Integrated Vehicle-Based Safety System Light Vehicle Extended Pilot Test Summary Report

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16. Abstract

This report describes the conduct and findings from an extended pilot test (EPT) for the Integrated Vehicle-Based Safety Systems (IVBSS) program light vehicle platform. The crash warning functionalities developed in this program addresses several crash types, including rear-end, road departure, lane drift, lane change, merging, and curve-speed crashes. The EPT was conducted to demonstrate that the program is ready to launch the light-vehicle field operational test (FOT). The specific criteria for readiness are: 1) positive driver acceptance of the integrated system, 2) integrated system performance in naturalistic driving that is consistent with expectations, 3) reliable operation of the hardware and software onboard the test vehicles, and 4) operational processes that are practical and efficient for conducting the FOT and maintaining the necessary quality standards.
The IVBSS light vehicle EPT has demonstrated that after minor revisions are made to the warning system and the experimental process, the program is ready for the full-scale FOT.

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List of Acronyms

ACAS	Automotive Collision Avoidance System
BSD	Blind Spot Detection
CSW	Curve Speed Warning
DAS	Data Acquisition System
FCW	Forward Crash Warning
FOT	Field Operational Test
IMU	Inertial Measurement Unit
IVBSS	Integrated Vehicle-Based Safety Systems
LCM	Lane-Change/Merge Warning
LDW	Lateral Drift Warning
LV	Light Vehicle
POV	Principal other Vehicle or Current in-path Vehicle
RDCW	Road Departure Crash Warning
SV	Subject Vehicle
U.S. DOT	United States Department of Transportation
UMTRI	University of Michigan Transportation Research Institute

Executive Summary

This report describes the conduct and findings from an extended pilot test (EPT) for the Integrated Vehicle-Based Safety Systems (IVBSS) program light vehicle platform. The crash warning functionalities developed in this program addresses several crash types, including rear-end, road departure, lane drift, lane change, merging, and curve-speed crashes. The EPT was conducted to demonstrate that the program is ready to launch the light-vehicle field operational test (FOT). The specific criteria for readiness are: 1) positive driver acceptance of the integrated system, 2) integrated system performance in naturalistic driving that is consistent with expectations, 3) reliable operation of the hardware and software onboard the test vehicles, and 4) operational processes that are practical and efficient for conducting the FOT and maintaining the necessary quality standards.

The EPT was conducted over three months and included the use of twelve drivers recruited from the general public in southeast Michigan. Test participants drove four integrated system-equipped vehicles over 12,600 miles with more than 1,200 crash alerts being issued to the drivers. Drivers completed a questionnaire and were interviewed by an UMTRI staff experimenter to assess their subjective opinion of the system. Driver acceptance was found to be positive, indeed more positive than previous tests of these types of systems. A few drivers rated some of the alerts as "not useful," but these events apparently did not outweigh the positive views of system safety and utility. The frequency of integrated system alerts and the driving scenarios in which they occurred were generally consistent with on-road testing results, so that the drivers' experience was similar to the expected experience. Areas of potential improvement were identified that may reduce false alerts and possible nuisance alerts. The operation of the integrated system itself was reliable in the field with minor exceptions. Some improvements were also identified regarding the details of system operations and data collection. While none of these findings suggests a major issue that would threaten the conduct or success of the FOT, this report includes suggestions for areas of system improvement.

1 Introduction

The Integrated Vehicle-Based Safety Systems (IVBSS) program involves the development and field operational testing of an integrated crash warning on light vehicles and heavy trucks. The warning system addresses rear-end, lane-change, and road-departure crashes on both platforms, and curve-speed crashes for the light vehicle platform. This report describes the conduct and findings of the extended pilot test (EPT) for the light-vehicle system. The EPT and the full-scale field operational test (FOT) that will follow are conducted to expose drivers from the general driving population to the integrated system as they engage in their normal vehicle travel. Because the FOT is a major undertaking, the objective of the EPT is to first verify that the integrated system and the experimental process are ready for the FOT itself. The criteria for moving from the EPT to the FOT include demonstrating the following:

- Positive driver acceptance of the system;
- Technical performance that is consistent with expectations,
- Reliability of operation in the field
- An experimental process that is practical and efficient, including aspects such as participant recruiting and management, fielding and monitoring the vehicles, and collecting sufficient data from the vehicles and from test participants.

Because of its relatively small scope, the EPT is not intended to study safety implications of the integrated system, except for noting any potentially negative consequences for safety that may be associated with it. Safety impacts will be a major theme in the full FOT to be conducted after conclusion of the EPT.

2 Methodology

The EPT involves 12 drivers each using an integrated system-equipped vehicle for a period that varies between 25 to 27 days. The integrated system was capable of providing crash alerts for the entire duration of the EPT driver's use of the vehicle. The twelve drivers were recruited so that half were male and half were female. For each gender, there were drivers in each of three age groups: younger drivers (20 to 30 years), middle-aged drivers (40 to 50 years), and older drivers (60 to 70 years). Drivers are recruited from the general driving population and invited to UMTRI for a short session to familiarize them with the integrated system as well as to administer pre-drive subjective questionnaires. The drivers then have use of a prototype vehicle as their own vehicle for the testing period. During that period– unless technical problems arise or the driver has a question – they do not interact directly with experimenters, but simply use the vehicle for daily travel, vacation travel, or whatever their vehicles needs may be. At the end of the testing period, the driver returns the vehicle to UMTRI and is debriefed. The debriefing involves a questionnaire as well as an interview by an experimenter, including viewing video from their use of the vehicle.

The IVBSS test vehicles are instrumented, and after each trip a small set of data is transferred to UMTRI via cellular modem to allow experimenters to remotely monitor vehicle travel, warning system health and activity, such as the number and key characteristics of crash alerts or types of information provided to the driver. After the driver returns the vehicle, the remaining data collected onboard the vehicle is uploaded and analyzed to provide a record of the drivers' experiences, as well as for information about the number and characteristics of interactions between the integrated system and the driver. The following sections provide a discussion of the participant recruitment and management, an overview of the integrated system, and a short overview of the data collected.

2.1 Participant Selection

Participants were recruited with the assistance of the Michigan Secretary of State (the State's driver licensing bureau). As in other FOTs that UMTRI has conducted, a random sample of a few hundred driving records were drawn from the Michigan Secretary of State's database for the population of licensed drivers from eight counties surrounding Ann Arbor (all within a 1.5-hour drive of UMTRI). These individuals received a postcard informing them that they qualified to participate in a study of new automotive technologies being conducted by UMTRI, and to call an 800 number if interested in learning more about participating. This sampling strategy help to ensure that a wide geographical area that includes urban (where lane change conflicts are likely to be greater), suburban, and rural (where single-vehicle road departures are concentrated) driving conditions. Prospective participants having any felony motor vehicle convictions, such as driving while intoxicated or under the influence of alcohol, within 36 months of recruitment were excluded from the extend pilot test. Additionally, drivers had to meet a minimum self-reported annual mileage requirement. The qualifying criterion was to report mileage not less than 25 percent below the National Personal Transportation Survey reported average for an age and gender category. All information obtained through State records is treated with strict confidentiality.

Twelve participants were selected for the extended pilot test, four drivers from each of three age groups: 20 to 30, 40 to 50, and 60 to 70 years old. An equal number of male and female participants were selected for each age group. Driver demographic information is presented in Table 1.

Table 1. Driver demographic information

Subject #	*Age*	*Age group*	*Gender*	*Driving Experience (yrs)*	*Annual Mileage*
1	27	Y	M	2	15,000
2	67	O	M	51	14,000
3	65	O	M	47	20,000
4	45	M	F	27	23,000
5	47	M	M	30	21,000
6	60	O	F	46	12,000
7	65	O	F	47	12,000
8	26	Y	M	10	15,000
9	28	Y	F	13	15,000
10	50	M	M	34	25,000
11	46	M	F	30	20,000
12	21	Y	F	5	20,000

2.2 The Light Vehicle Integrated System

The light vehicle integrated system issues crash alerts and provides visual driver information to help drivers avoid actions (or inactions) that may lead to four crash types. The system is an integrated set of functionalities that may be described as an integration of the following functionalities:

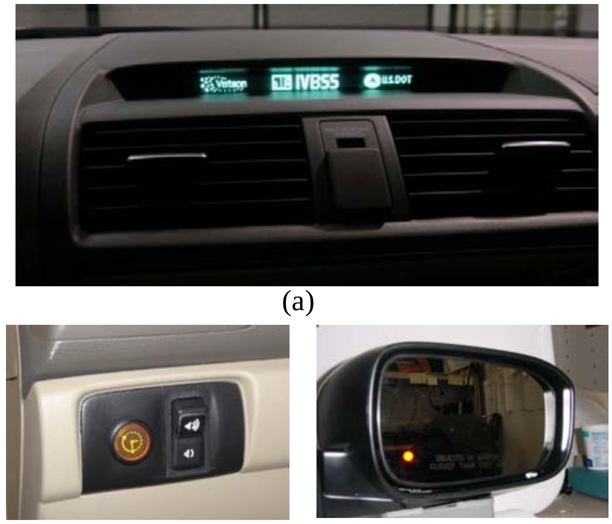
- Forward crash warning (FCW) is intended to help drivers avoid striking the rear-end of a same-direction vehicle.
- Curve-speed warning (CSW) is intended to help drivers avoid driving too quickly into and through curves, to avoid running off the road.
- Lane-departure warning (LDW) is intended to help drivers avoid drift-off road departure crashes as well as drifting out of lane in traffic.
- Lane-change/merge (LCM) warnings are intended to help drivers avoid potentially risky lane changes that again may lead to sideswipe or rear-end crashes.
- Blind-Spot Detection (BSD) information is intended to help drivers know when other same-direction vehicles are occupying space near the blind zones of the subject vehicle (SV).

Several reports are available on the design and evaluation of the light vehicle system. The vehicle platform is the 2006 and 2007 Honda Accord LX (V-6 model), shown in Figure 1. Physical elements of the system that are visible to the driver are shown in Figure 2. Not visible to the driver are the primary system sensors, which include seven radars; one long-range forward radar and six shorter-range, wide angle radars, a vision-based lane-tracking system, GPS, a yaw rate sensor, and a digital map database. Other measurements are also used by the integrated system, such as the driver brake switch, turn signals, and steering wheel angle.

The primary crash alert information is delivered to the driver through haptic cues or audible tones. A visual text display on the center stack display is provided shortly after each crash alert as confirmation of the type of alert (see Figure 2). From the driver's perspective, there are four warning types and one driver information feature, as shown in Table 2. These five correspond almost directly to the five functionalities listed in the bulleted list above, except for the threats associated with drifting, lane changes, or merging. For these lateral maneuvers, the table shows that drifting without a turn signal applied into a lane or onto a shoulder that is unoccupied is signaled by a haptic cue. Drifting into an occupied lane or shoulder is treated with an audible tone meant to be more salient to the driver; an intentional lane change or merging maneuver (i.e., with turn signal applied) into an occupied lane is treated with the same audible tone and visual text display, as shown in the table. The same audible tone and text are used because the crash threat is similar and the likely driver responses may be similar.

Table 2 also shows that the two forward crash threats (rear-end and curve-speed) are addressed using similar but not identical alerts to the driver. The FCW functionality provides an audible tone and a brake pulse. The CSW provides the same audible tone as FCW, without the brake pulse. The visual text to confirm the meaning of the alerts to the driver is different for these two, as indicated in the table.

Figure 1. The Honda Accord LX V-6 model used in the EPT



(a)

(b) (c)

Figure 2. Visible physical elements of the light vehicle driver interface: (a) text in OEM center-mounted display, (b) temporary mute and audio volume controls, and (c) blind spot detection icon in side mirror

Table 2. Crash alert and blind spot detection cues to the driver

Displayed text	Primary cues to driver	Functionality	Crash type addressed
"Hazard ahead"	Audible tone #1, Brake pulse	FCW	Rear-end crash
"Sharp curve"	Audible tone #1	CSW	Curve-speed crash
"Left Drift" or "Right Drift"	Seat vibration (directional)	LDW-Cautionary	Lane- or road-departure into an unoccupied lane or shoulder
"Left Hazard" or "Right Hazard"	Audible tone #2 (directional)	LDW-Imminent or LCM	Lane- or road-departure into an occupied lane or shoulder. Lane-change or merging crashes due to changing lanes into an occupied lane.
(None)	LED illuminated in side view mirror	Blind Spot Detection (BSD)	Lane-change or merging crashes.

The integrated system has an adjustable volume control for the audible components of alerts which is managed with a three-position rocker switch mounted near the left knee bolster. It does not, however, allow the driver to turn off the system or to adjust the timing of alerts. An exception to this statement is that a button near the driver's knee bolster allows them to temporarily suspend or "mute" all driver alerts and information for up to six minutes. This allows the driver some relief in the unusual case of travel through an environment that may lead to a series of false alerts. An example is traveling through a freeway construction zone in which a lane shift has been made without full removal of painted lane markers. The control for the audible volume and the temporary mute are shown in Figure 2.

The light vehicle integrated system is similar but not identical to the heavy truck integrated system. While the two systems were developed with many shared elements and partners, there are key differences between the two systems due to the nature of the platforms, their drivers, the purchasers of those systems, and the way in which they are driven are very different. Several documents are available to learn more about the integrated system design for each platform.

2.3 Objective Data Collection

A rich set of information is logged onboard the integrated system-equipped vehicles during the pilot test using a data acquisition system (DAS), shown in Figure 3. Because the integrated system is an advanced prototype, there is the opportunity for the DAS to capture sensor data, system alert decisions, and intermediate data directly from the vehicle data buses. The DAS also captures data from additional sensors installed on the vehicles which are not used for making decisions, but which are for used to study driver interactions. The DAS collects data continuously at rates of 10 to 50 Hz. Figure 4 shows an example of images from the five cameras, which include a forward view, a driver-face view, an over-the-driver's shoulder view, and rear/side views from cameras mounted on the two side mirrors, pointing back along the adjacent lanes. The forward and driver-face views are recorded continuously at 10 Hz, and the other views are recorded continuously at 2 Hz. A microphone has been installed to capture in-cabin sounds surrounding alert events. There are over 600 different measurements, and the video and audio information is time stamped to allow synchronizing these data with the remaining data.

