recommended to cover these types of expenses. For example, if you were injured outside of the automobile owned or leased by Virginia Tech, the cost of transportation to the hospital emergency room would be covered by your insurance.

BENEFITS

While there are no direct benefits to you from this research, you may find the experiment interesting. No promise or guarantee of benefits is made to encourage you to participate. Participation in this study will contribute to the improvement of future in-vehicle technology by assessing the effect of the in-vehicle system on driver distraction, desirability, and driver behavior.

EXTENT OF ANONYMITY AND CONFIDENTIALITY

The data gathered in this experiment will be treated with confidentiality. Shortly after participation, your name will be separated from your data. A coding scheme will be employed to identify the data by participant number only (e.g., Participant No. 1).

You may elect to have your data withdrawn from the study if you so desire, but you must inform the experimenters immediately of this decision so that the data may be promptly removed.

The data collected in this study may be used in future VTTI transportation research projects. IRB approval will be obtained prior to accessing the data for other projects. A digital video recording of your face will be captured by the data collection system. Blurred images of your face may be shown at professional conferences and meetings. The face video may also be used for future research projects at VTTI where they will be stored and used in a secure location. No electronic copies of these face video files will be provided to anyone other than approved VTTI staff.

It is possible that the Institutional Review Board (IRB) may view this study's collected data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

COMPENSATION

You will be paid $75 for full participation. This payment includes $5 to cover parking. You will be paid at the end of the session with a MasterCard from Virginia Tech. Note that if the session runs longer than expected, the pay is the same – i.e., you will still receive $75. All payments will be issued using a pre-loaded MasterCard. Please allow up to 1 full business day for activation of the card. Once activated, this card cannot be used past its expiration date. If there is no activity on the card for 5 months the card will become inactive.

You will be asked to provide researchers with your social security number or Virginia Tech I.D. number for the purposes of being paid for your participation. For tax recording purposes, the fiscal and accounting services office at Virginia Tech (also known as the Controller's Office) requires that all participants provide their social security number or Virginia Tech I.D. number to receive payment for participation in our studies.

FREEDOM TO WITHDRAW

As a participant in this research, you are free to withdraw at any time without penalty. If you choose to withdraw, you will be compensated for the portion of time of the study for which you participated. Furthermore, you are free to not answer any question or respond to experimental situations without penalty. If you choose to withdraw during the study session, please inform the experimenter of this decision and he/she will drive you back to the Virginia Tech Northern Virginia Center.

APPROVAL OF RESEARCH

This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University.

PARTICIPANT'S RESPONSIBILITIES

If you voluntarily agree to participate in this study, you will have the following responsibilities:

1. To follow the experimental procedures as best as you can.
2. To inform the experimenter if you have difficulties of any type.
3. To wear your seat and lap belt.
4. To maintain safe operation of the instrumented vehicle at all times.
5. To adhere to a speed that is safe and consistent with the flow of traffic.

PARTICIPANT'S ACKNOWLEDGMENTS

Check all that apply:

- ☐ I am not under the influence of any substances or taking any medications that may impair my ability to participate safely in this experiment.

- ☐ I am in good health and not aware of any health conditions that would increase my risk including, but not limited to lingering effects of a heart condition.
- ☐ I have informed the experimenter of any concerns/questions I have about this study.
- ☐ I understand that digital video including my image will be collected as part of this experiment.
- ☐ I understand that traffic conditions are unpredictable. My expected participation time has been explained to me, and I understand if there is heavier traffic than usual, the driving session may be longer than expected.

- ☐ If I am pregnant, I acknowledge that I have either discussed my participation with my physician, or that I accept any additional risks due to pregnancy.

PARTICIPANT'S PERMISSION

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project. **If I participate, I may withdraw at any time without penalty. I agree to abide by the rules of this project.**

____

Participant's name (Print)   Signature   Date

____

Researcher's name (Print)   Signature   Date

Should I have any questions about this research or its conduct, I may contact:

Dr. Tom Dingus @ (540) 231-1501, or by email: TDingus@vtti.vt.edu

Kayla Sykes @ (804) 652-9230, or by email: ksykes@vtti.vt.edu

If I should have any questions about the protection of human research participants regarding this study, I may contact: Dr. David Moore, Chair of the Virginia Tech Institutional Review Board for the Protection of Human Subjects, telephone: (540) 231-4991; email: moored@vt.edu.

Appendix I – Off-Peak Hour Informed Consent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants of Investigative Projects

NON-PEAK HOUR

Title of Project:

HUMAN FACTORS EVALUATION OF AN IN-VEHICLE ACTIVE TRAFFIC AND DEMAND MANAGEMENT (ATDM) SYSTEM

Investigators: Kayla Sykes, Tom Dingus, Pamela Murray-Tuite

THE PURPOSE OF THIS RESEARCH PROJECT

The purpose of this research is to test an in-vehicle traffic management system (ATDM). This system can send messages to drivers that show up on a display inside the vehicle. These messages inform the driver about traffic conditions ahead and include the same type of information currently seen on roadway signs. Before this type of system can be used by the general public, it is important that we obtain feedback from drivers. The system you will be using today is a prototype system.

PROCEDURES

During the course of this experiment, you will be asked to perform the following tasks:

1) Read this Informed Consent Form and sign it if you agree to participate.
2) Show the experimenter your valid driver's license.
3) Complete a general vision and a color vision test as well as an informal hearing test.
4) Drive along a portion of I-66 with the researcher present in the vehicle. Not every message you receive will be reflective of real traffic conditions; however, you should still follow instructions provided by the in-vehicle display. You will not need to operate the device or touch the display.
5) Complete pre and post-drive surveys to capture your opinions of the in-vehicle device.
6) Verbally respond to user satisfaction questions during the drive.

It is important for you to understand that we are not evaluating you or your performance in any way. You are helping us to evaluate in-vehicle technology and its implications while driving. The opinions you have will help us determine appropriate guidelines for new in-vehicle interfaces. The information and feedback that you provide is very important to this project. Today's total experiment time will be approximately 2 hours, depending upon traffic conditions and time of day.

The vehicle you will be driving is instrumented with small cameras that will be recording the exterior and the interior of the vehicle. The video recording of the interior will include your face.

RISKS

The tasks described here are believed to pose no more than minimal risk to your health or wellbeing. The risks of driving the test vehicle along I-66 for this experiment are similar to that of driving an unfamiliar vehicle during daylight hours while using unfamiliar technology during non-peak traffic conditions.

