Integrated Vehicle-Based Safety Systems
Heavy Truck Extended Pilot Test
Summary Report

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16. Abstract

This report describes the findings and recommendations from the heavy-truck (HT) extended pilot test (EPT) conducted by University of Michigan Transportation Research Institute (UMTRI) and its partners under the Integrated Vehicle-Based Safety Systems (IVBSS) program. The EPT was conducted to provide evidence of system performance (alert rate and reliable operation) and driver acceptance prior to conduct of the field operational test (FOT). The results of this test were to be used to modify the HT system performance and functionality as required, prior to the start of the FOT. The EPT entailed use of an integrated crash warning system in a heavy truck by seven drivers, over a period of five days each, in the course of their regular duties as drivers for Con-way Freight at the Ann Arbor distribution center. The test lasted four weeks starting on November 10 and ending December 12, 2008; the resultant data represent 5,300 miles of system use.

The extended pilot test of the heavy truck platform on the IVBSS program successfully evaluated system performance and driver acceptance. Driver recruitment and training procedures were tested, as were the driver survey and debriefing methodologies. The warning system and data acquisition hardware operated reliably through the EPT. However, the warning system had an alert rate that was higher than anticipated based on previous testing. Nonetheless, drivers were generally still accepting of the system. Valuable data obtained from the EPT have led to further system performance improvements in the detection of stopped and slower-moving objects by the FCW subsystem in order to reduce the alert rate, and these enhancements have been implemented into the heavy truck fleet for the full field operational test.

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AMR	Available Maneuvering Room
DAS	Data Acquisition System
DVI	Driver-Vehicle Interface
FCW	Forward Crash Warning
FOT	Field Operational Test
HT	Heavy Truck
IVBSS	Integrated Vehicle-Based Safety Systems
LCM	Lane-Change/Merge Warning
LDW	Lateral Drift Warning
NHTSA	National Highway Traffic Safety Administration
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

1 Executive Summary

This report describes the findings and recommendations from the heavy-truck (HT) extended pilot test (EPT) conducted by University of Michigan Transportation Research Institute (UMTRI) and its partners under the Integrated Vehicle-Based Safety Systems (IVBSS) program. The EPT was conducted to provide evidence of system performance (alert rate and reliable operation) and driver acceptance prior to conduct of the field operational test (FOT). The results of this test were to be used to modify the HT system performance and functionality as required, prior to the start of the FOT. The EPT entailed use of an integrated crash warning system in a heavy truck by seven drivers, for a period of five days each, in the course of their regular duties as drivers for Con-way Freight. The test lasted four weeks starting on November 10, 2008 and ending December 12', 2008; the resultant data represent 5,300 miles of system use.

The findings illustrate that the integrated crash warning system behaved in accordance with the System Performance Guidelines for a Prototype Integrated Vehicle-Based Safety System (LeBlanc, et al, 2008). However, in the naturalistic conditions of the pilot test, drivers experienced far more alerts than had been expected a priori, a combined 1162 alerts from the integrated crash warning system. Upon review of each of these alerts, researchers subjectively classified 551 (47 percent) as invalid. However, these invalid alerts were dominated by FCW alerts for stopped objects. Based on this finding, and a review of the data surrounding these invalid alerts, two software changes were recommended, and ultimately implemented, to reduce the occurrence of FCW invalid alerts with stopped or slow moving objects.

Regarding driver acceptance, the majority of drivers were generally neutral or favorable towards the concept of an integrated crash warning system. While one of the drivers expressed dissatisfaction with the consistency of the warnings, the remaining six drivers responded that they usually understood why warnings occurred. The majority of the drivers reported that the system provided the benefit of increased awareness of the traffic situation and were generally satisfied with the user-interface of the integrated crash warning system. However only two of the seven drivers would prefer to drive a truck with the integrated crash warning system, as opposed to a truck without one.

In summary, despite the higher than expected alert rate, the extended pilot testing of the heavy truck platform was successful in evaluating system reliably and driver acceptance. The driver recruitment and training procedure was pilot tested, as was the driver survey and debriefing methodology. The EPT process provided valuable data on system performance that led to further system improvements in the detection of stopped and slower moving objects by the FCW subsystem; these enhancements have been implemented into the heavy truck fleet for the full field operational test.