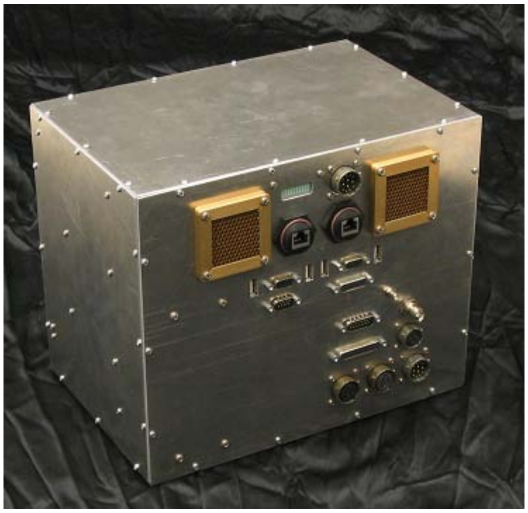


Figure 3. Data acquisition system

Figure 4. Sample of video views from the five cameras

3 Objective Data Collection and Results

This section presents observations and findings from the data collected during the EPT. This includes a description of the travel by the participants during the testing period, the frequency and nature of the alerts, and observations regarding any negative consequences of the integrated system. Suggestions are offered regarding possible areas of system improvements that should be implemented before the FOT begins.

The analysis of objective data includes all 12 drivers who used a prototype vehicle. Driver #201 was unable to complete his full period of test driving and ended up with 21 days of driving instead of the intended 25 to 27 days of driving. This driver was nevertheless included in all objective data analyses in this report. Note that because the driver was unavailable to complete the post-drive subjective data instruments, his data is not reflected in analyses of subjective data.

Four major sections follow. Section 3.1 summarizes the travel during the pilot test. Section 3.2 describes the frequency and nature of alerts and BSD icon illuminations provided for the drivers. Sections 3.2 and 3.3 respectively provide comments on the reliability of the integrated system operation in field testing and the success level of the data collection and remote monitoring of the fleet during the pilot test. The findings and suggestions for possible improvements are summarized in Section 5 of this report.

3.1 Travel During the Pilot Test

Travel by the drivers during the EPT is shown in Figure 5. The icons on the figure show the location at the end of each trip when the ignition is switched off. While most driving occurred in the southeast Michigan region, the figure shows that three drivers ventured into either the western portions of Michigan or into Ohio and the mountains of eastern Kentucky. The 12 drivers in the EPT covered a total of 12,629 miles, with individual driver travel distances ranging from a minimum of 433 miles (Driver #212) to 1934 miles (Driver #208). Travel distances by each driver will be presented in the following subsection’s description of alert rates.

Figure 6 below shows the miles accumulated with the wipers on, during dark lighting conditions, and with speeds greater than 25 mph and less than 55 mph. It is important to note that the EPT was conducted during a southeast Michigan winter, with launch on November 25, 2008 and completion on March 3, 2009. Thus, much of the rush-hour driving was in darkness, with the months of December, January, and February seeing significant snowfall. Figure 6 shows that approximately 30 percent of driving time was in the dark. Previous tests in the same region showed that in the winter, travel is somewhat reduced, and lane-tracking success is lower due to occasional snow on the roads and salt residue that reduces the daytime contrasts between painted lane markers and the roadway. Weather is cited later as a factor in some false alerts associated with lane tracking.

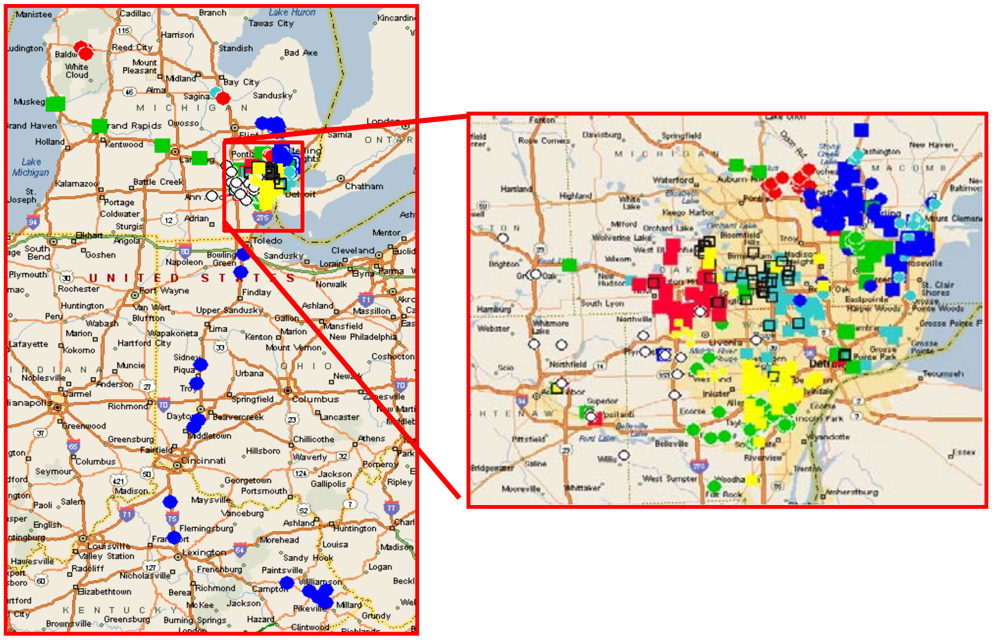


Figure 5. Travel by test participants (the map on the right is approximately 50 x 70 miles)

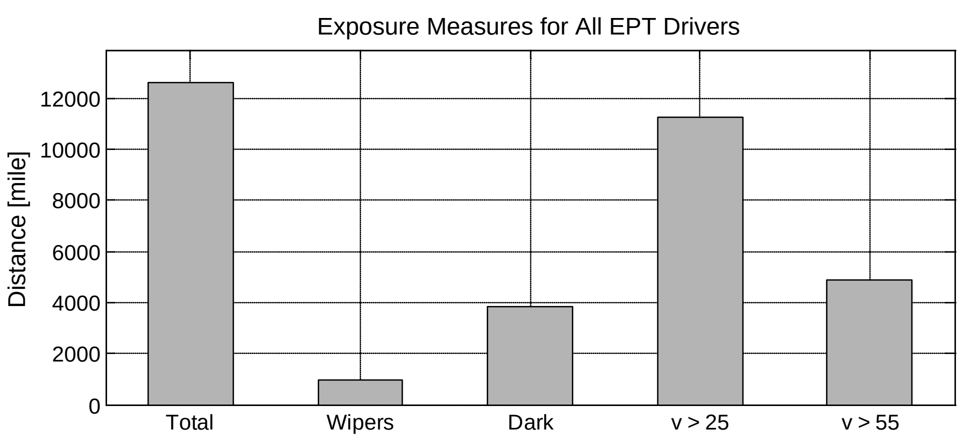


Figure 6. Travel in the pilot test by environmental condition and speed

3.2 Alert Events and Driver Information

This section describes the frequency and nature of the alert events and BSD driver information provided in the EPT. Section 3.2.1 below summarizes the number of alerts as well as the rate of alerts per unit of travel distance for each of the drivers. The remainder of this section treats the alert functionalities separately. This partitioning of alert types is artificial because as it is an integrated system, but the partitioning is useful for insight into the drivers' experience and the system operation. Some measures of integrated system performance will be also compared to performance measures for warning systems studied in previous projects to help validate that the system performance will be reasonable in terms of driver acceptance.

3.2.1 Number and Frequency of Alerts

Table 3 presents a summary of travel, alert counts, and alert rates for each driver. The upper portion of the table summarizes the number of days with the vehicle, the number of trips, and the miles traveled. The number of each alert type is listed as well. The lower portion of the table computes the alert rate per 100 miles traveled for each type of alert. Shading of the lower portion of the table indicates which drivers had the lowest alert rates for an alert type (no shading) or the highest rate (red or dark shading).

The number of alerts presented to individual drivers ranges from a minimum of 16 alerts (Driver #212) to 252 alerts (Driver #203). When normalized by travel distance, the minimum and maximum alert rates are 3.7 and 15.2 alerts per 100 miles.

While Table 3 provides the details, Figure 7 indicates the overall breakdown of alert types. The cautionary LDW alerts (drifting toward an unoccupied shoulder or lane) comprise 47 percent of all alerts, while the imminent LDW and LCM alerts associated with drifts or lane changes toward lanes or shoulders that are perceived to be potentially occupied together account for another 40 percent of all alerts. This means that the combined total of FCW and CSW alerts accounts for fewer than one in six alerts (13 percent).

Finally, the counts and alert rates are summarized graphically in Figure 8. The stacked bar chart at the bottom illustrates that there is indeed variation between drivers in which alerts they receive most often.

Table 3. Travel statistics, alert counts, and alert rates for individual drivers

	Individual Drivers												All Drivers
	201	**202**	**203**	**204**	**205**	**206**	**207**	**208**	**209**	**210**	**211**	**212**	
Gender (age)	M (20s)	M (60s)	M (60s)	F (40s)	M (40s)	F (60s)	F (60s)	M (20s)	F(20s)	M(40s)	F(40s)	F(20s)	6M,6F
Vehicle	LV2	LV1	LV3	LV5	LV3	LV4	LV5	LV1	LV3	LV4	LV5	LV1	--
Days	21	27	28	27	25	26	25	25	27	25	25	25	306
Trips	99	76	179	168	235	142	154	133	146	47	128	64	1571
Miles	757	664	1898	1390	1076	855	744	1934	932	716	1230	433	12629
FCW	11	11	8	3	7	16	6	8	1	5	26	7	109
CSW	2	1	39	5	0	4	1	4	4	10	7	0	77
LDW/cau	16	24	154	31	53	44	22	36	65	45	50	7	547
LDW/imm	3	5	31	30	34	19	6	25	38	8	64	1	264
LCM	20	6	20	14	16	6	9	51	20	19	40	1	222
ALL	52	47	252	83	110	89	44	124	128	87	187	16	1219
All/100 mi	6.9	7.1	13.3	6.0	10.2	10.4	5.9	6.4	13.7	12.2	15.2	3.7	9.2

Rates per 100 mi	**201**	**202**	**203**	**204**	**205**	**206**	**207**	**208**	**209**	**210**	**211**	**212**	**Avg**
FCW	1.5	1.7	0.4	0.2	0.7	1.9	0.8	0.4	0.1	0.7	2.1	1.6	1.0
CSW	0.3	0.2	2.1	0.4	0.0	0.5	0.1	0.2	0.4	1.4	0.6	0.0	0.5
LDW/cau	2.1	3.6	8.1	2.2	4.9	5.1	3.0	1.9	7.0	6.3	4.1	1.6	4.2
LDW/imm	0.4	0.8	1.6	2.2	3.2	2.2	0.8	1.3	4.1	1.1	5.2	0.2	1.9
LCM	2.6	0.9	1.1	1.0	1.5	0.7	1.2	2.6	2.1	2.7	3.3	0.2	1.7
Alert rate sum	6.9	7.1	13.3	6.0	10.2	10.4	5.9	6.4	13.7	12.2	15.2	3.7	9.2

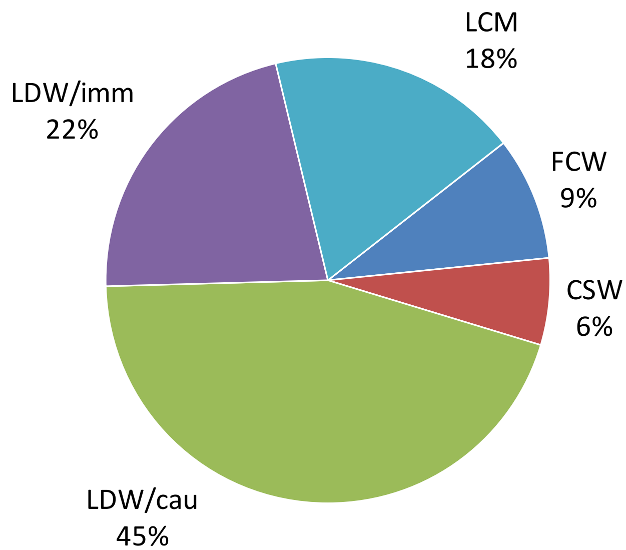


Figure 7. Relative rates of occurrence of each alert type (all drivers)

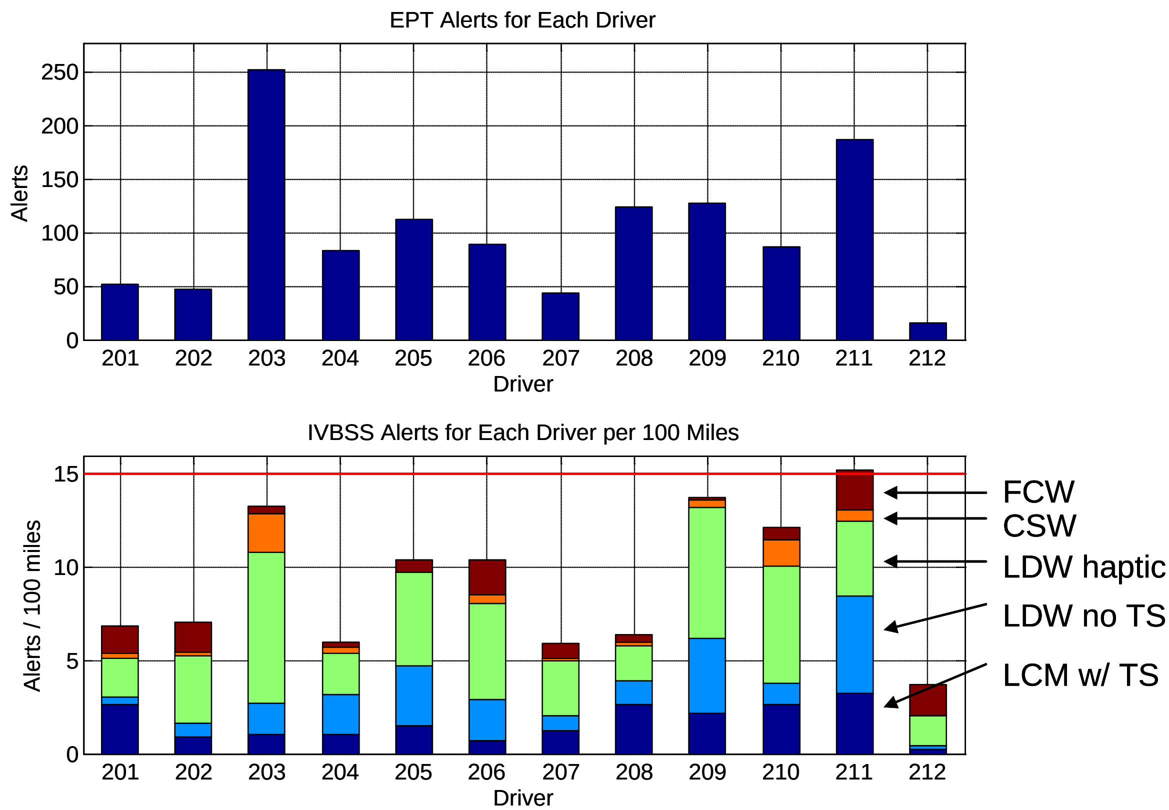


Figure 8. Alert counts and rates for individual drivers in the pilot test

3.2.2 Alert Characterization

While the system is intended to seamlessly integrate multiple crash warning functionalities, it is useful to isolate the functionalities for the purposes of describing driver experience and to study system performance. The following sections address crash alert and driver information functionalities separately, reporting on the frequency of each crash alert function as well as noting circumstances in which each type of alert occurs. Alert rates in this test are most useful as indicators of the driver's experience with the system, i.e., how often the integrated system is issuing alerts. The alert rates themselves depend upon the driving environment, the driver's style, and the system design. Because of this complexity, alert rates alone are not meaningful measures of technical performance in this pilot test. However, a high alert rate may suggest a potential for the system annoying the driver. (It may also suggest that the combination of the driver's environment and style is either unsafe or unexpected).