While the risk of participation in this study is considered to be no more than that encountered in everyday driving, if you are pregnant you should talk to your physician and discuss this consent form with them before making a decision about participation.

Please be aware that events such as equipment failure, accidents along I-66, stray or wild animals entering the road, and weather changes may require you to respond accordingly. If at any point in the session the experimenter believes that continuing the session would endanger you or the equipment, he/she will stop the testing.

The following precautions will be taken to ensure minimal risk to you:

1. An experimenter will be with you at all times to monitor your driving and will ask you to stop if he/she feels the risks are too great to continue. The experimenter will also provide you with directions along the route. There may be a second experimenter in the back seat.
2. You may take a break at the half-way point of the route if you would like.
3. You may decide not to participate at any time.
4. You will be required to adhere to a speed that is safe and consistent with the flow of traffic along I-66 throughout the session.
5. An experimenter will be present while you are driving; however, as long as you are driving the research vehicle, it remains your responsibility to drive in a safe and legal manner.
6. You will be required to wear your lap and shoulder belt restraint system while in the car. The vehicle is equipped with a driver's side and passenger's side airbag supplemental restraint system, fire extinguisher, first aid kit, and a passenger-side brake. The experimenter will also have a cell phone.
7. In the event of a medical emergency, or at your request, VTTI staff will arrange medical transportation to a nearby hospital emergency room. You may elect to undergo examination by medical personnel in the emergency room.
8. All data collection equipment is mounted such that, to the greatest extent possible, it does not pose a hazard to you in any foreseeable case.
9. Testing will be cancelled in the event of poor weather resulting in the use of windshield wipers beyond an intermittent speed or if the pavement is or becomes icy.
10. You do not have any medical condition that would put you at a greater risk, including but not restricted to history of neck/spine injury, epilepsy, balance disorders, lingering effects of head injuries and stroke, and advanced osteoporosis.

In the event of an accident or injury in an automobile owned or leased by Virginia Tech, the automobile liability coverage for property damage and personal injury is provided. The total policy amount per occurrence is $2,000,000. This coverage (unless the other party was at fault, which would mean all expense would go to the insurer of the other party's vehicle) would apply in case of an accident for all volunteers and would cover medical expenses up to the policy limit. For example, if you were injured in an automobile owned or leased by Virginia Tech, the cost of transportation to the hospital emergency room would be covered by this policy.

Participants in a study are considered volunteers, regardless of whether they receive payment for their participation; under Commonwealth of Virginia law, worker's compensation does not apply to volunteers; therefore, if not in the automobile, the participants are responsible for their own medical insurance for bodily injury. Appropriate health insurance is strongly recommended to cover these types of expenses. For example, if you were injured outside of the automobile owned or leased by Virginia Tech, the cost of transportation to the hospital emergency room would be covered by your insurance.

BENEFITS

While there are no direct benefits to you from this research, you may find the experiment interesting. No promise or guarantee of benefits is made to encourage you to participate. Participation in this study will contribute to the improvement of future in-vehicle technology by assessing the effect of the in-vehicle system on driver distraction, desirability, and driver behavior.

EXTENT OF ANONYMITY AND CONFIDENTIALITY

The data gathered in this experiment will be treated with confidentiality. Shortly after participation, your name will be separated from your data. A coding scheme will be employed to identify the data by participant number only (e.g., Participant No. 1). You may elect to have your data withdrawn from the study if you so desire, but you must inform the experimenters immediately of this decision so that the data may be promptly removed.

The data collected in this study may be used in future VTTI transportation research projects. IRB approval will be obtained prior to accessing the data for other projects. A digital video recording of your face will be captured by the data collection system. Blurred images of your face may be shown at professional conferences and meetings. The face video may also be used for future research projects at VTTI where they will be stored and used in a secure location. No electronic copies of these face video files will be provided to anyone other than approved VTTI staff.

It is possible that the Institutional Review Board (IRB) may view this study's collected data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

COMPENSATION

You will be paid $60 for full participation. This payment includes $5 to cover parking. You will be paid at the end of the session with a MasterCard from Virginia Tech. Note that if the session runs longer than expected, the pay is the same – i.e., you will still receive $60. All payments will be issued using a pre-loaded MasterCard. Please allow up to 1 full business day for activation of the card. Once activated, this card cannot be used past its expiration date. If there is no activity on the card for 5 months the card will become inactive.

You will be asked to provide researchers with your social security number or Virginia Tech I.D. number for the purposes of being paid for your participation. For tax recording purposes, the fiscal and accounting services office at Virginia Tech (also known as the Controller's Office) requires that all participants provide their social security number or Virginia Tech I.D. number to receive payment for participation in our studies.

FREEDOM TO WITHDRAW

As a participant in this research, you are free to withdraw at any time without penalty. If you choose to withdraw, you will be compensated for the portion of time of the study for which you participated. Furthermore, you are free to not answer any question or respond to experimental situations without penalty. If you choose to withdraw during the study session, please inform the experimenter of this decision and he/she will drive you back to the Virginia Tech Northern Virginia Center.

APPROVAL OF RESEARCH

This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University.

PARTICIPANT'S RESPONSIBILITIES

If you voluntarily agree to participate in this study, you will have the following responsibilities:

1. To follow the experimental procedures as best as you can.
2. To inform the experimenter if you have difficulties of any type.
3. To wear your seat and lap belt.
4. To maintain safe operation of the instrumented vehicle at all times.
5. To adhere to a speed that is safe and consistent with the flow of traffic.

PARTICIPANT’S ACKNOWLEDGMENTS

Check all that apply:

- ☐ I am not under the influence of any substances or taking any medications that may impair my ability to participate safely in this experiment.
- ☐ I am in good health and not aware of any health conditions that would increase my risk including, but not limited to lingering effects of a heart condition.
- ☐ I have informed the experimenter of any concerns/questions I have about this study.
- ☐ I understand that digital video including my image will be collected as part of this experiment.
- ☐ I understand that traffic conditions are unpredictable. My expected participation time has been explained to me, and I understand if there is heavier traffic than usual, the driving session may be longer than expected.

- ☐ If I am pregnant, I acknowledge that I have either discussed my participation with my physician, or that I accept any additional risks due to pregnancy.