2 Introduction

In November 2005, the U.S. Department of Transportation entered into a cooperative research agreement with an industry team led by the University of Michigan Transportation Research Institute (UMTRI) to develop and test an integrated, vehicle-based, crash warning system that addresses rear-end, lane-change and roadway departure crashes for light vehicles and heavy commercial trucks. The program being carried out under this agreement is known as the Integrated Vehicle-Based Safety Systems (IVBSS) program. The objectives of the IVBSS program include assessing the safety benefits and driver acceptance associated with a prototype integrated crash warning systems. The mechanism for achieving this objective is the conduct of a field operational test (FOT) in which instrumented heavy-trucks and passenger vehicles are deployed in a naturalistic driving study.

This report offers a description, findings, and recommendations from the heavy-truck (HT) extended pilot test (EPT). The EPT was conducted by University of Michigan Transportation Research Institute (UMTRI) to provide data on system performance (alert rate and reliable operation) and driver acceptance prior to conduct of the field operational test (FOT). Findings from the EPT were then used by system developers to improve performance and functionality prior to the start of the FOT.

3 Methodology

The methodology supporting the EPT involved the selection of an appropriate facility to conduct the study along with recruitment of subjects, upfit of an FOT-ready vehicle with both the integrated crash warning system and a data acquisition system documenting the experiment. A brief description of these elements is provided the subsections below.

3.1 Terminal Selection

Terminals belonging to Con-way Freight, an IVBSS program partner, were selected from which to conduct both the EPT and the FOT. It was of interest to find two sites in relative close proximity to Ann Arbor in order to facilitate a close working relationship between the administration of the project, monitoring of the trucks and drivers, and facilitating any system repairs, should they be required.

Because 20 drivers were needed to participate in the FOT, Con-way's Detroit Terminal (XDE) was selected for the FOT as it had enough drivers to ensure that 20 willing participants could be recruited. Also, it was determined that it was desirable to run the EPT out of a different terminal than the FOT to try to reduce the amount of crosstalk among drivers which could otherwise "taint" the pool of drivers from which to select participants in the FOT. Of concern was the possibility that drivers involved in the EPT would share their feelings on the system (whether positive or negative) with some of the drivers who would participate in the FOT, potentially biasing them before they had the opportunity to experience the system for themselves.

It was determined that Con-way's Ann Arbor (XAH) terminal in Whitmore Lake, Michigan provided the best location for the EPT. The crew of 24 drivers provided an adequate pool from which to recruit the eight drivers needed for the EPT, the nature of the truck routes operated out of the Ann Arbor terminal was similar to those of the Detroit terminal, and the location, very near UMTRI, all made it an ideal site from which to conduct the EPT.

3.2 Driver Selection

Initially, eight drivers were sought for the EPT. This group was intended to include four pick-up and delivery (P&D) drivers who would drive the tractor during the day and deliver freight to local destinations, and four line-haul drivers who would drive the tractor at night between various Con-way terminals. Each driver would drive the tractor for five consecutive workdays.

To begin the program, drivers at Con-way's Ann Arbor (XAH) terminal received a briefing on the IVBSS program. This presentation included some background on the integrated crash warning system accompanied by a short video describing its operation. After the presentation, drivers were given the opportunity to ask questions and to review consent forms they would be required to sign if they chose to participate. It was made clear to the drivers that their participation was voluntary, and that if they did choose to participate, no data would be shown to Con-way that could adversely affect their employment. Additionally, the drivers were given the option to prevent all of their video data from being seen by Con-way personnel. Only one driver exercised this option.

Because the subject pool was fairly small, (only 24 drivers operate out of the Ann Arbor Terminal, and even less consistently drive routes of interest) the selection criteria was broad. It was desirable to get drivers with varying levels of experience; however only three line-haul and four P&D drivers volunteered. Fortunately, these seven drivers represented a broad range of different commercial driving experience, with the most experienced driver holding a Commercial Driver's License (CDL) for 35 years and the least experienced driver holding a CDL for only six years.

It is important to note none of the participants had a history of driving the specific tractor used in the study. While the tractor was generally similar in class, number of gears and operation, it was nonetheless a new truck to all of the participants. As such some level of learning and adaptation to the new equipment had to take place.

A summary of the demographic data collected from the seven drivers in the EPT is displayed below in Table 1.