Alert circumstances are described differently for each alert type; however, they are all related somehow to a description of two or more different types of driving scenarios. For the purposes of this report, false alerts are defined as alerts that occur when the integrated system senses a potential threat that does not exist at the moment of alert onset. Examples of situations of false alerts are given in Table 4. The table uses the following terminology:

- Subject vehicle (SV): the integrated system-equipped vehicle.
- Principal other vehicle (POV): another vehicle that may pose a crash threat to the SV.

The definition of false alerts above is preliminary and an effort is underway to define a post-hoc labeling of individual alerts based on the falseness concept described here, as well as a function of the driving scenario and the actual and perhaps safety-necessary driver responses. In this report, false alerts are identified for FCW and CSW alert events, but not for LDW and LCM alert events.

Table 4. Examples of false alert scenarios

Functionality	Basic crash threat	Examples of false alert scenarios
FCW	A stopped, slower, or slowing same-direction POV is ahead within the SV's lane or with a path that may intersect the SV's path	An alert is triggered by roadside or overhead objects, e.g., road signs. An alert is triggered by adjacent lane traffic when neither the SV nor the POV is maneuvering laterally.
CSW	The SV is traveling on a road segment with at least one possible branch ahead with a curve.	There is no curve ahead on the current road or any possible branch. (e.g., map-matching places the vehicle on the wrong road)
LDW – no adjacent threat	The SV is drifting toward or over a properly perceived lane boundary.	A lane-tracking error has occurred, e.g., the system has incorrectly assumed that a visual feature is the lane boundary. No lane drifting is occurring.
LDW – crash threat present beyond lane edge	The SV is drifting toward or over a properly perceived lane boundary, with same-direction traffic or roadside objects posing a crash threat.	Same as for above. (Note that if no crash threat is present in the adjacent lane or shoulder, this alert would have the wrong level but not be false.)
LCM	The SV is moving to change lanes and a same-direction POV is beside the SV or approaching from the rear in such a way that their paths may intersect.	The SV is not moving to change lanes. The POV triggering the alert is not in the adjacent lane, but is two lanes over.

3.2.3 Forward Collision Warnings

A total of 109 FCW alerts were presented to drivers in the EPT. Figure 9 shows that the rate of FCW alerts per distance traveled varies significantly between individual drivers; in addition it illustrates that the average of the individual FCW alert rates is 1.0 alerts per 100 miles, and the minimum and maximum rates are 0.1 and 2.1 alerts per 100 miles. The variation in FCW alert rate has been previously observed to be affected by driving environment (exposure to decelerating or turning POVs or to roadside objects, for instance), as well as individual driving style.

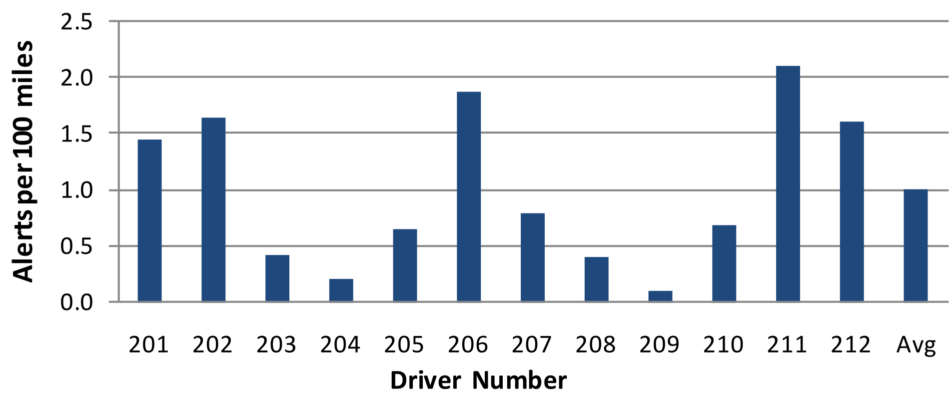


Figure 9. Rate of FCW alerts per 100 miles traveled by individual drivers

To better understand the drivers' experience, the following paragraphs present some characteristics of the circumstances in which FCW were provided. Of initial interest are the driving scenarios in which the alerts occurred. Table 5 presents the number of FCW alerts that were observed in each of several driving scenarios; the scenarios themselves are grouped into three general categories:

- Same-lane scenarios
- Transitioning path(s) scenarios
- False alerts

Same-lane scenarios are driving situations in which the SV is approaching a stopped, slower, and/or decelerating POV, and both vehicles remain in the same travel lane throughout the episode. Transitioning path(s) scenarios are those in which the SV and/or the POV are making lateral maneuvers, including lane changes, turns, and other maneuvers (as listed in Table 5). False alerts include several types of situations in which FCW alerts are issued without an actual threat of a rear-end crash; these are due to misinterpretation of sensor returns for POVs in the path of the SV. One exception to the false alert definition is that opposite-direction POVs turning left across the path of the SV are counted as transitioning path scenarios, not false alerts, due to the possible crash threat they may pose. Table 5 shows the percentage of all alerts that belong in these three categories. There are also six FCW alerts that are not classified due to missing video due to either a fogged forward-looking camera on a cold day (one event) or video files missing due to a faulty DAS Ethernet port configuration (five events). Table 5 also shows the exact counts within the individual scenarios. These distributions are roughly similar to those seen in a previous USDOT project, entitled the Automotive Collision Avoidance System (ACAS) FOT (Ervin, R., et al, 2005), except in this EPT the fraction of alerts given to stationary vehicles in the path of the SV is higher (five of 109 alerts, or 5 percent). Also shown in Figure 10 is the SV speed at which the FCW alerts are presented. The alerts are most common at lower travel speeds. Some of these are curve entry alerts occurring on surface roads with narrow shoulders; for instance, one driver received four alerts over his test period for garbage cans lining the roads of a hilly and curve neighborhood.

Table 5 summarizes the lessons-learned from the EPT, suggesting that there are three areas for improvement of forward crash warning system performance:

- Reducing false alerts due to roadside objects when the SV is approaching a curve,
- Reducing the number of alerts that occur when the POV is slowing to make a turn, while still protecting the driver in case the POV stops before leaving the lane, and
- Reducing the number of alerts for some crossing path POVs when those vehicles are relatively distant, but providing alerts if the POVs are dwelling within the path of the SV.

Overall, however, the fraction of false alerts (33 percent) is less than that observed in the ACAS FOT system. Throughout the review of the 109 alerts, there were cases where the driver needed to brake quickly and firmly following an alert.

Table 5. FCW alert occurrence by scenario and scenario group

Scenario Group	Scenario Label	FCW Alerts Scenario	FCW Alerts Scenario Group
False alerts	Adjacent-lane moving vehicle target	1	
	Cause of stationary target alert is unknown	5	
	Ghost target while passing large vehicle	8	
	Roadside object upon curve entry	16	33
	Roadside object while entering turn lane	3	(33%)
Same-lane scenarios	LV accelerating from rest or a low speed	2	
	LV at slower but constant speed	2	
	LV decelerating with predictable future speed or stop location	7	
	LV decelerating with unpredictable future speed or stop location	7	23
	LV stopped in path	5	(23%)
Transitioning path(s) scenarios	Opposite direction vehicle cuts across path, almost perpindicular	8	
	LV changing to a different lane	5	
	LV cuts in front of host	1	
	LV turning to leave roadway	27	39
	Vehicle is crossing path but moving in same direction	6	(38%)
Unknown scenario	Unknown scenario	6	6 (6%)
		All FCW alerts:	**101**

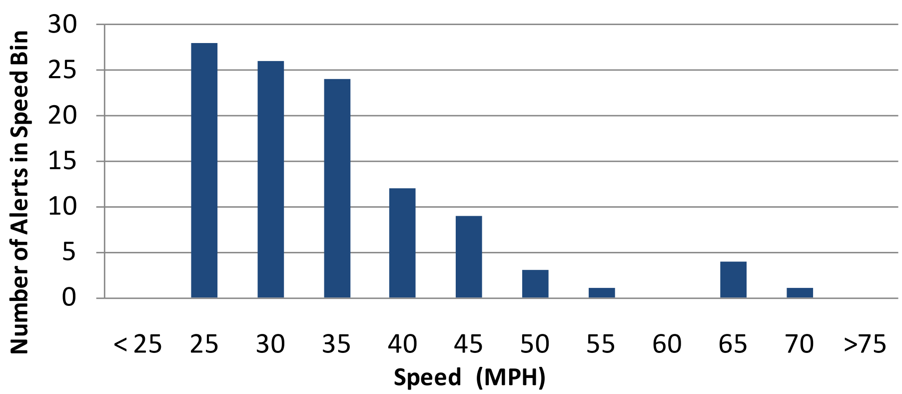


Figure 10. FCW alert occurrence by subject vehicle speed

3.2.4 Curve Speed Warnings

There were 77 CSW alerts presented to drivers during the EPT. Figure 11 shows that the rate of CSW alerts per distance traveled varied significantly between individual drivers. The figure shows that the average of the individual CSW alert rates is 0.5 alerts per 100 miles, and the minimum and maximum rates are 0.0 and 2.1 alerts per 100 miles. Thus CSW alerts were the alert type least frequently presented to drivers in this study.

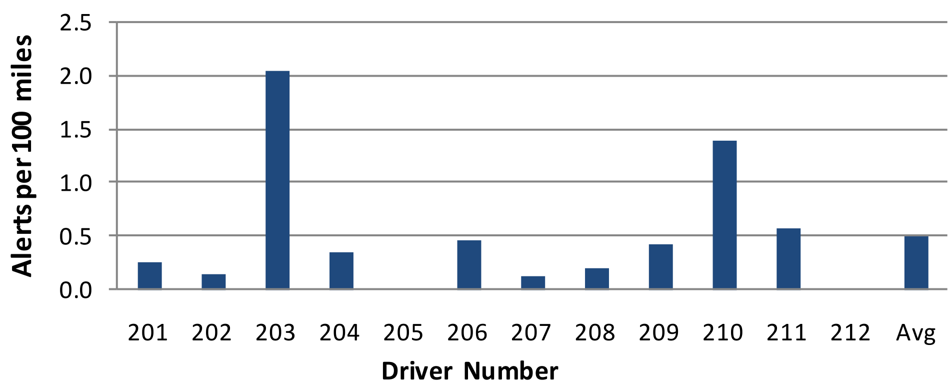


Figure 11. CSW alert rates per unit distance traveled for individual drivers

Despite this relatively low alert rate, the average rate of CSW alerts per unit distance traveled is influenced greatly by two drivers whose rates were much higher than the other 10 drivers. Driver #210 had 1.4 CSW alerts per 100 miles and Driver #203 had even more: 2.1 CSW alerts per 100 miles. The data on CSW alerts from one portion of Driver #203's use of the test vehicle is noteworthy. During 414 miles of travel in the mountains of eastern Kentucky, the driver received 34 alerts. This includes rather curvy roadways. Table 6 compares the rate of CSW alerts in this driving segment to the remaining driving in the pilot, including more than 1,400 miles driving by Driver #203 in Michigan and en route to eastern Kentucky through the flatter terrain of Ohio and northern Kentucky. The rate in the mountains was more than 20 times that of the remaining driving.

A final note is that the rate of CSW alerts in the Road Departure Crash Warning System Field Operational Test (RDCW FOT) was 6.1 per 100 miles; that test was also based in southeast Michigan, so that the rate for this alert type has been reduced by 90 percent over the RDCW FOT system, based on the EPT data. This is mentioned because the CSW system in RDCW received mixed driver acceptance results. The lower rate of alerts from the integrated version may lead to higher driver acceptance of the CSW portion of the system.

Table 6. Comparing CSW alert rates during rural mountain driving in eastern Kentucky with alert rates in the remaining EPT

	Miles	CSW alerts	Alerts/100 mi
Eastern Ky	414	34	8.21
Other driving	12,215	43	0.35
Total	12,629	77	0.61

To describe the drivers' experience with CSW, the video and data captured for the 77 alerts were reviewed to assign driving scenario labels and provide a snapshot of the overall experience. Table 7 presents the scenarios and scenario groups associated with these alerts. False CSW alerts are defined as events in which there is no curve present, either in the actual path taken by the SV or in any possible branch that is within several seconds ahead of the vehicle. There were seven false alerts (9% of all CSW alerts), and these include a single map-matching error, in which the SV was traveling on a freeway but the system perceived its position as being on a nearby surface street that had a sharp curve. There were six cases of "spurious" CSW alerts caused by a system error that was identified in the course of the EPT and subsequently corrected.

A second group of CSW event scenarios are those situations in which the SV traverses the curve that triggers the alert. This accounts for 75 percent of the CSW alerts, as shown in Table 7. This includes qualitatively different situations, such as traversing simple curves on surface streets (i.e., no roadway branches present) or traveling on freeway entrance or exit ramps. Note that half of this group of alerts occurred on freeways or on freeway entrance and exit ramps. Six alerts are shown to be due to curves on the freeway itself – these were all actual curves including a sharp urban curve in Dayton, Ohio, and others in the mountains of Kentucky. If Driver #203's travels in the mountains had not occurred, then the freeway/ramp events would have accounted for almost all of these alert types. Driver #203's mountain travels accounted for 26 of the 29 occurrences of CSW alerts on simple curves on surface roads. Thus the driver's experience of CSW may depend strongly on the roadway system they use, including the curvatures and the map quality.