PARTICIPANT’S PERMISSION

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project. **If I participate, I may withdraw at any time without penalty. I agree to abide by the rules of this project.**

____

Participant’s name (Print) Signature Date

____

Researcher’s name (Print) Signature Date

Should I have any questions about this research or its conduct, I may contact:

Dr. Tom Dingus @ (540) 231-1501, or by email: TDingus@vtti.vt.edu

Kayla Sykes @ (804) 652-9230, or by email: ksykes@vtti.vt.edu

If I should have any questions about the protection of human research participants regarding this study, I may contact: Dr. David Moore, Chair of the Virginia Tech Institutional Review Board for the Protection of Human Subjects, telephone: (540) 231-4991; email: moored@vt.edu.

Appendix J – Pre-Drive Questionnaire

1) Age: ___________

   Gender: _______________

2) Please complete the following information regarding the vehicle you drive most frequently.

Vehicle Make	Model	Year

3) Please complete the following information regarding any other vehicle(s) you drive regularly.

Vehicle Make	Model	Year

4) How many years of driving experience do you have? (Check One)
   - ☐ Less than 1 year
   - ☐ 1 – 5 years
   - ☐ 6 – 10 years
   - ☐ 11 – 15 years
   - ☐ 16 – 20 years
   - ☐ Over 20 years

5) Are you familiar with vehicle-to-infrastructure and/or vehicle-to-vehicle technology (systems located ***inside*** your vehicle that use various communication technologies to provide information to the driver, such as travel delay, crash warnings, etc.)? (Circle one)

1 2 3 4 5

Not at all **Somewhat** **Very Familiar**

6) *If your response was "3 or higher" for Question 5,* what are your opinions about vehicle-to-infrastructure and/or vehicle-to-vehicle technology?

____

____

____

7) Are you familiar with out-of-vehicle traffic management technology (systems located ***outside*** your vehicle that notify drivers of upcoming traffic conditions, provide travel delay estimates, etc.)? (Circle one)

1	2	3	4	5
Not at all		**Somewhat**		**Very Familiar**

8) *If your response was "3 or higher" for Question 7,* what are your opinions about out-of-vehicle traffic management technology?

____

____

____

9) Have you seen overhead signs similar to the picture on the right? (Circle one)

Yes **No**

10) How frequently do you travel in HOV lanes per week? (Check one)

- ☐ Never *(Skip to Question 12)*
- ☐ 1 – 2 days/week
- ☐ 3 – 4 days/week
- ☐ 5+ days/week

11) When you are driving along routes with HOV lanes, is it easy to determine the status of the HOV lanes with the traditional road sign, shown to the right? (Circle one)

Yes **No**

12) How frequently do you travel along ***routes*** with a lane management system like the one shown on the right? (Check one)
- ☐ Never *(Skip to Question 15)*
- ☐ 1 – 2 days/week
- ☐ 3 – 4 days/week
- ☐ 5+ days/week

13) How frequently do you travel in the lane management ***lanes*** per week? (Check one)
- ☐ Never
- ☐ 1 – 2 days/week
- ☐ 3 – 4 days/week
- ☐ 5+ days/week

14) When you are driving along routes with lane management lanes, is it easy to determine the status of the lanes using the traditional system shown to the right? (Circle one)

Yes **No**

15) I am generally aware of the speed limit while driving on the interstate. (Circle one)

1	2	3	4	5
Strongly Disagree		**Neutral**		**Strongly Agree**

16) How frequently do the Variable Message Signs, similar to the one shown below, impact your route decision-making? (Check one)

- ☐ Never
- ☐ 1 – 2 days/week
- ☐ 3 – 4 days/week
- ☐ 5+ days/week

17) I believe the Variable Message Signs, similar to the example in Question 16, are clear and concise. (Circle one)

1	2	3	4	5
Strongly Disagree		**Neutral**		**Strongly Agree**

18) How frequently do you travel ***<u>on I-66</u>*** where HOV lanes, lane management systems, and Variable Message Signs are present?

- ☐ Never
- ☐ 1 – 2 days/week
- ☐ 3 – 4 days/week
- ☐ 5+ days/week

19) If an in-vehicle system existed that would give you information on HOV hours, lane management, speed limit, and variable message signs, would you use it? (Circle one)

Yes **No**

Please explain your response.

____

____

____

____

Appendix K – AM Peak In-Vehicle Questionnaire

Time When Leaving Falls Church Parking Lot: ___________			
ALERT 1 – LM ONSET			
TASK (WB – "O O X"):	Lane Management – After Exit 62 Sign		
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) ________ / ________	
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')			
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)		
The following questions will be ranked on a scale from 1 – 5.			
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?		
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?		
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?		
PARTICIPANT COMMENTS:			
EXPERIMENTER COMMENTS:			

ALERT 2 – LM OFFSET			
TASK (WB – "O O X"):	Lane Management – After Exit 57B Sign		
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) ________ / ________	
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')			
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)		
The following questions will be ranked on a scale from 1 – 5.			
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?		
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?		
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?		

PARTICIPANT COMMENTS:	
EXPERIMENTER COMMENTS:	

ALERT 3 – SL			
TASK (WB – "O O X"):	Speed Limit – After 60 MPH Sign (Exit 52, Over Bridge)		
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) ____________ / ____________	
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')			
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)		
The following questions will be ranked on a scale from 1 – 5.			
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?		
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?		
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?		
PARTICIPANT COMMENTS:			
EXPERIMENTER COMMENTS:			

ALERT 4 – VMS 1			
TASK (WB – "O O X"):	Variable Message Sign – After alert offset ("Manassas Exits" Sign)		
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) ____________ / ____________	
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')			
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)		
The following questions will be ranked on a scale from 1 – 5.			
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?		

DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?	
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?	
PARTICIPANT COMMENTS:		
EXPERIMENTER COMMENTS:		

Time Once Parked in Bowl America Parking Lot: ________________

ALERT 5 – VMS 2			
TASK (WB – "O O X"):	Variable Message Sign – After Exit 47A (Break spot or red traffic light) (0.3 miles to turn left)		
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) ___________ / ___________	
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')			
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)		
The following questions will be ranked on a scale from 1 – 5.			
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?		
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?		
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?		
PARTICIPANT COMMENTS:			
EXPERIMENTER COMMENTS:			

For the following questions, please consider the entire WB route, which includes everything you have experienced so far.