Table 1. Driver demographic information

Part. #	*Age*	*Type*	*License (yrs)*	*CDL (yrs)*	*Driving Hrs/Wk*	*Mileage/Year*	*Yrs Employed at*
1	29	P&D	13	6	30	26,000	5
2	58	LH	41	32	34	50,000	23
3	51	P&D	35	25	40	10,000	23
4	48	LH	31	20	18	60,000	8
5	35	P&D	20	18	35	20,800	5
6	48	LH	32	25	15	25,000	4
7	48	P&D	32	26	35	20,000	26
Mean	45.3		29.2	21.7	29.6	30257.1	13.4
Std. Dev.	9.9		9.5	8.3	9.4	17912.6	10.0
Max	58		41	32	40	60000	26
Min	29		13	6	15	10000	4

3.3 Research Equipment

The IVBSS heavy-truck EPT was conducted with the first of ten tractors being up fitted with the integrated crash warning technology and data acquisition system for the FOT. The details of this tractor and the associated warning technologies can be found in the IVBSS Phase I Interim Report (UMTRI, 2008). In brief, the heavy truck sensor suite consists of multiple vision, radar, inertial and vehicle sensors that are, for the most part, commercially available, off-the-shelf technologies. Figure 1 illustrates the primary sensors, including the coverage regions surrounding the vehicle.

To communicate warnings and system status to drivers, the integrated crash warning system uses a combination of cab-mounted modules as illustrated in Figure 2. The main component of the driver-vehicle interface (DVI) resides in the center of the instrumentation cluster and allows driver input for selection of trailer length, volume and brightness control. This unit also provides visual feedback to the driver for each alert and audio warning for forward crash warning (FCW) alerts. Side-mounted LED modules provide visual feedback to the driver when the area adjacent to the vehicle is restricted by the presence of another vehicle, and speakers mounted just behind the A-pillar on each side of the cab provide directional alert sounds for the lateral warning subsystems [lateral drift warning (LDW) and lane change/merge (LCM) warnings].

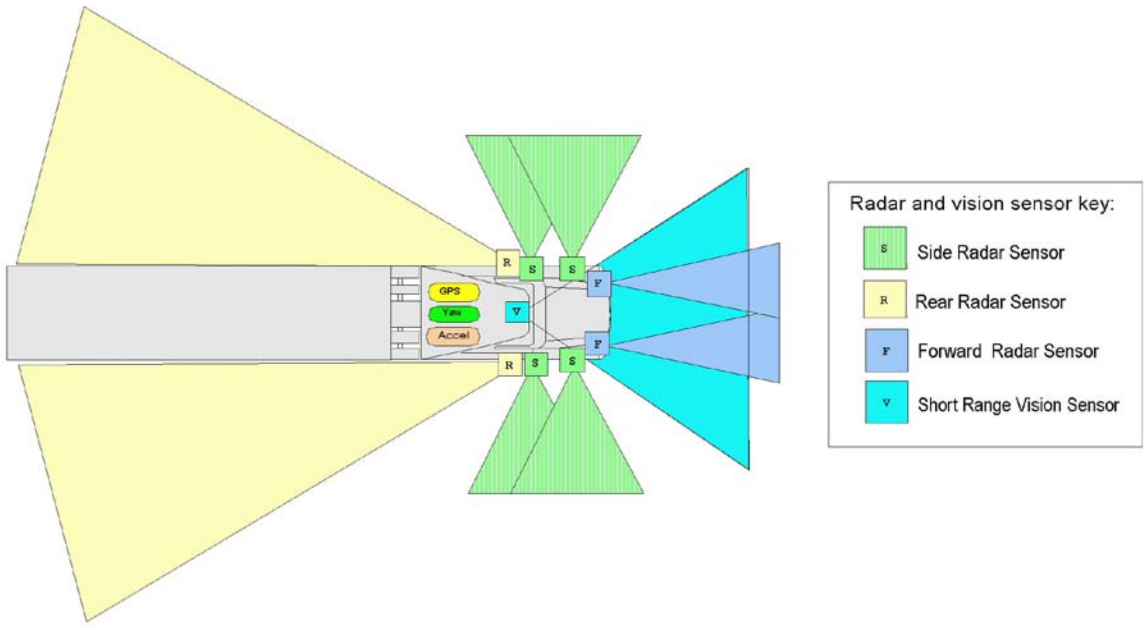

Figure 1. Heavy-truck sensor suite overview (not to scale)

Figure 2. Heavy-truck DVI components

3.3.1 Objective Data Collection

The primary goal of the IVBSS FOT is to evaluate the effectiveness and driver acceptance of the integrated crash warning system, and objectively measure changes in driver performance that are likely to affect heavy-truck and light-vehicle crash rates. The bulk of the data necessary to answer the effectiveness question will be provided by a purpose-built data acquisition system (DAS) that operates autonomously, and, for purposes of the heavy truck implementation, has minimal impact on Con-way Freight operations. The DAS used during the HT EPT collected hundreds of data channels along with substantial video footage of the scene around the vehicle and within the truck cab.