The third category of CSW alerts is those after which the SV does not traverse the curve that triggered the alert. These are not considered false alerts because a potential threat does exist at the time of the alert onset. (See the false alert definition in Section 3.2.2). The system also cannot predict the future action of the driver. This type of alert accounts for 16 percent of the CSW alerts in the EPT. Note that a basic challenge of CSW, as described at length in LeBlanc et al., 2006, is predicting whether a vehicle that is approaching a roadway branch will continue on the original roadway or move onto the branch and possibly encounter a sharp curve. The most challenging case of roadway branching for CSW is nearing a freeway exit ramp, since the vehicle is traveling at high speed and the exit ramp may have a curve that would require significant slowing to navigate safely. This accounted for seven of the 70 non-false alerts (10 percent), which is far fewer than observed in the RDCW FOT. Thus the CSW functionality has demonstrated a much lower alert rate than previously observed. This may help improve driver acceptance of this functionality and the entire integrated system.

Overall, the CSW study suggests there is one area of obvious potential improvement, which is the removal of the spurious alerts, as noted above. Since 75 percent of the CSW alerts were associated with traversing the curve, the only other major reduction possibility is to adjust the thresholds for warning, perhaps as a function of the road type.

Table 7. CSW alerts by scenario and scenario group

Scenario Group	Scenario Label	CSW Alerts Scenario	CSW Alerts Scenario Group
False alerts	Map match error	1	7
	Spurious alerts	6	(9%)
Curve traversed	On entrance ramp	9	
	On exit ramp	6	
	On fwy, alert due to curve on fwy	6	
	On fwy, preparing to exit	5	
	On other fwy transition segment, drives through curve	3	58
	On surf rd, simple curve	29	(75%)
Curve not traversed	On fwy, passing by exit	7	
	On other fwy transition segment, passes branch with curve that triggers alert	3	12
	On surf rd, about to pass by a branch with curve	2	(16%)
		Total CSW alerts	**77**

3.2.5 Lane Departure Warnings

During the course of the EPT, there were 812 LDW alerts presented to the drivers. This included 547 cautionary LDW alerts associated with drifting in the direction of an unoccupied lane or shoulder, and 265 imminent LDW alerts associated with drifting toward an occupied lane. Thus cautionary alerts comprised 67 percent of the LDW alerts and imminent alerts 33 percent of the LDW alerts. (Section 2.1 summarized the driver displays associated with each alert type.)

Figure 12 shows that the rate of LDW alerts per unit distance traveled varies significantly between drivers. The average of the individual LDW alert rates is 6.1 alerts per 100 miles, and the minimum and maximum rates are 1.8 and 11.0 alerts per 100 miles. Thus LDW alerts, specifically cautionary LDWs, were the alert type most frequently presented to drivers in this study. For comparison, the average LDW alert rate across the drivers in the RDCW FOT was 10.6 alerts per 100 miles, which had a positive driver acceptance (LeBlanc et al., 2006). The lower rate is most likely due to more advanced heuristics and thresholding logic intended to suppress false LDW alerts.

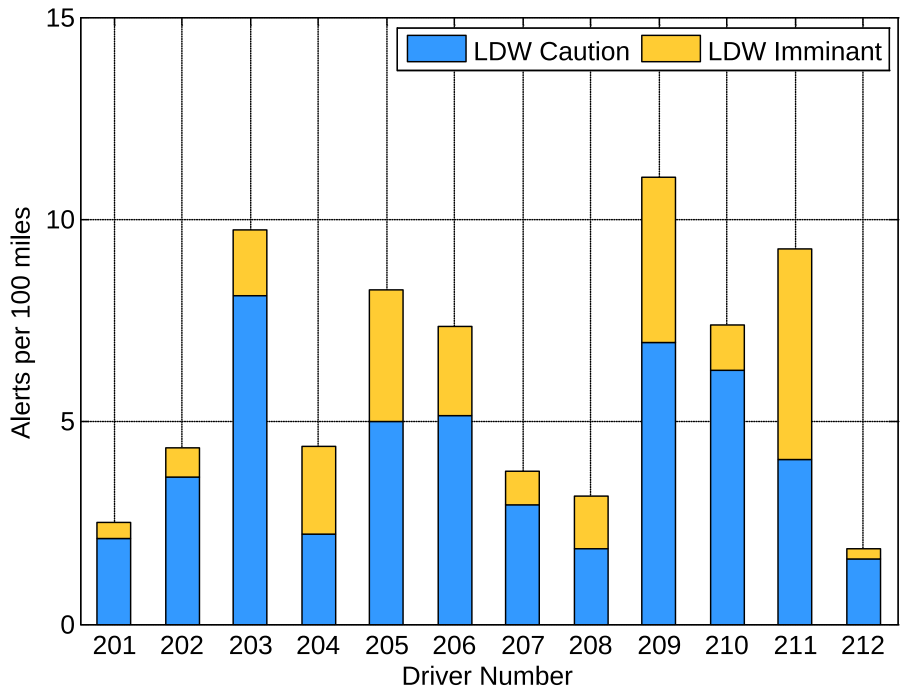


Figure 12. LDW alert rates per 100 miles traveled for individual drivers for both cautionary alerts and imminent alerts

An important part of the LDW system performance is lane tracking availability. Figure 13 shows LDW lane tracking availability as a percentage of driving time in three speed bins that roughly correspond to travel on minor surface, major surface, and limited access road types. LDW availability is defined as the system having confidence in its lane tracking with lane boundary(s) being perceived. The LDW subsystem will suppress any warnings, making it unavailable, when tracking confidence is low or lane position estimates are inconsistent. The availabilities shown below are higher than observed in the RDCW FOT despite the fact that the EPT was conducted in winter when snow and salt residue pose challenges to tracking visual features on the roadway.

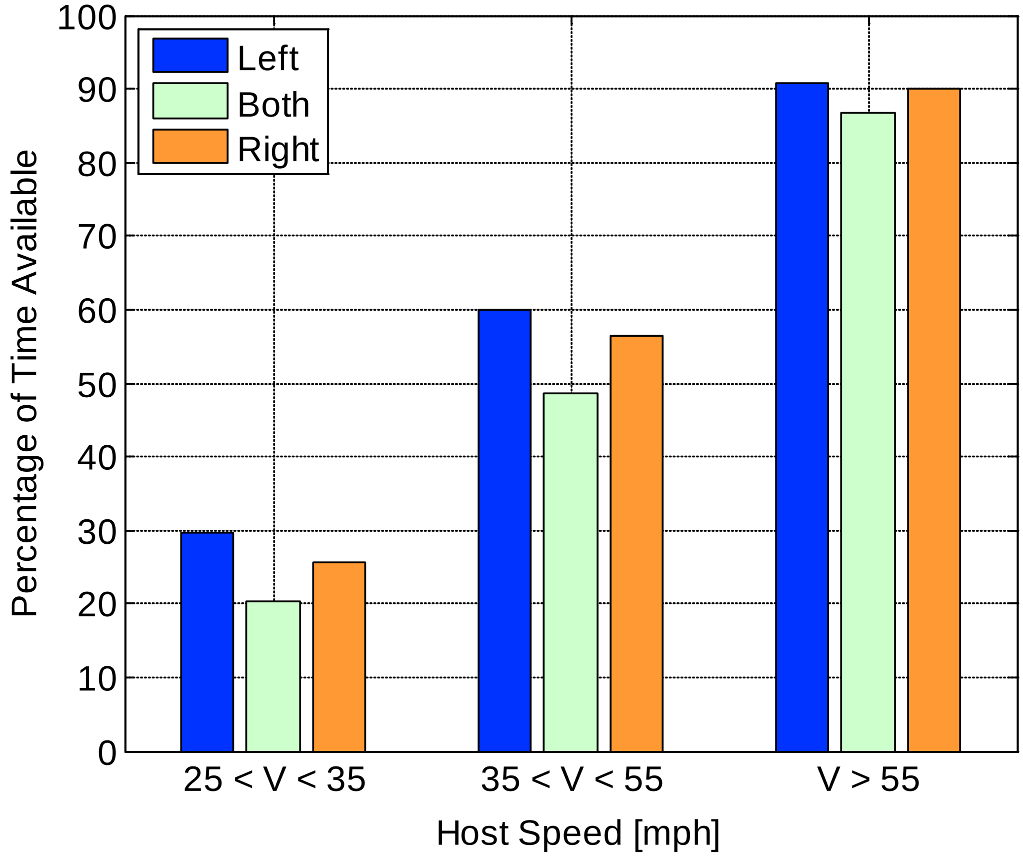


Figure 13. LDW lane tracking availability for different speed bins for all EPT driving

One notable aspect of the LDW alerts is the large bias for alerts occurring on the left side of the vehicle. As shown in Figure 14, overall there were three times as many left alerts as right alerts. This difference was investigated by looking at the left/right bias between drivers, between the two alert types, across various speeds, and across boundary types. No obvious reason could be observed. Over a third of the LDW alerts have been viewed by a researcher (viewing was random initially followed by analysis that focused on measured data that were expected to result in false alerts). Based on these observations there was no significant difference between left and right false alerts associated with poor lane tracking (40% of left alerts were false and 33% of right alerts were false). The RDCW FOT had a slight bias to the left for imminent alerts, but not as large as the difference for the prototype integrated system (LeBlanc et al., 2006). Therefore the drivers using this system will have a slightly different experience with the LDW subsystem. This bias prompted a review of all the light vehicle calibrations, and most of the vehicles that required calibration centering would have triggered an alert earlier for left drifts.

As mentioned above, over a third of the LDW events have been viewed and classified based on lane tracking accuracy and descriptive scenarios. Due to the poor weather and resulting road conditions, the LDW system often had difficulty accurately estimating the position of the lane boundaries. Poor lane tracking during adverse weather conditions resulted in a majority of the false alerts where the SV did not drift towards or over a lane boundary. Other situations that caused poor lane tracking include difficult lighting conditions (sun glare or shadows) and poorly maintained roads. Based on the observed events, it was determined that 85% percent of alerts with lateral velocities over 1.3 m/s in the previous 3 seconds were false and 80% of alerts at night with the wipers on during the first 60 seconds after the LDW system had been disabled were false. While conducting the video observations, the overall performance of the LDW system was consistent with expectations and no unintended negative safety effects were observed.

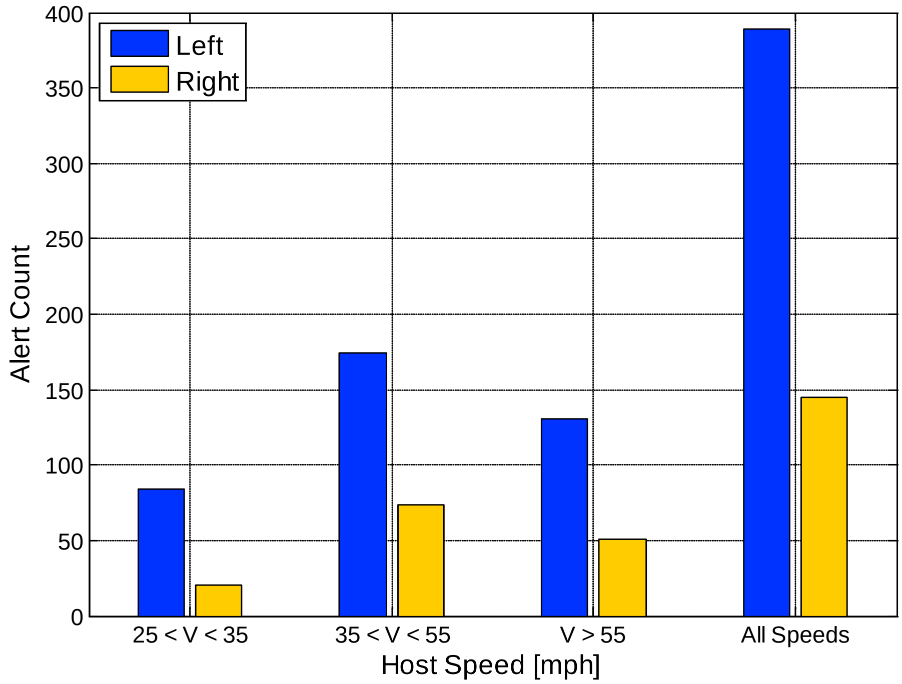


Figure 14. LDW left and right alerts for all drivers in various speed bins

3.2.6 Lane Change Merge Warnings

The EPT drivers received 222 LCM alerts. Like the previous alert types, Figure 15 shows that the LCM alert rate also varies significantly between individual drivers. The average of the individual LCM alert rates is 1.6 alerts per 100 miles, and the minimum and maximum rates are 0.2 and 3.3 alerts per 100 miles. This variation in LCM alert rates is expected to be affected by driving environment, including the traffic density and road types. A preliminary analysis, shown in Figure 16, examined this connection by plotting the LCM alert rate as a function of travel time with the BSD icon illuminated. This figure suggests a higher LCM alert rate for drivers in high traffic environments, assuming BSD events correspond to traffic density.