SECTION 1		
TASK (WB – “O O X”):	Section 1 (LM, SL, VMS)	
WEATHER: **(Clear – ‘C’; Overcast – ‘O’; Light Rain – ‘LR’; Heavy Rain – ‘HR’)**		
MENTAL DEMAND:	How mentally demanding was this half of the route, where 1 is not at all mentally demanding and 5 is very mentally demanding?	
TEMPORAL DEMAND:	How hurried or rushed were you, where 1 is not at all hurried and/or rushed and 5 is very hurried and/or rushed?	
FRUSTRATION:	How insecure, discouraged, irritated, stressed, and annoyed were you, where 1 is not at all stressed/annoyed, etc. and 5 is very stressed/annoyed, etc.?	
Do you have any comments regarding anything you have experienced so far?		

ALERT 6 – SL		
TASK (EB – “<> <> O”):	Speed Limit – At 55 MPH Sign (Exit 52 – ½ Mile Sign)	
WEATHER: **(Clear – ‘C’; Overcast – ‘O’; Light Rain – ‘LR’; Heavy Rain – ‘HR’)**		**LANE #:** **(Rightmost Lane = 1)** ___________ / ___________
TRAFFIC DENSITY: **(Low – ‘L’; Medium – ‘M’; High – ‘H’)**		
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)	
The following questions will be ranked on a scale from 1 – 5.		
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?	
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?	
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?	
PARTICIPANT COMMENTS:		
EXPERIMENTER COMMENTS:		

ALERT 7 – VMS 3		
TASK (EB – “<> <> O”):	Variable Message Sign – After alert offset (Exit 64B)	
WEATHER: (Clear – ‘C’; Overcast – ‘O’; Light Rain – ‘LR’; Heavy Rain – ‘HR’)		**LANE #:** (Rightmost Lane = 1) ___________ / ___________
TRAFFIC DENSITY: (Low – ‘L’; Medium – ‘M’; High – ‘H’)		
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)	
The following questions will be ranked on a scale from 1 – 5.		
USEFULNESS:	How relevant and clear was the information presented, <where 1 is not at all relevant/clear and 5 is very relevant/clear?>	
DISTRACTION:	How distracting was the alert, <where 1 is not at all distracting and 5 is very distracting?>	
TIMING:	How appropriate was the timing of the alert, <where 1 is not at all appropriate and 5 is very appropriate?>	
PARTICIPANT COMMENTS:		
EXP. COMMENTS:		

Time Once Parked in Falls Church Parking Lot: _________________

ALERT 8 – VMS 4		
TASK (EB – “<> <> O”):	Variable Message Sign – After Exit 66 (Falls Church office) (0.3 miles to turn left)	
WEATHER: (Clear – ‘C’; Overcast – ‘O’; Light Rain – ‘LR’; Heavy Rain – ‘HR’)		**LANE #:** (Rightmost Lane = 1) ___________ / ___________
TRAFFIC DENSITY: (Low – ‘L’; Medium – ‘M’; High – ‘H’)		
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)	
The following questions will be ranked on a scale from 1 – 5.		
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?	
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?	

TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?	
PARTICIPANT COMMENTS:		
EXPERIMENTER COMMENTS:		

For the following questions, please consider the entire EB route, which includes everything you experienced since we left the Bowl America parking lot.

SECTION 2		
TASK (EB – “<> <> O”):	Section 2 (SL, VMS)	
WEATHER: **(Clear – ‘C’; Overcast – ‘O’; Light Rain – ‘LR’; Heavy Rain – ‘HR’)**		
MENTAL DEMAND:	How mentally demanding was this half of the route, where 1 is not at all mentally demanding and 5 is very mentally demanding?	
TEMPORAL DEMAND:	How hurried or rushed were you, where 1 is not at all hurried and/or rushed and 5 is very hurried and/or rushed?	
FRUSTRATION:	How insecure, discouraged, irritated, stressed, and annoyed were you, where 1 is not at all stressed/annoyed, etc. and 5 is very stressed/annoyed, etc.?	
Do you have any comments regarding anything you have experienced so far?		

Appendix L – Off-Peak In-Vehicle Questionnaire

<table>
<tr><td colspan="3">Time When Leaving Falls Church Parking Lot: ______________
ALERT 1 – LM ONSET</td></tr>
<tr><td>**TASK (WB – "O O X"):**</td><td colspan="2">Lane Management – After Exit 62 Sign</td></tr>
<tr><td>**WEATHER:**
(Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')</td><td></td><td rowspan="2">**LANE #:**
(Rightmost Lane = 1)
__________ / __________</td></tr>
<tr><td>**TRAFFIC DENSITY:**
(Low – 'L'; Medium – 'M'; High – 'H')</td><td></td></tr>
<tr><td>**COMPREHENSION:**</td><td>Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)</td><td></td></tr>
<tr><td colspan="3">***The following questions will be ranked on a scale from 1 – 5.***</td></tr>
<tr><td>**USEFULNESS:**</td><td>How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?</td><td></td></tr>
<tr><td>**DISTRACTION:**</td><td>How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?</td><td></td></tr>
<tr><td>**TIMING:**</td><td>How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?</td><td></td></tr>
<tr><td>**PARTICIPANT COMMENTS:**</td><td colspan="2"></td></tr>
<tr><td>**EXPERIMENTER COMMENTS:**</td><td colspan="2"></td></tr>
</table>

<table>
<tr><td colspan="3">**ALERT 2 – LM OFFSET**</td></tr>
<tr><td>**TASK (WB – "O O X"):**</td><td colspan="2">Lane Management – After Exit 57B Sign</td></tr>
<tr><td>**WEATHER:**
(Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')</td><td></td><td rowspan="2">**LANE #:**
(Rightmost Lane = 1)
__________ / __________</td></tr>
<tr><td>**TRAFFIC DENSITY:**
(Low – 'L'; Medium – 'M'; High – 'H')</td><td></td></tr>
<tr><td>**COMPREHENSION:**</td><td>Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)</td><td></td></tr>
<tr><td colspan="3">***The following questions will be ranked on a scale from 1 – 5.***</td></tr>
<tr><td>**USEFULNESS:**</td><td>How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?</td><td></td></tr>
<tr><td>**DISTRACTION:**</td><td>How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?</td><td></td></tr>
<tr><td>**TIMING:**</td><td>How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?</td><td></td></tr>
</table>

PARTICIPANT COMMENTS:	
EXPERIMENTER COMMENTS:	

ALERT 3 – SL			
TASK (WB – "O O X"):	Speed Limit – After 60 MPH Sign (Exit 52, Over Bridge)		
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) ___________ / ___________	
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')			
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)		
The following questions will be ranked on a scale from 1 – 5.			
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?		
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?		
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?		
PARTICIPANT COMMENTS:			
EXPERIMENTER COMMENTS:			

ALERT 4 – VMS 1			
TASK (WB – "O O X"):	Variable Message Sign – After alert offset ("Manassas Exits" Sign)		
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) ___________ / ___________	
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')			
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)		
The following questions will be ranked on a scale from 1 – 5.			
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?		

DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?	
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?	
PARTICIPANT COMMENTS:		
EXPERIMENTER COMMENTS:		

Time Once Parked in Bowl America Parking Lot: ________________

ALERT 5 – VMS 2			
TASK (WB – "O O X"):	Variable Message Sign – After Exit 47A (Break spot or red traffic light) (0.3 miles to turn left)		
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) ___________ / ___________	
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')			
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)		
The following questions will be ranked on a scale from 1 – 5.			
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?		
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?		
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?		
PARTICIPANT COMMENTS:			
EXPERIMENTER COMMENTS:			

For the following questions, please consider the entire WB route, which includes everything you have experienced so far.

SECTION 1		
TASK (WB – "O O X"):	Section 1 (LM, SL, VMS)	
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		
MENTAL DEMAND:	How mentally demanding was this half of the route, where 1 is not at all mentally demanding and 5 is very mentally demanding?	
TEMPORAL DEMAND:	How hurried or rushed were you, where 1 is not at all hurried and/or rushed and 5 is very hurried and/or rushed?	
FRUSTRATION:	How insecure, discouraged, irritated, stressed, and annoyed were you, where 1 is not at all stressed/annoyed, etc. and 5 is very stressed/annoyed, etc.?	
Do you have any comments regarding anything you have experienced so far?		

ALERT 6 – SL			
TASK (EB – "O O X"):	Speed Limit – At 55 MPH Sign (Exit 52 – ½ Mile Sign)		
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) ____________ / ____________	
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')			
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)		
The following questions will be ranked on a scale from 1 – 5.			
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?		
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?		
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?		
PARTICIPANT COMMENTS:			
EXPERIMENTER COMMENTS:			

ALERT 7 – LM ONSET			
TASK (EB – "O O X"):	Lane Management – After Exit 57A		
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) __________ / __________	
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')			
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)		
The following questions will be ranked on a scale from 1 – 5.			
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?		
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?		
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?		
PARTICIPANT COMMENTS:			
EXPERIMENTER COMMENTS:			

**** At this point, are you comfortable with the 1 – 5 scale?***

ALERT 8 – LM OFFSET			
TASK (EB – "O O X"):	Lane Management – After Exit 64A/B Sign		
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) __________ / __________	
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')			
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)		
The following questions will be ranked on a scale from 1 – 5.			
USEFULNESS:	How relevant and clear was the information presented, <where 1 is not at all relevant/clear and 5 is very relevant/clear?>		
DISTRACTION:	How distracting was the alert, <where 1 is not at all distracting and 5 is very distracting?>		
TIMING:	How appropriate was the timing of the alert, <where 1 is not at all appropriate and 5 is very appropriate?>		

PARTICIPANT COMMENTS:	
EXPERIMENTER COMMENTS:	

ALERT 9 – VMS 3		
TASK (EB – "O O X"):	Variable Message Sign – After alert offset (Exit 64B)	
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) ___________ / ___________
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')		
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)	
The following questions will be ranked on a scale from 1 – 5.		
USEFULNESS:	How relevant and clear was the information presented, <where 1 is not at all relevant/clear and 5 is very relevant/clear?>	
DISTRACTION:	How distracting was the alert, <where 1 is not at all distracting and 5 is very distracting?>	
TIMING:	How appropriate was the timing of the alert, <where 1 is not at all appropriate and 5 is very appropriate?>	
PARTICIPANT COMMENTS:		
EXP. COMMENTS:		

Time Once Parked in Falls Church Parking Lot: ________________

ALERT 10 – VMS 4		
TASK (EB – "O O X"):	Variable Message Sign – After Exit 66 (Falls Church office) (0.3 miles to turn left)	
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) ___________ / ___________
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')		
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)	
The following questions will be ranked on a scale from 1 – 5.		
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?	
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?	

TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?	
PARTICIPANT COMMENTS:		
EXPERIMENTER COMMENTS:		

For the following questions, please consider the entire EB route, which includes everything you experienced since we left the Bowl America parking lot.

SECTION 2		
TASK (EB – "O O X"):	Section 2 (LM, SL, VMS)	
WEATHER: **(Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')**		
MENTAL DEMAND:	How mentally demanding was this half of the route, where 1 is not at all mentally demanding and 5 is very mentally demanding?	
TEMPORAL DEMAND:	How hurried or rushed were you, where 1 is not at all hurried and/or rushed and 5 is very hurried and/or rushed?	
FRUSTRATION:	How insecure, discouraged, irritated, stressed, and annoyed were you, where 1 is not at all stressed/annoyed, etc. and 5 is very stressed/annoyed, etc.?	
Do you have any comments regarding anything you have experienced so far?		

Appendix M – PM Peak In-Vehicle Questionnaire

Time When Leaving Falls Church Parking Lot: ___________________		
ALERT 1 – SL		
TASK (WB – "0 <> (7) 0"):	Speed Limit – After 60 MPH Sign (Exit 52, Over Bridge)	
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) ___________ / ___________
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')		
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)	
The following questions will be ranked on a scale from 1 – 5.		
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?	
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?	
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?	
PARTICIPANT COMMENTS:		
EXPERIMENTER COMMENTS:		

ALERT 2 – VMS 1		
TASK (WB – "0 <> (7) 0"):	Variable Message Sign – After alert offset ("Manassas Exits" Sign)	
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) ___________ / ___________
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')		
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)	
The following questions will be ranked on a scale from 1 – 5.		
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?	
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?	

TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?	
PARTICIPANT COMMENTS:		
EXPERIMENTER COMMENTS:		

Time Once Parked in Bowl America Parking Lot: ________________

ALERT 3 – VMS 2			
TASK (WB – “0 <> (7) 0”):	Variable Message Sign – After Exit 47A (Break spot or red traffic light) (0.3 miles to turn left)		
WEATHER: (Clear – ‘C’; Overcast – ‘O’; Light Rain – ‘LR’; Heavy Rain – ‘HR’)		**LANE #:** (Rightmost Lane = 1) ___________ / ___________	
TRAFFIC DENSITY: (Low – ‘L’; Medium – ‘M’; High – ‘H’)			
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)		
The following questions will be ranked on a scale from 1 – 5.			
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?		
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?		
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?		
PARTICIPANT COMMENTS:			
EXPERIMENTER COMMENTS:			

For the following questions, please consider the entire WB route, which includes everything you have experienced so far.