The interface panel and main components of the DAS are illustrated in Figure 3. Figure 4 through 6 show images from each of the five video cameras along with their capture rates. The data archive from the HT EPT covers a total of 5585 miles (8992 km) and 459 trips.[1] Total ignition-on time for the EPT was 158 hours. The overall data collection archive for the test was 10.5 GB of numerical data (nominally, sampled at 10 Hz), and 22.4 GB of video.

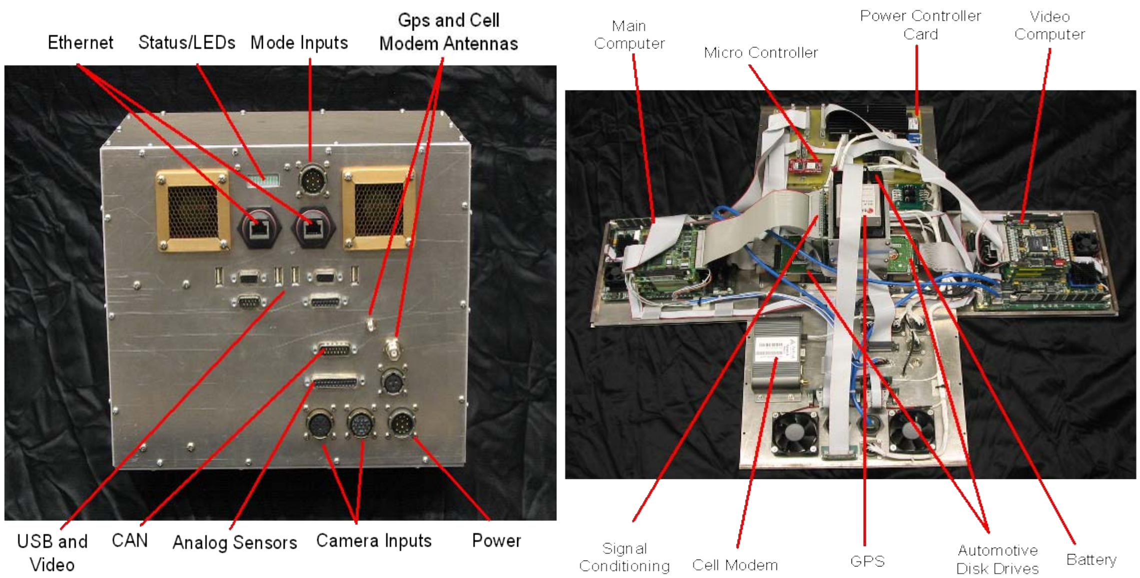

Figure 3. DAS interface panel and main components

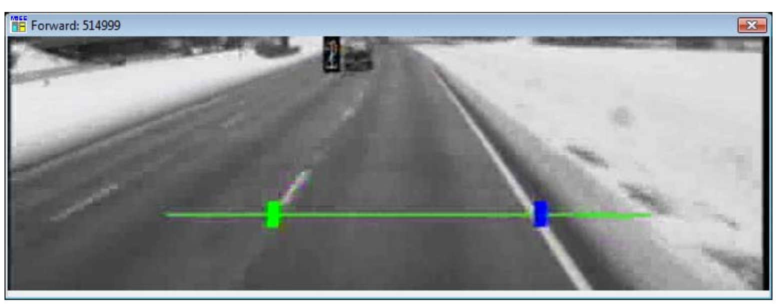

Figure 4. Forward view captured at 5 Hz continuously

[1] A trip is defined as an ignition cycle of the test vehicle and as recorded by the data acquisition system.