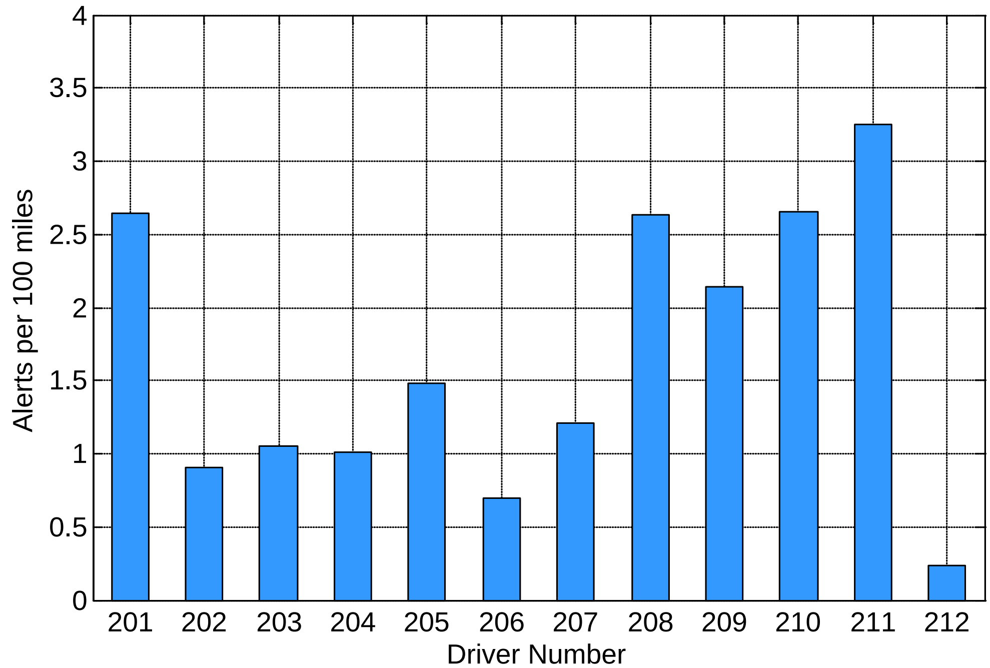


Figure 15. LCM alert rates per 100 miles for each driver

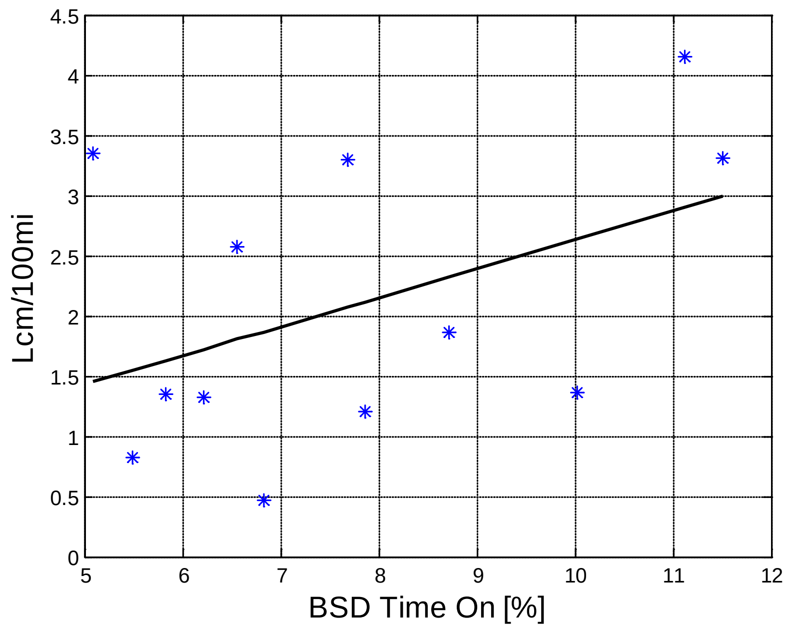


Figure 16. LCM alert rate per 100 miles as a function of travel time with BSD on

Two driving scenarios are intended to trigger an LCM alert: namely, a POV in the blind spot, and a fast moving POV that is quickly overtaking the subject vehicle. Both of these scenarios trigger the same alert to the driver, but the data recorded by the DAS can be used to distinguish between the two. These two alert scenarios are activated at different speeds; SV speeds over 31 mph will enable the blind spot warnings and speeds over 43.5 mph will enable the closing zone warnings. Figure 17 shows the blind spot and closing zone alerts for all the drivers in various speed bins. It can be seen from the figure that LCM alerts are dominated by the closing zone situations.

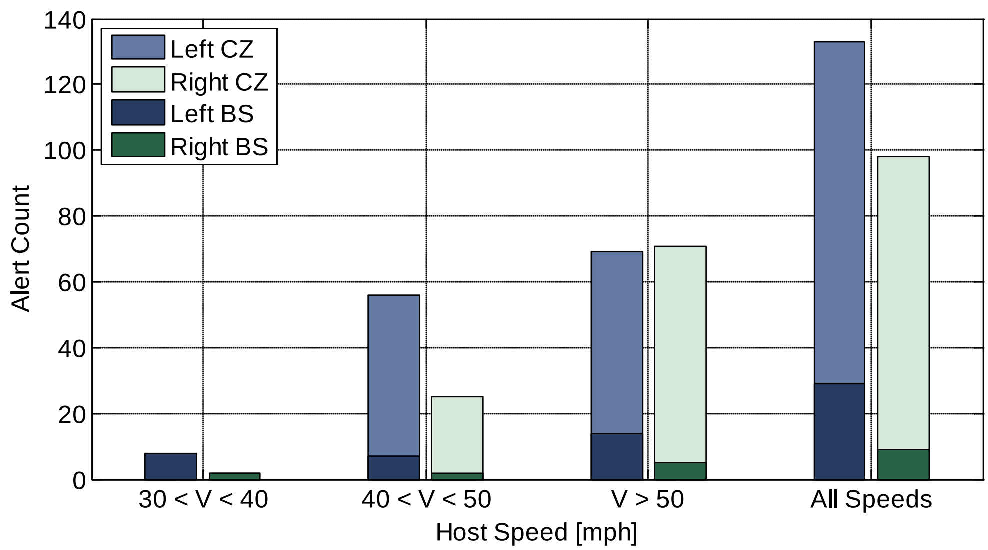


Figure 17. LCM alerts for closing zone and blind spot alerts for various speed bins

Over half of the 222 LCM alert events have been viewed and classified based on the presence of a POV in the blind spot or closing zone while the SV attempts to perform a lane change. Every other event for each driver was viewed and a number of additional events were viewed while investigating additional questions (e.g., UMTRI review of the events reviewed during participant interviews, or alerts with specific conditions for boundary type, lateral speed, and alert zone). While conducting these video observations, the overall performance of the LCM system was consistent with design expectations and no unintended negative safety effects were observed.

Based on the video observations, a number of the closing zone alerts were determined to be false. Two situations that elicited false alerts involved mistaken closing zone alerts where: 1) the SV passed a slower moving POV and then changed lanes in front of the slower POV, and 2) the SV was passed by a faster moving POV and then initiated a lane change after the POV was clear. In both of these situations the BSD lights were off and the driver usually continued their intended maneuver despite the LCM alert. Reducing false alerts in these situations may be a useful improvement for the FOT.

3.2.7 Blind Spot Detection Information

In addition to alerts from the LCM subsystem, the BSD provides the driver with LED icons in the side mirrors when same-direction, adjacent-lane traffic is within the blind zone. These LED icons are intended to be used by drivers consulting their mirrors, using central vision, and should not stimulate the drivers' peripheral vision when they are not considering a lane change. The blind spot extends from 0.5 to 3 meters laterally from the side from the subject vehicle and runs from approximately the B pillar to 3 meters rearward of the back bumper. Figure 18 shows the percentage of time that either side BSD light is on for all the EPT drivers in four speed bins where the BSD is enabled. Thus, the fraction of time with the BSD icon illuminated varies from approximately 4 to 12 percent of travel time. Higher speed (highway) travel over 55 mph is associated with the highest percentage of travel time with an illuminated BSD time; this is true for 11 of the 12 drivers. The duration and circumstances of these events have not yet been characterized. Note that the greater fraction time with illuminated BSD icon cannot alone be assumed to imply a heightened risk of lane-change conflict at higher speeds. The number and nature of lane changes in traffic at different speeds have not been studied.

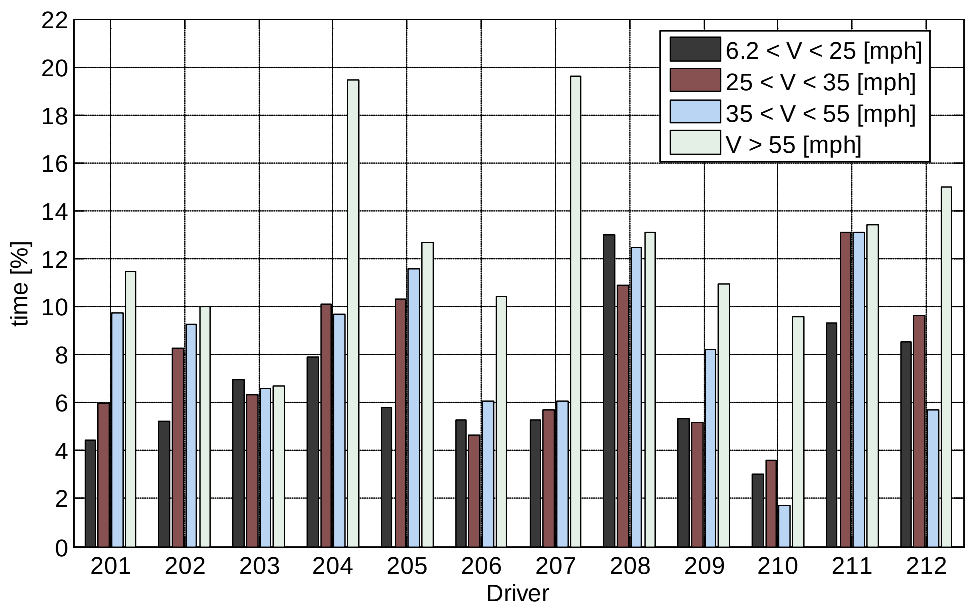


Figure 18. Percentage of time that at least one of the BSD lights is on for each driver in various speed bins

3.2.8 Arbitrated Warnings

The integrated system is designed to handle multiple-threat scenarios when more than one conflict occurs or is developing. With its almost 360-degree sensing capabilities and its integrated design, the system development process included deliberations regarding how to internally address multiple threat situations and present information to the driver. The IVBSS Phase I Interim Report (UMTRI 2008) describes the arbitration logic as a rule set that may delay or suppress alert requests that closely follow a previous alert request. Both the suppressed and delayed alerts are termed arbitrated warnings.

During the EPT, the arbitration subsystem flagged 62 alerts that occurred within three seconds of a previous alert. One alert was a “competing” alert situation, in which an LDW cautionary alert on the right side was issued for drifting to the right without a turn signal, followed by an LCM alert 0.12 seconds later for changing lanes into a closing zone situation with the turn signal. Upon video review of this event, the LCM alert was judged to be false because the POV was a slow moving heavy truck outside of the closing zone or blind spot. On the other hand, the other 61 alert requests (about 5% of total alerts requested) were suppressed by the arbitration system because they were repetitions of the same alert issued within the previous 3 seconds.

3.3 System Reliability in the Field

The integrated system proved to be fairly reliable in its operation during the EPT, despite the winter weather and at least three nights with temperatures below -14 F (-26 C). The following items were noted, however:

- CSW function was not available during approximately 1% of the trips. This appeared to be correlated but not limited to extremely cold days. (In parallel, cold-soak testing at Visteon Corporation resulted in a failure for the CSW hard disk to bootup.) This issue might be investigated to determine whether the risk and cost of newer hardware is worth the benefit. Note that the pilot data is from the three coldest months of the year and the FOT will be conducted over all 12 months.
- The snow and slush associated with winter led to at least three instances of a long-range forward radar being blocked for multiple trips during the pilot test. This can be expected for such systems. The important step is for the system to notify the driver. While error messages have been implemented since the EPT, these messages were not presented to the drivers in the pilot test. Instead, the issue was noted by experimenters via the cellular modem data. In one case the driver was phoned and asked to clear the radar fascia and the cellular data showed that the problem had disappeared. In the other two cases, the radar became unblocked due to warmer weather or possibly other factors.
- One case of an error associated with an LDW issue arose during the pilot. This occurred during a trip in which the vehicle was not moving, but rather parked in a

driveway for several seconds while a CD was removed from the audio system after having been parked outside for several days. The cause of this is under investigation.

The number of known issues with the integrated system is quite low for a pilot test and is encouraging to the experimental team. Nevertheless, the next section suggests that additional system diagnostic messages are recommended.

3.4 Objective Data Collection and Remotely Monitoring the Fleet

The data collection using the DAS was generally successful, but areas of improvement were also noted. An overall statistic is that the DAS collected data over a travel distance that equaled 99.7% of the travel distance, as recorded by the vehicle odometers. Given that the DAS takes almost 30 seconds to boot up, this suggests a very high rate of operation. Looking deeper, of course, uncovers some issues that can be addressed before the FOT launch:

- The inertial measurement unit (IMU) was not properly connected before launching Driver #202, thus an independent (non-integrated system) measurement of vehicle angular rates and accelerations is missing for that driver's data.
- The same vehicle suffered from lost video files for several trips on Driver #202. This was due to a faulty Ethernet port that connects the main DAS CPU with the video CPU. This has been remedied, as evidenced by success in later fielding the same unit for another driver in the EPT.
- Cellular modem transfer of a data snapshot at the end of the trip was poor for two drivers whose use of vehicles was near the end of the EPT. While this did not impact the collection of data, it prevented remote monitoring of the system. A similar problem occurred during the heavy truck FOT which has already launched and ran in parallel with the light vehicle EPT. Since the EPT has finished, a problem in model configuration settings has been found and corrected. This failure to connect was geographical in nature, i.e., associated with the cellular network's coverage, thus the problem was not detected in pre-pilot testing.

A further observation regarding remote monitoring of the fleet is a need for substantially increasing the use of onboard diagnostics and histograms to track the fleet health. Adding diagnostic messages for DAS capture has been planned for the integrated system itself. Equally necessary is for the DAS to summarize and transfer via the cellular modem information from these and other existing system diagnostics. This is necessary to track a fleet of 15 complex vehicles over a year of FOT usage with a minimum of expert input and analysis.

4 Subjective Data Collection and Results

At the end of the four- week exposure period, drivers completed a post-drive questionnaire regarding their experience with the system. A copy of the post-drive questionnaire is included in Appendix A, and Section 4.1 below summarizes highlights from that data. Additionally, there were six questions to which the responses can be transformed into measures of usefulness and satisfaction on the Van der Laan scale (Van der Laan, Heino, and De Waard, 1997). This scale was used to measure acceptance of the integrated system in terms of usefulness and satisfaction. These results are shown in Section 4.2.

After completing the post-drive questionnaire, drivers met with a researcher who interviewed them. During the interview, participant responses to the questionnaire were reviewed and potentially clarified or elaborated on. Additionally, each driver reviewed approximately 12 video clips of warnings and provided feedback about the usefulness of each warning. Results from the review of these warnings are in Section 4.3.

One driver was unable to complete his participation in the extended pilot test. As such, he did not participate in a debriefing session. Therefore, the results presented below, represent data from eleven drivers.

4.1 Subjective Results

After all drivers completed four weeks of driving, they participated in a debriefing session that consisted of completing a post-drive questionnaire (Appendix A) and rating about 12 warnings for their usefulness. The first two post-drive questions asked drivers to indicate what they liked most and least about the integrated system. Almost all of the other questions consisted of a 7-point Likert scale with higher numbers indicating positive attributes. A rating of a “4” was a neutral response.