SECTION 1		
TASK (WB – “0 <> (7) 0”):	Section 1 (SL, VMS)	
WEATHER: (Clear – ‘C’; Overcast – ‘O’; Light Rain – ‘LR’; Heavy Rain – ‘HR’)		
MENTAL DEMAND:	How mentally demanding was this half of the route, where 1 is not at all mentally	

	demanding and 5 is very mentally demanding?	
TEMPORAL DEMAND:	How hurried or rushed were you, where 1 is not at all hurried and/or rushed and 5 is very hurried and/or rushed?	
FRUSTRATION:	How insecure, discouraged, irritated, stressed, and annoyed were you, where 1 is not at all stressed/annoyed, etc. and 5 is very stressed/annoyed, etc.?	
Do you have any comments regarding anything you have experienced so far?		

ALERT 4 – SL			
TASK (EB – "O O X"):	Speed Limit – At 55 MPH Sign (Exit 52 – ½ Mile Sign)		
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1)	
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')		__________ / __________	
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)		
The following questions will be ranked on a scale from 1 – 5.			
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?		
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?		
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?		
PARTICIPANT COMMENTS:			
EXPERIMENTER COMMENTS:			

ALERT 5 – LM ONSET			
TASK (EB – "O O X"):	Lane Management – After Exit 57A		
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1)	

TRAFFIC DENSITY: **(Low – 'L'; Medium – 'M'; High – 'H')**		_________ / _________
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)	
The following questions will be ranked on a scale from 1 – 5.		
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?	
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?	
TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?	
PARTICIPANT COMMENTS:		
EXPERIMENTER COMMENTS:		

**** At this point, are you comfortable with the 1 – 5 scale?***

ALERT 6 – LM OFFSET		
TASK (EB – "O O X"):	Lane Management – After Exit 64A/B Sign	
WEATHER: **(Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')**		**LANE #:** **(Rightmost Lane = 1)**
TRAFFIC DENSITY: **(Low – 'L'; Medium – 'M'; High – 'H')**		_________ / _________
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)	
The following questions will be ranked on a scale from 1 – 5.		
USEFULNESS:	How relevant and clear was the information presented, <where 1 is not at all relevant/clear and 5 is very relevant/clear?>	
DISTRACTION:	How distracting was the alert, <where 1 is not at all distracting and 5 is very distracting?>	
TIMING:	How appropriate was the timing of the alert, <where 1 is not at all appropriate and 5 is very appropriate?>	
PARTICIPANT COMMENTS:		
EXPERIMENTER COMMENTS:		

ALERT 7 – VMS 3		
TASK (EB – "O O X"):	Variable Message Sign – After alert offset (Exit 64B)	
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) __________ / __________
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')		
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)	
The following questions will be ranked on a scale from 1 – 5.		
USEFULNESS:	How relevant and clear was the information presented, <where 1 is not at all relevant/clear and 5 is very relevant/clear?>	
DISTRACTION:	How distracting was the alert, <where 1 is not at all distracting and 5 is very distracting?>	
TIMING:	How appropriate was the timing of the alert, <where 1 is not at all appropriate and 5 is very appropriate?>	
PARTICIPANT COMMENTS:		
EXP. COMMENTS:		

Time Once Parked in Falls Church Parking Lot: ______________

ALERT 8 – VMS 4		
TASK (EB – "O O X"):	Variable Message Sign – After Exit 66 (Falls Church office) (0.3 miles to turn left)	
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		**LANE #:** (Rightmost Lane = 1) __________ / __________
TRAFFIC DENSITY: (Low – 'L'; Medium – 'M'; High – 'H')		
COMPREHENSION:	Regarding the alert last presented, what information was the system trying to give you? (Was their answer correct? Yes/No)	
The following questions will be ranked on a scale from 1 – 5.		
USEFULNESS:	How relevant and clear was the information presented, where 1 is not at all relevant/clear and 5 is very relevant/clear?	
DISTRACTION:	How distracting was the alert, where 1 is not at all distracting and 5 is very distracting?	

TIMING:	How appropriate was the timing of the alert, where 1 is not at all appropriate and 5 is very appropriate?	
PARTICIPANT COMMENTS:		
EXPERIMENTER COMMENTS:		

For the following questions, please consider the entire EB route, which includes everything you experienced since we left the Bowl America parking lot.

SECTION 2		
TASK (EB – "O O X"):	Section 2 (LM, SL, VMS)	
WEATHER: (Clear – 'C'; Overcast – 'O'; Light Rain – 'LR'; Heavy Rain – 'HR')		
MENTAL DEMAND:	How mentally demanding was this half of the route, where 1 is not at all mentally demanding and 5 is very mentally demanding?	
TEMPORAL DEMAND:	How hurried or rushed were you, where 1 is not at all hurried and/or rushed and 5 is very hurried and/or rushed?	
FRUSTRATION:	How insecure, discouraged, irritated, stressed, and annoyed were you, where 1 is not at all stressed/annoyed, etc. and 5 is very stressed/annoyed, etc.?	
Do you have any comments regarding anything you have experienced so far?		

Appendix N – AM/PM Peak Post-Drive Questionnaire

1) How distracting and/or annoying was the in-vehicle speed limit alert? (Circle one)

1	2	3	4	5
Not at all		**Moderately**		**Highly**

2) *If your response was "3 or higher" for Question 1*, which aspects of the alert were distracting and/or annoying? (Check all that apply)
   - ☐ The auditory "ding" prior to the verbal message
   - ☐ The verbal/voice message
   - ☐ Other:

   ____

   ____

3) How distracting and/or annoying was the in-vehicle Variable Message Sign (VMS) alert? (Circle one)

1	2	3	4	5
Not at all		**Moderately**		**Highly**

4) *If your response was "3 or higher" for Question 3*, which aspects of the alert were distracting and/or annoying? (Check all that apply)
   - ☐ The auditory "ding" prior to the verbal message

- ☐ The verbal/voice message
- ☐ Other:

____

____

5) How distracting and/or annoying was the in-vehicle lane management alert? (Circle one)

1	2	3	4	5
Not at all		**Moderately**		**Highly**

6) *If your response was "3 or higher" for Question 5*, which aspects of the alert were distracting and/or annoying? (Check all that apply)