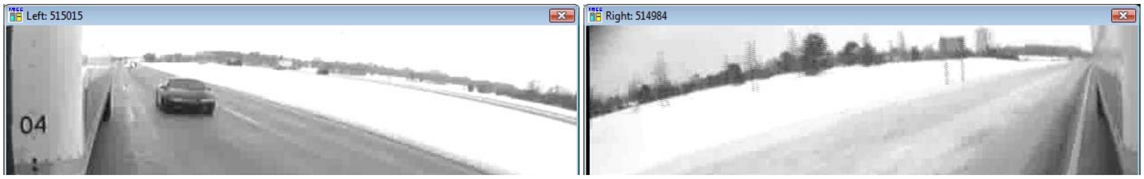

Figure 5. Left and right rear-looking views captured at 2 Hz continuously

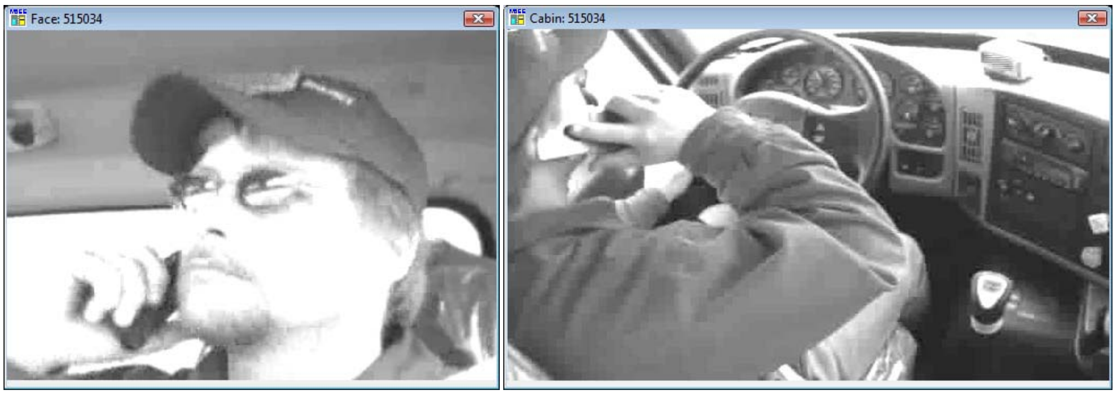

Figure 6. Drivers face and cabin views captured at 5 and 2 Hz (continuously), respectively

3.3.2 Driver Acceptance

Along with the digital and video data that was collected, it was important to assess driver acceptance of the integrated crash warning system. At the end of the five-day exposure period, each driver completed a post-drive questionnaire regarding his experience with, and acceptance of, the system. A copy of the post-drive questionnaire, along with summary statistics of driver responses, is included in Appendix A of this report. For P&D drivers, the questionnaire was administered immediately following their Friday shift. For line-haul drivers the questionnaire was administered before their first Monday night shift, 1.5 days after the completion of their exposure period the previous Saturday morning. This schedule was established in order to allow the line-haul drivers to rest after a long night on the road, but to get the information from the P&D drivers while it was still fresh in their minds.

After the driver completed the post-drive questionnaire, he met with a researcher for a brief interview, during which the responses to the questionnaire were reviewed, clarified or elaborated upon This served to elicit more in-depth responses from the drivers in specific areas of interest, as well as giving the researcher an opportunity to explain why the system performed as it did in specific situations. These interviews were conducted in private, away from Con-way management, in order to give the drivers the freedom to be open about their assessment of the integrated crash warning system.

4 Results

The following section presents results from the HT EPT both in terms of objective findings based on the data collected by the DAS and subjective findings from the post-drive questionnaires. Additionally, a section is included that briefly discusses the exposure of the drivers which adds context to the results and forms the foundation from which the conclusions are drawn.

4.1 Exposure and DAS Performance

A single-instrumented Navistar 8600, Class 8 tractor, was used to conduct the EPT from Con-way's Ann Arbor distribution center. The test lasted four weeks starting on November 10, 2008 and ending December 12, 2008. Seven drivers participated in the test with three driving line-haul routes and four driving P&D routes.[2] Overall, a total of 5585 miles (8992 km) were accumulated during the EPT on 459 trips. Total ignition on-time for the EPT was 158 hours. The overall data collection archive for the test was 10.5 GB of numerical data (nominally, sampled at 10 Hz), and 22.4 GB of video from the five tractor mounted cameras.