4.1.1 Overall Impressions

Overall, drivers rated the system quite positively. The top three answers to the question, “What did you like most about it?” were BSD (seven drivers), the LDW drift warnings (three drivers), and FCW (two drivers). There was no consensus concerning what drivers liked least about the integrated system. Three drivers had nothing to report. Other drivers mentioned false warnings, the brake pulse, delay in receiving L/R hazard warnings, seat vibrations, BSD, and system inaccuracies in inclement weather. Overall, drivers found the system to be helpful (Q3, mean = 6.3); found the auditory warnings to be attention-getting (Q13, mean = 6.6), but not annoying (Q15, mean = 6.1) nor distracting (Q8, mean = 5.7); and reported being very satisfied with the integrated system

(Q9, mean = 6.4). When asked to rate the frequency with which they received warnings, drivers reported receiving warnings with about the right frequency (Q10, Mean = 4.1). While drivers disagreed somewhat with the statement, “The integrated system never gave me warnings when I did not need them (i.e., nuisance warnings)” (Q26, Mean = 3.6), they reported that they did not receive nuisance warnings too frequently (Q27, mean = 5.3). Further, they believe that the integrated system is going to increase their driving safety (Q5, mean = 6.3). A summary of the results from the post-drive questionnaire are presented in Appendix B.

4.1.2 Van der Laan Scale of Acceptance

In this study, the Van der Laan scale is used to measure acceptance of the integrated system as well as the individual subsystems. A description of the scale follows, along with the results from the present study. In addition, a comparison is presented between these Van der Laan results and the results from other field operational tests of crash avoidance technologies (i.e., RDCW FOT).

Each item on the Van der Laan scale is anchored by two polar adjectives, such as good and bad, and the driver is asked to rate their perception of the technology by marking a box along a continuum between these two poles. An example of one item is presented below:

useful						useless

Most of the adjective pairs are presented such that the positive adjective is on the left (as above), although a few items present the positive adjective on the right. The scale is usually scored from -2 to +2, with higher numbers corresponding to values closer to the positive adjectives and vice versa. For example, a mark in the left-most box in the above example would by scored as +2. The nine adjective pairs are: useful—useless, pleasant—unpleasant, good—bad, nice—annoying, effective— superfluous, likeable—irritating, assisting—worthless, desirable—undesirable, and raising alertness—sleep inducing. References to scale item numbers (see paragraph below) refer to these nine adjective pairs, in the order that they were written above.

A series of principal component analyses carried out by Van der Laan, et al. suggests that the scale can usually be reliably reduced to two components, a usefulness composite measure (consisting of items 1, 3, 5, 7, and 9) and a satisfaction composite measure (consisting of items 2, 4, 6, and 8). The authors also provide some guidelines for how to use the scale and analyze the results, such as how to assess whether the two components fit a particular set of data. They first suggest using scale reliability analyses (e.g., Cronbach's alpha) to determine how well items in each component correlate with each other. Their recommended criterion for the Cronbach's alpha is at least 0.65 for each component. They then suggest averaging the component scores for each subject to arrive at a single usefulness and a single satisfaction score for each subject. These two scores, averaged across subjects, represent the overall perceptions of usefulness and satisfaction associated with the technology.

Positive numbers correspond to positive perceptions about the technology, and negative numbers correspond to negative perceptions. All of these recommended steps were carried out for the six Van der Laan scales in the present study.

4.1.2.1. The Integrated System

One driver did not complete one item on the overall system Van der Laan scale, an item that was included in the satisfaction component. Consequently, this driver's data were not included in the calculations for the overall system satisfaction score.

Scale reliability tests were run for system components of usefulness and satisfaction. Cronbach's alphas for system usefulness and satisfaction were 0.55 and 0.72 respectively. While the Cronbach's alpha for the usefulness score is below the 0.65 that Van der Laan recommends, an examination of the raw usefulness ratings reveal that drivers rated the integrated system as very useful. In fact, of the 50 ratings that were analyzed, 45 were a "2" and five were a "1" (recall that scores range from -2 to +2). Because correlation is sensitive to range, and drivers only used a small part of the available range for this question, the rather low Cronbach's alpha is an artifact of the scale reliability method which assumes that the entire range is being used.

The usefulness component had a mean score of 1.89 (SD = 0.19), which indicates positive perceptions of usefulness about the system as a whole. The satisfaction component had a mean score of 1.33 (SD = 0.52), also indicating positive feelings of satisfaction associated with the integrated system.

4.1.2.2. Forward Collision Warning

Scale reliability tests for the FCW components of usefulness and satisfaction showed Cronbach's alphas of 0.94 and 0.84 respectively. The usefulness component for

FCW had a mean score of 1.49 (SD = 0.77) while the satisfaction component had a mean score of 1.02 (SD = 0.72), indicating a positive perception of FCW.

4.1.2.3. Curve Speed Warning

Scale reliability tests for the CSW components of usefulness and satisfaction showed Cronbach's alphas of 0.92 and 0.85 respectively. The usefulness component for CSW had a mean score of 1.34 (SD = 0.67) while the satisfaction component had a mean score of 1.08 (SD = 0.76), indicating a positive perception of CSW.

4.1.2.4. Lane Change Merge and Lateral Drift Warning Imminent

Drivers heard the same auditory warning for LCM and LDW imminent warnings therefore Van der Laan ratings of them were done as if they were a single type of warning (i.e., Left/Right Hazard). Scale reliability tests for the Left/Right hazard components of usefulness and satisfaction showed Cronbach's alphas of 0.92 and 0.88 respectively. The usefulness component for Left/Right hazard had a mean score of 1.80 (SD = 0.50) while the satisfaction component had a mean score of 1.43 (SD = 0.62), indicating a positive perception of Left/Right hazards.

4.1.2.5. Lateral Drift Warning-Cautionary

Scale reliability tests for the LDW drift components of usefulness and satisfaction showed Cronbach's alphas of 0.95 and 0.93 respectively. The usefulness component for LDW drifts had a mean score of 1.76 (SD = 0.48) while the satisfaction component had a mean score of 1.36 (SD = 0.66), indicating a positive perception of LDW drifts.

4.1.2.6. Blind Spot Detection

Scale reliability tests for the BSD components of usefulness and satisfaction showed Cronbach's alphas of 0.95 and 0.96 respectively. The usefulness component for BSD had a mean score of 1.67 (SD = 0.75) while the satisfaction component had a mean score of 1.59 (SD = 0.80), indicating a positive perception of BSD.

4.1.2.7. Comparisons across Studies

Overall, drivers had very positive perceptions of the integrated system, including each individual subsystem. For each of the subsystems as well as the integrated system, drivers gave higher ratings for usefulness than they did for satisfaction. It appears that drivers value the system functionality even if there are aspects of it that they are not entirely satisfied with (Figure 19). Finally, drivers rated the lateral systems, (i.e., LCM, LDW, and BSD) to be more useful and more satisfying than the forward systems (i.e., FCW and CSW).

It is useful to compare these results to Van der Laan scores from a study of different driver assistance technologies. Doing so allows one to see whether the integrated system was perceived much differently, relative to other systems in other experiments. This comparison does not include any statistical analysis, and it is likely that there would be no power in such an analysis. These are different test participants using the systems in unstructured driving. However, if the system or its separate functionalities were rated as much worse than other systems, it would be prudent to investigate the reasons.

Figure 20 shows that instead, the integrated system is not rated as much worse, but at least for these drivers, it fares well. The figure provides a comparison of the Van der Laan scores for this integrated system, the RDCW system (which consisted of two technologies, CSW and LDW) and the FCW subsystem of the ACAS system (Ervin, et al., 2005). LDW is not compared in this figure because the Van der Laan ratings for LDW in this EPT were divided into LDW drifts and LDW imminent alerts which were grouped with the LCMs for purposes of the Van der Laan ratings. As can be seen, drivers had positive perceptions of both systems; however, they found the integrated system to be more useful and more satisfying than RDCW. When comparing the individual subsystems, these subsystems were rated more highly than either those of RDCW or ACAS.

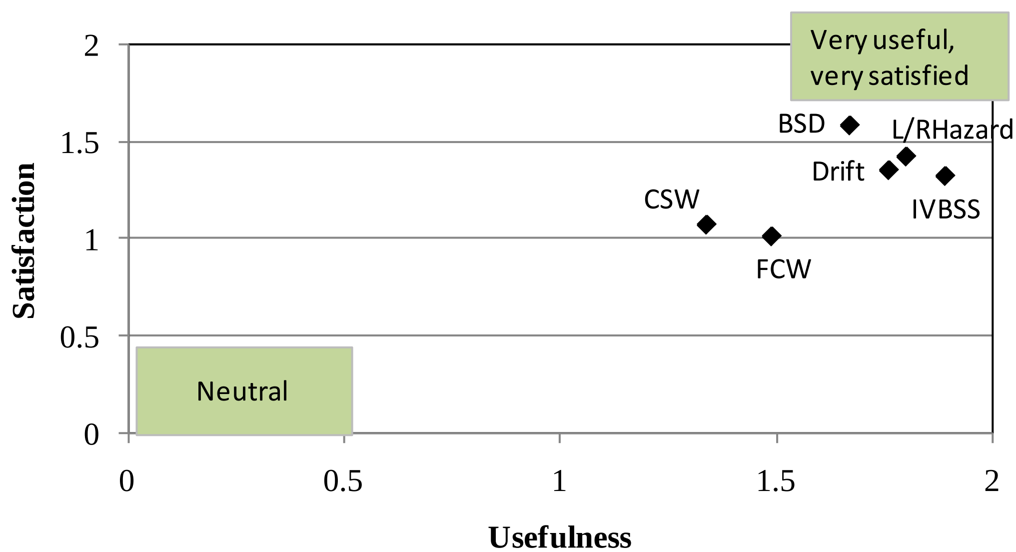


Figure 19. Average Van der Laan scores for usefulness and satisfaction for subsystems and overall integrated system

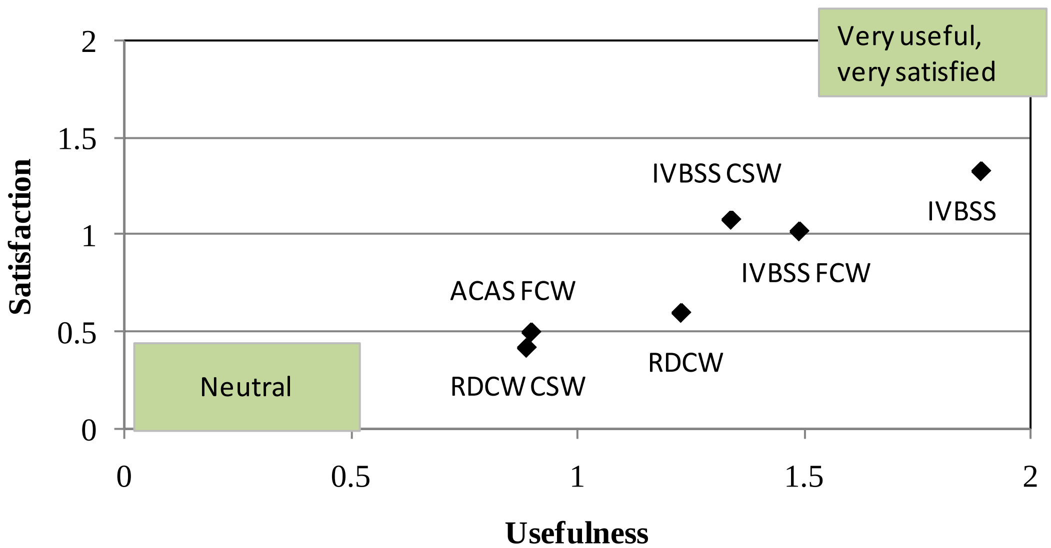


Figure 20. Average Van der Laan scores for usefulness and satisfaction for several crash warning systems

4.1.3 Driver Video Review of Their Own Alerts

Of the eleven drivers who participated in a debriefing session, only ten reviewed videos of situations in which they received warnings, because the viewer was not operational during one driver's debriefing session. Each driver reviewed approximately 12 videos. Whenever possible, they viewed true and false warnings for each warning type. For each warning, they were asked, "Was the warning useful?" If they replied, "yes," then they were asked to use the five-point scale below to state how useful the warning was.

1	2	3	4	5
Not at all Useful	Slightly Useful	Somewhat Useful	Fairly Useful	Quite Useful

4.1.3.1. Forward Collision Warnings

Drivers reviewed a total of 36 FCW alerts. The alerts were classified in one of three ways: False; the SV and POV were in the same lane; or the SV and/or POV path(s) were transitioning between lanes. The highest percentage of useful FCW alerts (100%) occurred when both the SV and POVs were in the same lane (Figure 21). Inexplicably, drivers rated false FCW alerts as more useful than when the SV and POVs were in the same lane (Means of 4.6 and 3.5, respectively) (Figure 22).

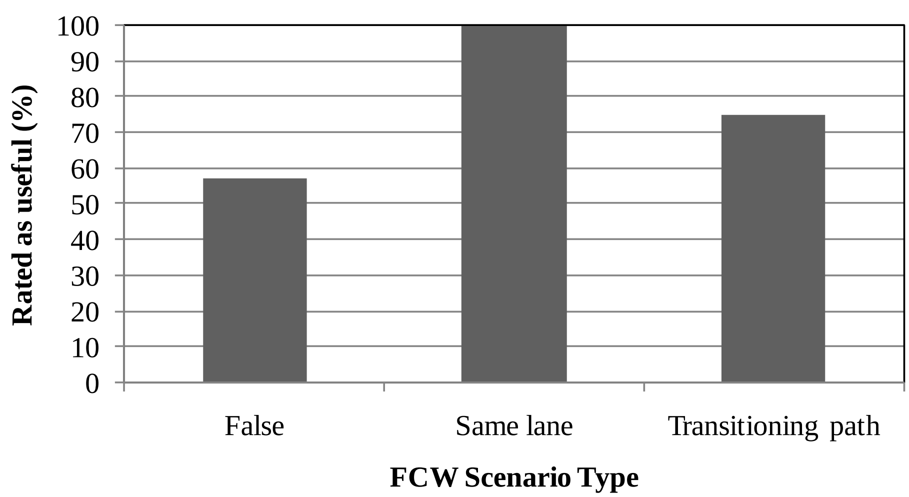


Figure 21. The percentage of useful FCW alerts by scenario type

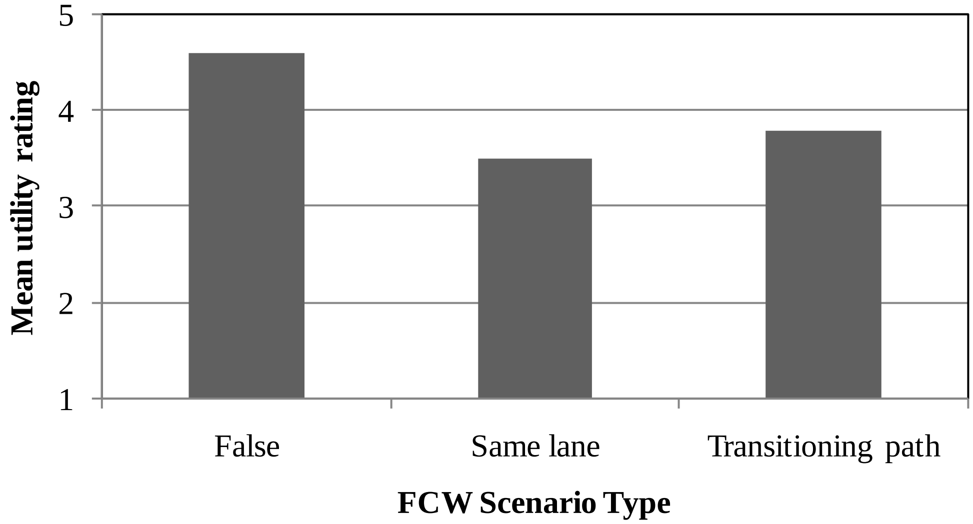


Figure 22. Average usefulness rating across all drivers by FCW scenario type

4.1.3.2. Curve Speed Warnings

Drivers reviewed a total of 21 CSW alerts. One CSW alert was excluded from the analysis which follows because the driver indicated that he was experimenting when he received that warning. The alerts were classified in one of three ways: False; the driver traversed the curve; or the driver did not traverse the curve. The highest percentage of useful CSW alerts (75%) occurred when the driver did not traverse the curve. Regardless of curve scenario, drivers' average rating for the usefulness of CSW alerts was "fairly useful" (Mean = 4) (Figure 30).