- ☐ The auditory "ding" prior to the flashing symbol
- ☐ The flashing symbol
- ☐ Other:

____

____

7) How distracting and/or annoying was the presentation of the HOV information? (Circle one)

1	2	3	4	5
Not at all		**Moderately**		

8) Is there anything you would change about the HOV information and/or how it was presented? (Check all that apply)

- ☐ I would not change anything about the current system
- ☐ Add an auditory "ding" when the system updates
- ☐ Add a verbal/voice alert when the system updates
- ☐ Have the HOV symbol flash when the system updates
- ☐ I would rather NOT have HOV information
- ☐ Other: ____

____

Highly

9) Is there anything you would change about the in-vehicle ***alert*** system? (Check all that apply)

- ☐ I would not change anything about the current system
- ☐ I would alter the speed limit alert
  - Please explain: ____

    ____
- ☐ I would alter the Variable Message Sign alert
  - Please explain: ____

    ____
- ☐ I would alter the lane management alert
  - Please explain: ____

    ____
- ☐ Other: ____

  ____

10) Is there anything you would change about the ***entire*** in-vehicle system?

____

____

____

____

11) Which notification style did you prefer? (Check one)

- ☐ Ding + Voice
- ☐ Ding + Flashing Symbol

☐ No Alert

12) Rank the following alerts from "most useful" to "least useful." (Rank from 1 – 4, where 1 is the least useful and 4 is the most useful):

______ Speed Limit

______ Variable Message Signs

______ Lane Management

______ HOV

13) I would want this in-vehicle technology in my next vehicle. (Circle one)

1	2	3	4	5
Strongly Disagree		**Neutral**		**Strongly Agree**

14) *If your response was "4 or higher" for Question 13*, approximately how much money would you be willing to pay for this in-vehicle technology? ____________________

15) *If your response was "3 or lower" for Question 13*, which of the following explains your rating? (Check all that apply)

☐ The system as a whole was distracting
☐ The information was not clear and concise
☐ The system did not provide information that is important to me
☐ Other:
____

____

16) The in-vehicle system gave me information that I am interested in. (Circle one)

1	2	3	4	5
Strongly Disagree		**Neutral**		**Strongly Agree**

17) *If your response was "3 or lower" for Question 16,* which aspect(s) of the in-vehicle system are you ***not*** interested in? (Check all that apply)

☐ Speed Limit
☐ Variable Message Signs

- ☐ Lane Management
- ☐ HOV

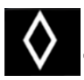
18) The speed limit alert system motivated me to change my speed. (Circle one)

1	2	3	4	5
Strongly Disagree		**Neutral**		**Strongly Agree**

19) *If your response was "3 or lower" for Question 18*, which of the following explains your rating? (Check all that apply)
- ☐ I was already going the speed limit
- ☐ I was not traveling much faster than the speed limit
- ☐ I alter my speed based on surrounding vehicle speeds, not the speed limit
- ☐ Other:

____

____

20) The presence of  or  altered my travel lane choice. (Circle one)

1	2	3	4	5
Strongly Disagree		**Neutral**		**Strongly Agree**

21) *If your response was "3 or lower" for Question 20*, which of the following explains your rating? (Check all that apply)
- ☐ I was not traveling in the HOV lane
- ☐ I remained in the HOV lane because I had 2+ passengers
- ☐ I was traveling in the HOV lane, but I did not notice the "diamond" symbol
- ☐ Other:

____

____

22) The presence of  or  altered my travel lane choice. (Circle one)

1	2	3	4	5
Strongly Disagree		**Neutral**		**Strongly Agree**

23) *If your response was "3 or lower" for Question 22*, which of the following explains your rating? (Check all that apply)
- ☐ I was not traveling in the lane management lane
- ☐ I was traveling in the lane management lane, but I did not notice the red "X"
- ☐ Other:

____

____

24) The Variable Message Signs (VMS) messages were clear and concise. (Circle one)

1	2	3	4	5
Strongly Disagree		**Neutral**		**Strongly Agree**

25) *If your response was "3 or lower" for Question 24*, which of the following explains your rating? (Check all that apply)

- ☐ The yellow message on the in-vehicle device was not clear/concise
- ☐ The verbal/voice message was not clear/concise
- ☐ The entire alert was not clear/concise
- ☐ Other:

____

____

26) How comfortable were you looking away from the road to receive information from the in-vehicle device? (Circle one)

1	2	3	4	5
Uncomfortable		**Neutral**		**Comfortable**

27) If an in-vehicle system existed that would give you information on HOV hours, lane management, speed limit, and variable message signs, would you use it? (Circle one)

Yes **No**

Please explain your response.

____

____

____

Appendix O – Off-Peak Post-Drive Questionnaire

1) How distracting and/or annoying was the in-vehicle speed limit alert? (Circle one)

1 2 3 4 5

Not at all **Moderately** **Highly**

2) *If your response was "3 or higher" for Question 1*, which aspects of the alert were distracting and/or annoying? (Check all that apply)
   - ☐ The auditory "ding" prior to the verbal message
   - ☐ The verbal/voice message
   - ☐ Other:

   ____

   ____

3) How distracting and/or annoying was the in-vehicle Variable Message Sign (VMS) alert? (Circle one)

1 2 3 4 5

Not at all **Moderately** **Highly**

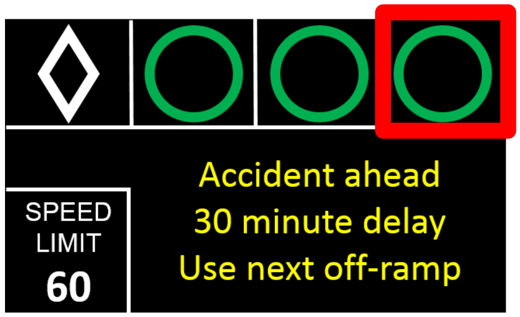
4) *If your response was "3 or higher" for Question 3*, which aspects of the alert were distracting and/or annoying? (Check all that apply)
   - ☐ The auditory "ding" prior to the verbal message

- ☐ The verbal/voice message
- ☐ Other:

____

____

5) How distracting and/or annoying was the in-vehicle lane management alert? (Circle one)



1	2	3	4	5
Not at all		**Moderately**		**Highly**

6) *If your response was "3 or higher" for Question 5*, which aspects of the alert were distracting and/or annoying? (Check all that apply)

- ☐ The auditory "ding" prior to the flashing symbol
- ☐ The flashing symbol
- ☐ Other:

____

____

7) Skip this question.
8) Skip this question.