The data acquisition system (DAS) performed reliably throughout the EPT, with no significant downtime or lost data. Figure 7 illustrates the actual (odometer) and measured (DAS) distance as a function of week for the EPT. The total measured distance for the EPT was 5244 miles (8443 km) or 94 percent of the actual distance with the bulk of the missing distance occurring during the week of Nov 17, 2008.[3]

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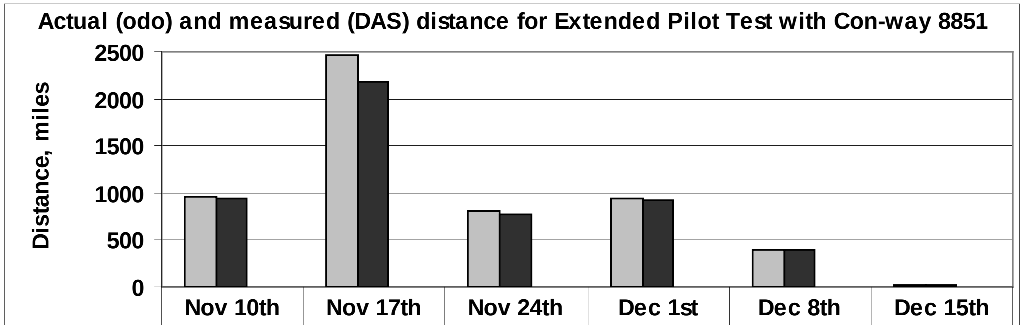
[2] Line-haul routes are between distribution terminals and almost exclusively involve a double combination (twin 28 ft. trailers) while P&D (pickup and delivery) routes involve the movement of freight in a local area around a distribution terminal.

[3] Some of the missing distance is due to the DAS boot-up time. Typically, between 30 and 45 seconds are needed for the DAS to power-up and begin data collection and any distance traveled during this time will not be logged by the DAS. Quantitatively, this is a small fraction of the missed distance since most trips involve zero or slow speeds during the first few minutes of the trip as the vehicle maneuvers around parking lots and other staging areas.



	Nov 10th	Nov 17th	Nov 24th	Dec 1st	Dec 8th	Dec 15th
Actual	961	2464	806	938	394	23
Measured	949	2172	778	930	392	23
Ratio	0.99	0.88	0.97	0.99	1.00	1.00

Overall average 94 percent

Figure 7. Actual and measured distance for EPT

As expected, line-haul drivers (2, 4, and 6) accumulated the most mileage (3,693 miles (5,946 km). Driver 2 clearly stands out from the entire population in that he accumulated 40 percent of all miles, and 60 percent of the line-haul miles, collected during the EPT. P&D drivers averaged 413 miles (665 km) and were consistent as compared to the line-haul drivers, with standard deviations of 60 and 852 miles for the two groups, respectively.

Maps of the P&D and line-haul routes are shown in Figure 8 and Figure 9, respectively. A closer look at the distribution of distance traveled as a function of driver and route type is illustrated in Figure 10