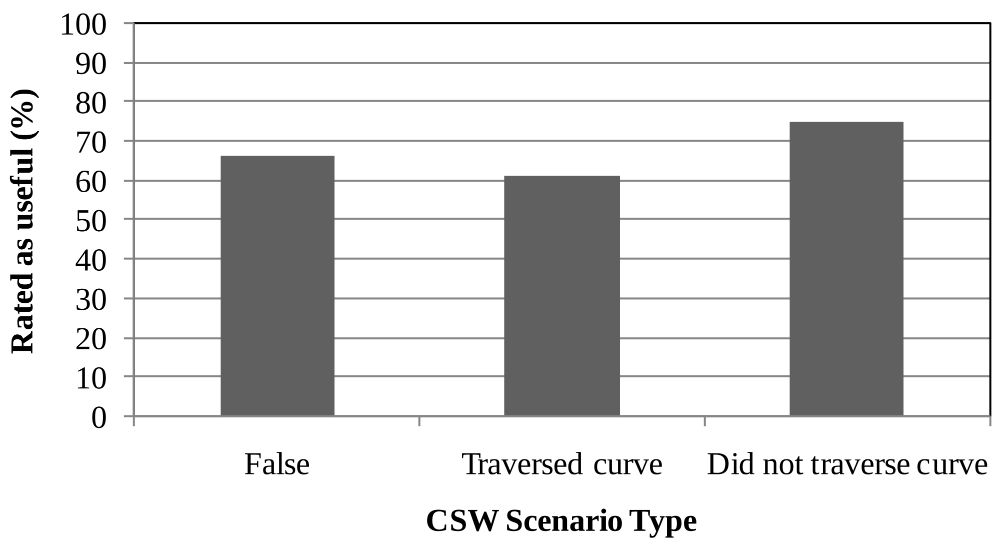


Figure 23. The percentage of useful CSW alerts by scenario type

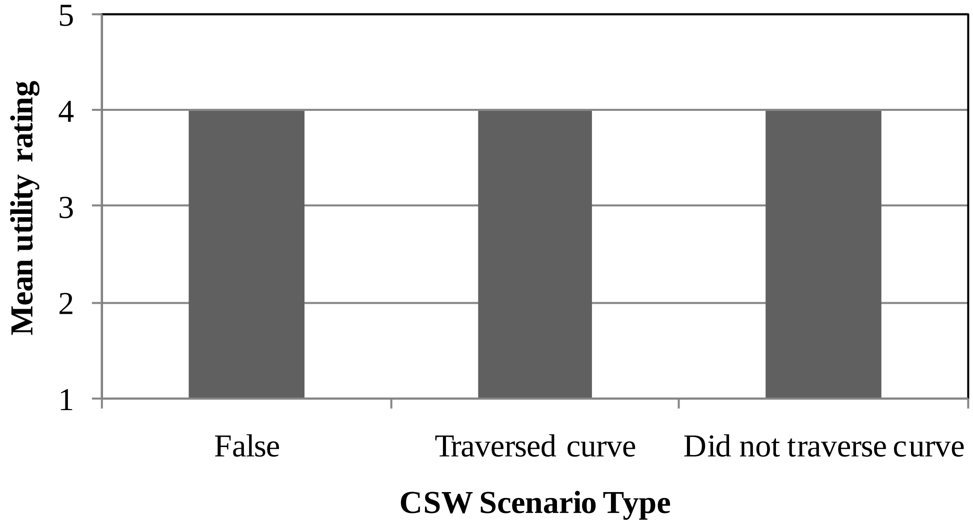


Figure 24. Average usefulness rating across all drivers by CSW scenario type

4.1.3.3. Lane Change/Merge Warnings

Drivers reviewed a total of 32 LCM alerts. The alerts were classified as either true or false. Drivers rated 89% of the true LCM alerts and 77% of the false alerts as useful (Figure 25), but provided similar ratings for both types of alerts when asked to rate how useful the warnings were (Figure 26).

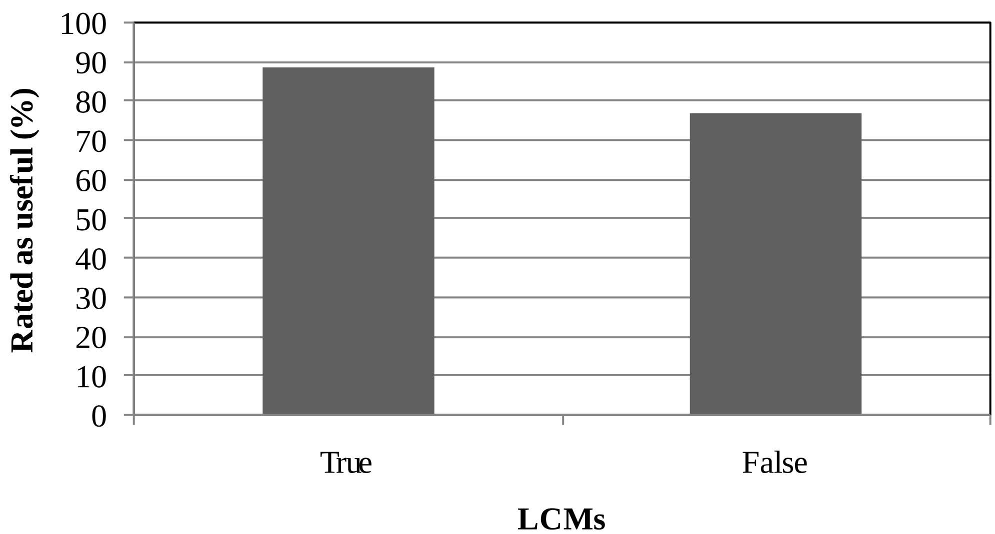


Figure 25. The percentage of useful true and false LCM alerts

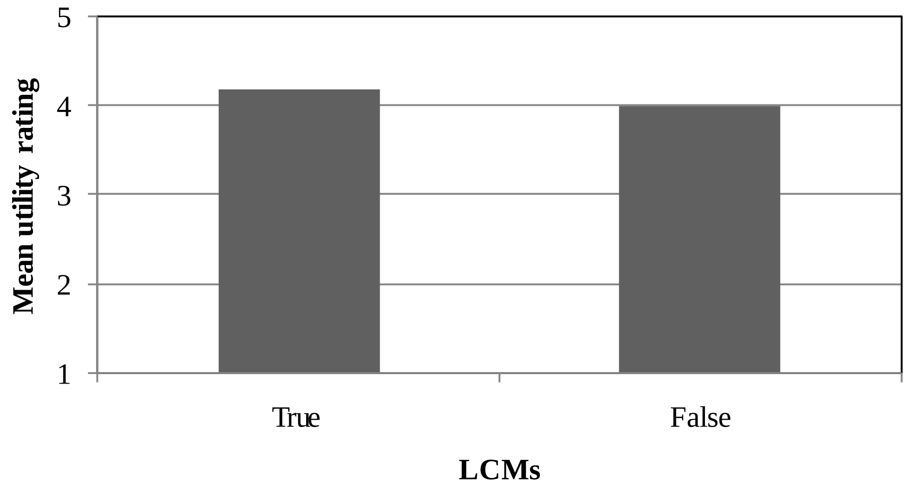


Figure 26. Average usefulness rating across all drivers for true and false LCM alerts

4.1.3.4. Lateral Drift Warnings

Drivers reviewed a total of 39 LDW alerts. The alerts were classified into one of the following categories: False; lane change without a turn signal; intentional maneuver (e.g., steering to avoid a pothole); or a curve. The highest percentage of useful LDW alerts (100%) occurred while driving in a curve (Figure 27). Drivers rated the usefulness of the false LDW alerts the lowest (mean = 3.8), while rating the alerts received in curves the highest (Mean = 4.8) (Figure 28).

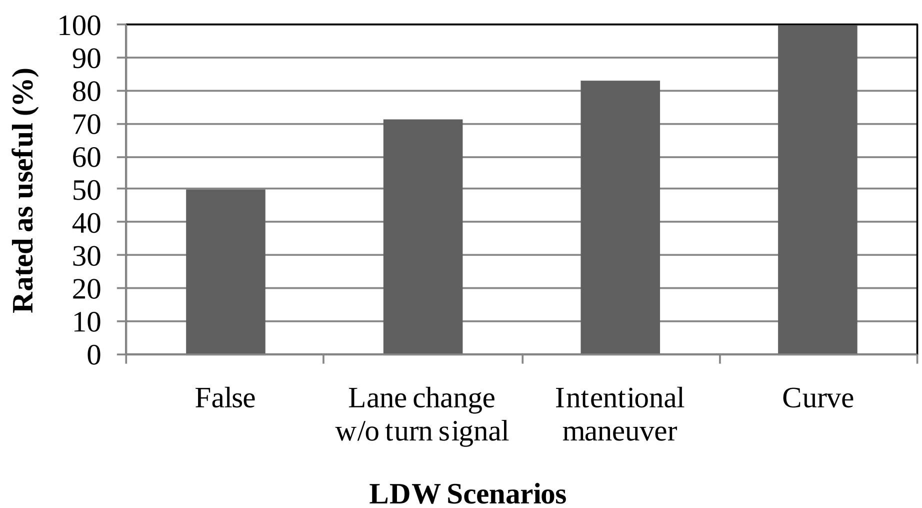


Figure 27. The percentage of useful LDW alerts by scenario type

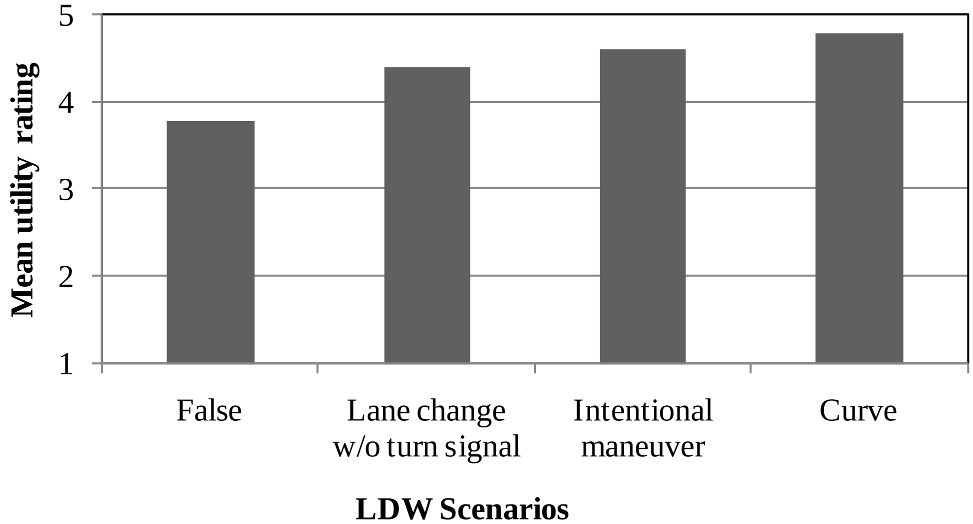


Figure 28. Average usefulness rating across all drivers by LDW scenario type

5 Conclusions

The IVBSS light vehicle EPT has demonstrated that after minor revisions are made to the warning system and the experimental process, the program is ready for the full-scale FOT. Highlights of specific findings include:

- Positive driver acceptance was received from the eleven drivers whose subjective data was available. Upon questioning, some drivers identified individual alert events that were not useful to them, but on the whole, the ratings of usefulness and satisfaction were quite positive; in addition, the ratings were higher for integrated system functionalities that were similar to functionalities studied in previous U.S. DOT-sponsored FOTs. These findings, although from a small sample, suggest that driver acceptance of the integrated system in the full-scale FOT should be positive.
- Additional onboard diagnostics need to be implemented and used in remote fleet monitoring (see Table 9)
- The integrated system performance has generally been acceptable, however there are several opportunities to reduce the false alert rate and improve system performance. These improvements do not require substantial changes in the system design, but rather changes addressing specific troublesome scenarios. These areas of improvement are summarized in Table 8.
- No unintended negative safety consequences associated with the integrated system were observed during the test.
- The pilot test did not uncover surprises that would suggest considering changes in the basic method or FOT experimental design. Improvements in the collection of objective and subjective data, remote monitoring of the fleet, and fleet operations were also identified and are presented in Table 9. These steps can be developed and should be implemented before the launch of the FOT.

The next steps following the analysis of the EPT results include an assessment of whether and how to pursue changes identified in Table 8 and Table 9. This assessment should be a collaborative effort between the UMTRI team and U.S. DOT to ensure that the FOT will be a successful and efficient test.

Table 8. Potential areas of improvement for the integrated system

Area of experimental process	**Need for improvement**
CSW readiness	Improve the ability to operate in temperature below 0 deg F (-18 deg C)
CSW false alerts	Eliminate the system error that lead to spurious and unnecessary alerts
CSW alerts without driver braking	Consider addressing the number of CSWs that now occur and are not followed by significant driver braking
FCW false alerts	Reduce false alerts triggered by roadside objects when the FCW is approaching a curve
FCW alerts for crossing traffic-	Reduce alerts triggered by oncoming vehicles that are turning across the path of the SV
FCW alerts for turning POVs	Reduce the occurrence of alerts triggered by vehicles ahead that are slowing and turning from the roadway, while still protecting the driver in case those vehicles stop abruptly in their turns.
LDW false alerts	Reduce the false alert rate. Some notable situations associated with false alerts are: wet nighttime driving, false perception of high lateral velocity.
LDW alerts on the left side	Explore whether the higher alert rate for left-moving drifts is associated with a mis-calibration of the system.
LCM false alerts	Reduce the number of alerts that occur when the SV is changing lanes in front of a slower vehicle that it has just passed.
LCM alerts while changing lanes behind other traffic	Reduce the number of alerts that occur when the SV is changing lanes behind a faster-moving vehicle that has just passed the SV.