9) Is there anything you would change about the in-vehicle ***alert*** system? (Check all that apply)

- ☐ I would not change anything about the current system
- ☐ I would alter the speed limit alert
  - Please explain:

    ____

    ____
- ☐ I would alter the Variable Message Sign alert
  - Please explain:

    ____

- ☐ I would alter the lane management alert
    - Please explain: ______________________________

      ____

      ____

- ☐ Other:

  ____

  ____

10) Is there anything you would change about the ***entire*** in-vehicle system?

    ____

    ____

    ____

    ____

11) Which notification style did you prefer? (Check one)

    - ☐ Ding + Voice
    - ☐ Ding + Flashing Symbol

12) Rank the following alerts from "most useful" to "least useful." (Rank from 1 – 3, where 1 is the least useful and 3 is the most useful):

    ______ Speed Limit

    ______ Variable Message Signs

    ______ Lane Management

13) I would want this in-vehicle technology in my next vehicle. (Circle one)

1	2	3	4	5
Strongly Disagree		**Neutral**		**Strongly Agree**

14) *If your response was "4 or higher" for Question 13*, approximately how much money would you be willing to pay for this in-vehicle technology? ______________

15) *If your response was "3 or lower" for Question 13*, which of the following explains your rating? (Check all that apply)

- ☐ The system as a whole was distracting
- ☐ The information was not clear and concise
- ☐ The system did not provide information that is important to me
- ☐ Other:

____

____

16) The in-vehicle system gave me information that I am interested in. (Circle one)

1	2	3	4	5
Strongly Disagree		**Neutral**		**Strongly Agree**

17) *If your response was "3 or lower" for Question 16*, which aspect(s) of the in-vehicle system are you ***not*** interested in? (Check all that apply)

- ☐ Speed Limit
- ☐ Variable Message Signs
- ☐ Lane Management

18) The speed limit alert system motivated me to change my speed. (Circle one)

1	2	3	4	5
Strongly Disagree		**Neutral**		**Strongly Agree**

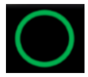
19) *If your response was "3 or lower" for Question 18*, which of the following explains your rating? (Check all that apply)

- ☐ I was already going the speed limit
- ☐ I was not traveling much faster than the speed limit
- ☐ I alter my speed based on surrounding vehicle speeds, not the speed limit
- ☐ Other:

____

____

20) Skip this question.
21) Skip this question.

22) The presence of  or  altered my travel lane choice. (Circle one)

1 2 3 4 5

Strongly Disagree **Neutral** **Strongly Agree**

23) *If your response was "3 or lower" for Question 22*, which of the following explains your rating? (Check all that apply)
- ☐ I was not traveling in the lane management lane
- ☐ I was traveling in the lane management lane, but I did not notice the red "X"
- ☐ Other:

____

____

24) The Variable Message Signs (VMS) messages were clear and concise. (Circle one)

1 2 3 4 5

Strongly Disagree **Neutral** **Strongly Agree**

25) *If your response was "3 or lower" for Question 24*, which of the following explains your rating? (Check all that apply)
- ☐ The yellow message on the in-vehicle device was not clear/concise
- ☐ The verbal/voice message was not clear/concise
- ☐ The entire alert was not clear/concise
- ☐ Other:

____

____

26) How comfortable were you looking away from the road to receive information from the in-vehicle device? (Circle one)

1 2 3 4 5

Uncomfortable **Neutral** **Comfortable**

27) If an in-vehicle system existed that would give you information on HOV hours, lane management, speed limit, and variable message signs, would you use it? (Circle one)

Yes **No**

Please explain your response.

____

____

____

____

Appendix P – W-9 Form

Virginia Tech

VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY

VENDOR REGISTRATION
Substitute Form W-9
Mail, e-mail or Fax completed form to:
201 Southgate Center, Blacksburg, VA 24061
W9@vt.edu Phone: (540) 231-2544/Fax: (540) 231-7221

Legal Name:
(as it appears on your tax return) ________________________________

Trade Name:
(DBA) ________________________________

Mail PURCHASE ORDERS and BIDS to:		Mail PAYMENTS to:	
PO Telephone # *(preferably toll free)*	PO Fax # *(preferably toll free)*	Email address:	
		AP email address:	

Taxpayer Identification Number:		
Employer Identification Number(EIN):	AND/OR	**Social Security Number (SSN):**

Entity Type (one MUST be checked)

☐ Corporation ☐ LLC ☐ Partnership

☐ Government Entity

☐ Non-Profit Organization

If "LLC" is checked, type MUST be marked below:
☐ Disregarded (D) ☐ Sole Proprietor
☐ Partnership (P)
☐ Corporation (C) ☐ Individual (see below)

For Individuals ONLY:
____ I am a U.S. Citizen, **or**
____ I have been granted permanent residency (green card holder), **or**

____ I am a Resident Alien for tax purposes and have contacted the international tax specialist at 540-231-3754 or jakunz@vt.edu to discuss additional documentation that is required by federal law.

Business Classification Type (check ALL that apply): *for descriptions see: http://www.purch.vt.edu/Vendor/class.html*

☐ Large Business ☐ Small Business ☐ Minority owned Business ☐ Women Owned Business ☐ Other

Certification: Under penalties of perjury, I certify that:
(1) The number(s) shown on this form is my correct taxpayer identification number(s) (or I am waiting for a number to be issued to me), ***and*** (2) The organization entity and all other information provided is accurate, ***and*** (3) I am not subject to backup withholding either because I have not been notified that I am subject to backup withholding as a result of a failure to report all interest or dividends, or the Internal Revenue Service has notified me that I am no longer subject to backup withholding.

You must cross out item (3) above if you have been notified by IRS that you are currently subject to backup withholding because of underreporting interest or dividends on your tax return.

______________________ ______________________
Authorized Signature *Title*

______________________ ______________________ ______________
Printed or Typed Name *Phone Number* *Date*

Appendix Q – Debrief Payment Form

Payment Acknowledgment

Project: Roadrunner

Fund: 451346

Principle Investigator: Kayla Sykes

Date:____

Participant Name:____

(print)

Social Security Number:____

I have received a MasterCard preloaded with $_________ for my

participation today. I understand that the initial activation of my card may take up to 1 business day. After activation, I understand that any period of inactivity exceeding 5 months will cause the card to become invalid.

Participant Signature:____

Experimenter Initials: ___________________________________