Table 9. Potential areas of improvement for the experimental process

Area of experimental process	Need for improvement
Remotely monitoring the IVBSS fleet	Remote monitoring should use more diagnostic information from the subsystems and a more complete set of tools for ongoing, automatic review of system status.
Remotely monitoring the IVBSS fleet	Cellular modem issues should be resolved
Data collection	Errors should be fixed in the collection of several data signals
Driver questionnaires	The questionnaire should be revisited to ensure that drivers are not confused by any questions.
Driver debriefing	Tools for debriefing drivers need to be more robust, and the process of probing drivers in interactive questioning might be made more uniform and objective.

6 References

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7 Appendix A. Post-Drive Questionnaire and Evaluation

Subject ___________

Date ______________

IVBSS LV Extended Pilot Testing Questionnaire and Evaluation

Please answer the following questions about the Integrated Vehicle Based Safety System (IVBSS). If you like, you may include comments alongside the questions to clarify your responses.

Example:

A.) Strawberry ice cream is better than chocolate.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

If you prefer chocolate ice cream over strawberry, you would circle the "1", "2" or "3" according to how strongly you like chocolate ice cream, and therefore disagree with the statement.

However, if you prefer strawberry ice cream, you would circle "5", "6" or "7" according to how strongly you like strawberry ice cream, and therefore agree with the statement.

If a question does not apply:

Write "NA," for "not applicable," next to any question which does not apply to your driving experience with the system. For example, you might not experience every type of warning the questionnaire addresses.

General Impression of the Integrated System

1. **What did you like most about the integrated system?**

____

____

____

____

2. **What did you like least about the integrated system?**

____

____

____

____

3. **How helpful were the integrated system's warnings?**

1	2	3	4	5	6	7
Not all Helpful						Very Helpful

4. **In which situations were the warnings from the integrated system helpful?**

____

____

____

5. **Overall, I think that the integrated system is going to increase my driving safety.**

1 2 3 4 5 6 7

Strongly Disagree — Strongly Agree

6. **Driving with the integrated system made me more aware of traffic around me and the position of my car in my lane.**

1 2 3 4 5 6 7

Strongly Disagree — Strongly Agree

7. **Overall, I felt that the integrated system was predictable and consistent.**

1 2 3 4 5 6 7

Strongly Disagree — Strongly Agree

8. **I was not distracted by the warnings.**

1 2 3 4 5 6 7

Strongly Disagree — Strongly Agree

9. **Overall, how satisfied were you with the integrated system?**

1 2 3 4 5 6 7

Very Dissatisfied — Very Satisfied

10. Overall, I received warnings . . .

1	2	3	4	5	6	7
Too Frequently						Never

Branching – if their answer is a 1, 2, or 3 ask the following:

a. **If you received warnings too frequently, which type (s) of warnings did you receive too frequently? (circle all that apply)**

Left/Right Hazard   Left/Right Drift   Hazard Ahead   Sharp Curve

If their answer is a 5, 6, or 7, ask the following:

b. **If you received warnings too infrequently, which type (s) of warnings did you receive too infrequently? (circle all that apply)**

Left/Right Hazard   Left/Right Drift   Hazard Ahead   Sharp Curve

11. I always understood why the integrated system provided me with a warning.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

12. I always knew what to do when the integrated system provided a warning.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

13. The auditory warnings got my attention.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

14. I always understood why the integrated system provided me with an auditory warning.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

15. The auditory warnings were not annoying.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

16. The seat vibration warnings got my attention.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

17. I always understood why the integrated system provided me with a seat vibration.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

18. The seat vibration warnings were not annoying.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

19. The brake pulse warnings got my attention.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

20. I always understood why the integrated system provided me with a brake pulse warning.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

21. The brake pulse warning was not annoying.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

22. The yellow lights in the mirrors got my attention.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

23. I always understood why the integrated system provided me with a yellow light in the mirror.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

24. The yellow lights in the mirrors were not annoying.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

25. I knew what to do when I received more than one warning within a few seconds (approximately three seconds).

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

26. The integrated system never gave me warnings when I did not need them (i.e., nuisance warnings)

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

27. Overall, I received nuisance warnings . . .

1	2	3	4	5	6	7
Too Frequently						Never

28. The integrated system never gave me a left/right hazard warning when I did not need one.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

29. The integrated system never gave me a left/right drift warning when I did not need one.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

30. The integrated system never gave me a hazard ahead warning when I did not need one.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

31. The integrated system never gave me a sharp curve warning when I did not need one.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Overall Acceptance of the Integrated System

32. Please indicate your overall acceptance rating of the integrated system *warnings*

For each choice you will find five possible answers. When a term is completely appropriate, please put a check (√) in the square next to that term. When a term is appropriate to a certain extent, please put a check to the left or right of the middle at the side of the term. When you have no specific opinion, please put a check in the middle.

The integrated system **warnings** were:

useful						useless
pleasant						unpleasant
bad						good
nice						annoying
effective						superfluous
irritating						likeable
assisting						worthless
undesirable						desirable
raising alertness						sleep-inducing

Displays and Controls

33. The integrated system display was useful.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

34. The mute button was useful.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

35. The volume adjustment control was useful.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

36. Cost aside, how likely would you be to consider purchasing the integrated system if you were purchasing a new vehicle today?

1	2	3	4	5
Definitely Not	Probably Not	Might or Might not	Probably Would	Definitely Would

37. What is the maximum amount that you would pay for the integrated system? Circle one price range.

Less than $1000

$1000-$1249

$1250-$1499

$1500-$1749

$1750-$1999

$2000-$2249

More than $2500

Hazard Ahead Warning Acceptance

The Hazard Ahead warning provided an auditory warning accompanied by a brake pulse whenever you were approaching the rear of the vehicle in front of you and there was potential for a collision. When you received this type of warning, the display read “Hazard Ahead”.

38. Please indicate your overall acceptance rating of the Hazard Ahead warnings.

For each choice you will find five possible answers. When a term is completely appropriate, please put a check (√) in the square next to that term. When a term is appropriate to a certain extent, please put a check to the left or right of the middle at the side of the term. When you have no specific opinion, please put a check in the middle.

The hazard ahead **warnings** when I was approaching a vehicle ahead were:

useful						useless
pleasant						unpleasant
bad						good
nice						annoying
effective						superfluous
irritating						likeable
assisting						worthless
undesirable						desirable

raising alertness						sleep-inducing

Sharp Curve Warning Acceptance

The Sharp Curve warning provided an auditory warning whenever you were approaching a curve at too great a speed. When you received this type of warning, the display read “Sharp Curve”.

39. Please indicate your overall acceptance rating of the Sharp Curve warnings.

For each choice you will find five possible answers. When a term is completely appropriate, please put a check (√) in the square next to that term. When a term is appropriate to a certain extent, please put a check to the left or right of the middle at the side of the term. When you have no specific opinion, please put a check in the middle.

The sharp curve **warnings** when I approached a curve at too great a speed were:

useful	☐	☐	☐	☐	☐	useless
pleasant	☐	☐	☐	☐	☐	unpleasant
bad	☐	☐	☐	☐	☐	good
nice	☐	☐	☐	☐	☐	annoying
effective	☐	☐	☐	☐	☐	superfluous
irritating	☐	☐	☐	☐	☐	likeable
assisting	☐	☐	☐	☐	☐	worthless
undesirable	☐	☐	☐	☐	☐	desirable
raising alertness	☐	☐	☐	☐	☐	sleep-inducing

Left/Right Hazard Warning Acceptance

The Left/Right Hazard warning provided an auditory warning whenever your turn signal was on AND you were changing lanes or merging and there was the possibility of a collision with a vehicle in the lane to which you were moving. Or, The Left/Right Hazard warning provided an auditory warning whenever your turn signal was not on and you were drifting out of your lane and there was the possibility of a collision with another vehicle or a solid object (e.g. a guard rail). When you received this type of warning, the display read “Left Hazard” or “Right Hazard” depending on your direction of travel.

40. Please indicate your overall acceptance rating of the Left/Right Hazard warnings.

For each choice you will find five possible answers. When a term is completely appropriate, please put a check (√) in the square next to that term. When a term is appropriate to a certain extent, please put a check to the left or right of the middle at the side of the term. When you have no specific opinion, please put a check in the middle.

The left/right hazard **warnings** were:

useful						useless
pleasant						unpleasant
bad						good
nice						annoying
effective						superfluous
irritating						likeable
assisting						worthless

undesirable						desirable
raising alertness						sleep-inducing

Left/Right Drift Warning Acceptance

If you were drifting out of your lane and there was no danger of you striking a solid object, you received a seat vibration and the display read “Left Drift” or “Right Drift” depending on the direction in which you were drifting.

41. Please indicate your overall acceptance rating of the Left/Right Drift warnings.

For each choice you will find five possible answers. When a term is completely appropriate, please put a check (√) in the square next to that term. When a term is appropriate to a certain extent, please put a check to the left or right of the middle at the side of the term. When you have no specific opinion, please put a check in the middle.

The left/right drift **warnings** were:

useful						useless
pleasant						unpleasant
bad						good
nice						annoying
effective						superfluous
irritating						likeable
assisting						worthless
undesirable						desirable
raising alertness						sleep-inducing

Yellow Lights in the Mirrors Acceptance

When a vehicle was approaching or was in the research vehicle's blind spots, a yellow light in the exterior mirrors was illuminated.

42. Please indicate your overall acceptance rating of the yellow lights in the mirrors.

For each choice you will find five possible answers. When a term is completely appropriate, please put a check (√) in the square next to that term. When a term is appropriate to a certain extent, please put a check to the left or right of the middle at the side of the term. When you have no specific opinion, please put a check in the middle.

The **yellow lights** in the mirrors were:

useful	☐	☐	☐	☐	☐	useless
pleasant	☐	☐	☐	☐	☐	unpleasant
bad	☐	☐	☐	☐	☐	good
nice	☐	☐	☐	☐	☐	annoying
effective	☐	☐	☐	☐	☐	superfluous
irritating	☐	☐	☐	☐	☐	likeable
assisting	☐	☐	☐	☐	☐	worthless
undesirable	☐	☐	☐	☐	☐	desirable
raising alertness	☐	☐	☐	☐	☐	sleep-inducing

8 Appendix B. Summary of Light-Vehicle Post-Drive Questionnaire Responses

Question	Anchors	Mean	St Dev.
How helpful were the integrated system's warnings?	1=Not at all helpful, 7=Very helpful	6.3	0.8
Overall, I think that the integrated system is going to increase my driving safety.	1=Strongly disagree, 7=Strongly agree	6.3	0.6
Driving with the integrated system made me more aware of traffic around me and the position of my car in my lane	1=Strongly disagree, 7=Strongly agree	5.8	1.3
Overall, I felt that the integrated system was predictable and consistent	1=Strongly disagree, 7=Strongly agree	5.5	1.0
I was not distracted by the warnings	1=Strongly disagree, 7=Strongly agree	5.7	1.1
Overall, how satisfied were you with the integrated system?	1=Very dissatified, 7=Very satisfied	6.4	0.8
Overall, I received warnings . . .	1=Too frequently, 7=Never	4.1	0.8
I always understood why the integrated system provided me with a warning.	1=Strongly disagree, 7=Strongly agree	5.9	1.1
I always knew what to do when the integrated system provided a warning.	1=Strongly disagree, 7=Strongly agree	6.3	0.8
The auditory warnings got my attention.	1=Strongly disagree, 7=Strongly agree	6.6	0.8
I always understood why the integrated system provided me with an auditory warning.	1=Strongly disagree, 7=Strongly agree	6.0	1.0
The auditory warnings were not annoying.	1=Strongly disagree, 7=Strongly agree	6.1	0.9
The seat vibration warnings got my attention	1=Strongly disagree, 7=Strongly agree	6.5	0.7
I always understood why the integrated system provided me with a seat vibration	1=Strongly disagree, 7=Strongly agree	5.7	2.0
The seat vibration warnings were not annoying.	1=Strongly disagree, 7=Strongly agree	5.9	1.6
The brake pulse warnings got my attention.	1=Strongly disagree, 7=Strongly agree	6.4	1.6
I always understood why the integrated system provided me with a brake pulse	1=Strongly disagree, 7=Strongly agree	5.1	2.0

Question	Anchors	Mean	St Dev.
warning.			
The brake pulse warning was not annoying.	1=Strongly disagree, 7=Strongly agree	5.7	1.8
The yellow lights in the mirrors got my attention.	1=Strongly disagree, 7=Strongly agree	6.3	1.6
I always understood why the integrated system provided me with a yellow light in the mirror.	1=Strongly disagree, 7=Strongly agree	6.9	0.3
The yellow lights in the mirrors were not annoying.	1=Strongly disagree, 7=Strongly agree	6.8	0.4
I knew what to do when I received more than one warning within a few seconds (approximately three seconds).	1=Strongly disagree, 7=Strongly agree	6.0	1.1
The integrated system never gave me warnings when I did not need them (i.e., nuisance warnings)	1=Strongly disagree, 7=Strongly agree	3.6	2.1
Overall, I received nuisance warnings . . .	1=Too frequently, 7=Never	5.3	1.4
The integrated system never gave me a left/right hazard warning when I did not need one.	1=Strongly disagree, 7=Strongly agree	5.1	2.0
The integrated system never gave me a left/right drift warning when I did not need one.	1=Strongly disagree, 7=Strongly agree	5.4	1.9
The integrated system never gave me a hazard ahead warning when I did not need one.	1=Strongly disagree, 7=Strongly agree	5.2	1.8
The integrated system never gave me a sharp curve warning when I did not need one.	1=Strongly disagree, 7=Strongly agree	5.5	2.2
The integrated system display was useful.	1=Strongly disagree, 7=Strongly agree	6.1	1.6
The mute button was useful.	1=Strongly disagree, 7=Strongly agree	5.2	1.1
The volume adjustment control was useful.	1=Strongly disagree, 7=Strongly agree	5.8	1.7
Cost aside, how likely would you be to consider purchasing the integrated system if you were purchasing a new vehicle today?	1=Definitely not, 5=Definitely would	4.5	0.7