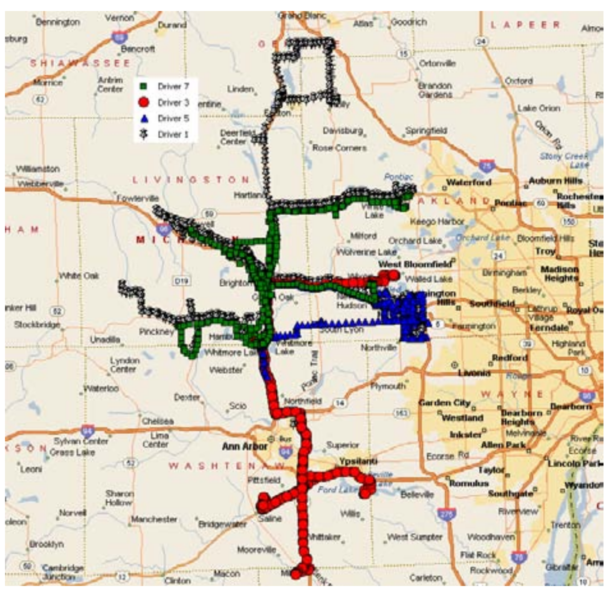


Figure 8. Pick-up and delivery routes for the IVBSS extended pilot test

Figure 9. Line-haul routes for the IVBSS extended pilot test

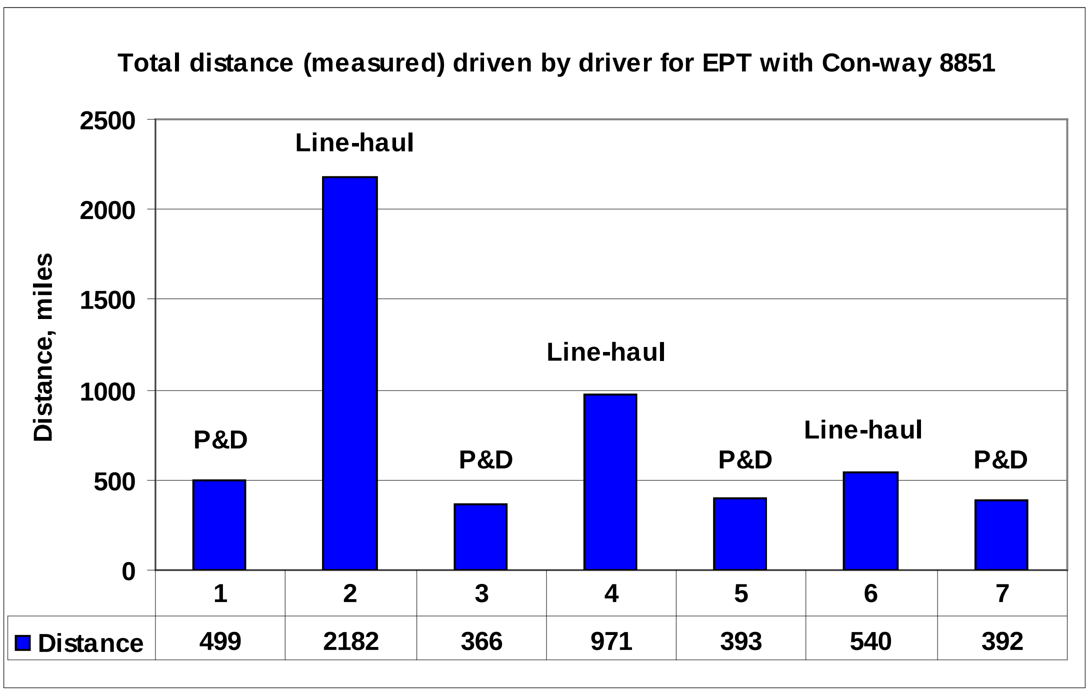
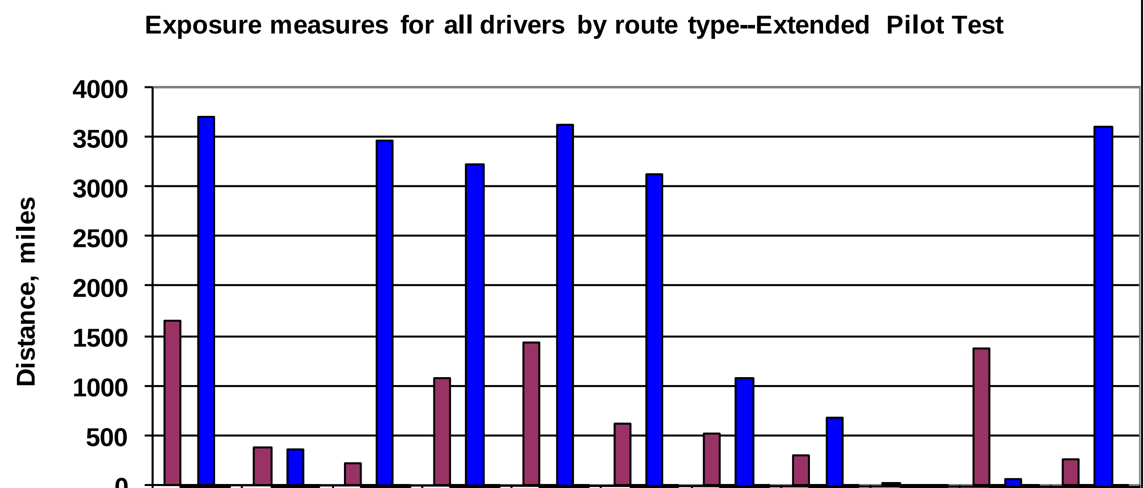


Figure 10. Total distance by driver for the EPT.

A different distribution of measured distance is illustrated in Figure 11. This figure shows measured distance for a collection of exposure criteria as a function of the two route types. The results of this distribution for many of these exposure criteria are not surprising and are consistent with expectations prior to the start of the EPT. The following conclusions can be drawn from this figure:

- Dark (ambient light level)—Line-haul generally runs at night while P&D runs during the day, hence only 13 percent of the P&D distance is at night compared to 94 percent for line-haul.
- Lateral Drift Warning (LDW) Availability—for P&D routes which are typically on local and major surface roads, 65 percent of the distance measured was with the system available (i.e. tracking boundary lines) while 88 percent of the line-haul (principally limited access roads) distance was with the system available. This is not surprising since freeways have good lane markings with few discontinuities as compared to surface roads. Additionally, these results are considerably better than the RDCW FOT (LeBlanc, et al., 2006) which showed for passenger cars an availability of less than 50 percent for local and surface roads and 75 percent for limited access roadways.
- Speeds above 55 mph—the majority (85 percent) of line-haul miles are accrued at higher speeds, while less than 40 percent of the P&D miles were logged at speeds above 55 mph. These findings are consistent with differences in roadway classification between the route types.
- Trailer Configuration—Ninety-eight percent of the line-haul miles were accrued with a double trailer configuration, while 83 percent of the P&D distance was logged with a single trailer. These are rates consistent with Conway's operational model.



	Total	Wiper On	Dark	Ldw Avail.	V>25 mph	V>55 mph	No Amr L	No Amr R	Bob tail	Single	Double
P&D	1651	377	217	1075	1434	625	511	298	20	1369	262
Fraction	1.0	0.23	0.13	0.65	0.87	0.38	0.31	0.18	0.01	0.83	0.16
Line-haul	3693	370	3458	3234	3613	3129	1090	678	12	80	3601
Fraction	1.0	0.10	0.94	0.88	0.98	0.85	0.30	0.18	0.00	0.02	0.98

Figure 11. Exposure measures for all drivers by route type.

Of interest in Figure 11 are the categories “wipers-on” and “no available maneuvering room” (shown as No AMR right and left). Available maneuvering room is a space adjacent to the vehicle that is not occupied by either another vehicle or roadway attribute (i.e., guardrail or barrier). Generally, this space is either another lane or roadway shoulder. The “wiper on” category is a surrogate for inclement weather that may have a negative effect on integrated crash warning system performance since both the LDW and LCM subsystems rely on lane boundary detection for lane position information. The figure shows that only 10 percent of the line-haul miles (and associated alert rate) might have been influenced negatively by reduced LDW availability, while almost 25 percent of the P&D distance was traveled with the wipers on for P&D. Given the likelihood of inclement weather in Michigan during the period when the EPT was conducted (November and December), these numbers seem reasonable. Inclement weather may very well account for most of the miles when LDW was unavailable, particularly on line-haul routes that generally have good lane boundary conditions—but are driven at night. As seen in previous FOTs, especially nighttime, wet road conditions are the most challenging for the vision-based lane detection system due to glare that is created by the reflective quality of the wet pavement.

In terms of available maneuvering room, the results are remarkably consistent for both sides of the vehicle independent of the route type. This is surprising given the different road exposures of the two route types, predominantly highway for line-haul routes and surface-street for P&D routes. Although there is a difference comparing the left and right sides, with the left side showing more time occupied or restricted than the right. This seems consistent with the general understanding that given roads with multiple thru-lanes, heavy vehicles are more likely to stay in the right-most lanes to allow faster moving traffic to pass on the left—and hence reduce the amount of time that there is maneuvering room on the left side of the vehicle.

4.2 Alert Rate

This section discusses the experience of the drivers in the EPT as it relates to how often the integrated crash warning system issued both valid and invalid alerts. During the exposure period, 1,162 alerts where issued by the system. The results given below classify alerts into two categories, namely valid and invalid. Here, an invalid alert is broadly, and somewhat subjectively, defined as an alert caused by either the misclassification of a target (i.e., a highway overpass is considered a stopped object in the vehicle path), misinterpretation of lane boundaries or other pavement markers, or the identification of a phantom object in the space adjacent to the vehicle, i.e., the system thinks the available maneuvering room is occupied when it is not.[4] The discussion, which follows, centers on normalizing alerts by driving distance, and is reported as an alert rate per 100 miles of travel. As previously identified by the system designers, and outlined in the System Performance Guidelines for a Prototype Integrated Vehicle-Based Safety System (LeBlanc, et al, 2008), an invalid alert no greater than 15 alerts per 100 miles was to be achieved.

Figure 12 below shows the total and invalid alert rates for each of the route types and for all driving. Overall, drivers received 21.7 alerts per 100 miles of travel. In terms of alert frequency, when above 25 mph (the nominal speed threshold for the system), a driver received approximately 11.7 alerts per hour, or one alert every five minutes on average[5]. However, as the figure shows more than 50% of these alerts where considered valid and were issued per the system design and performance criteria. In terms of invalid alerts, the overall rate was 10.3 per 100 miles, which is below the 15 alerts per 100 miles goal identified by the design team.

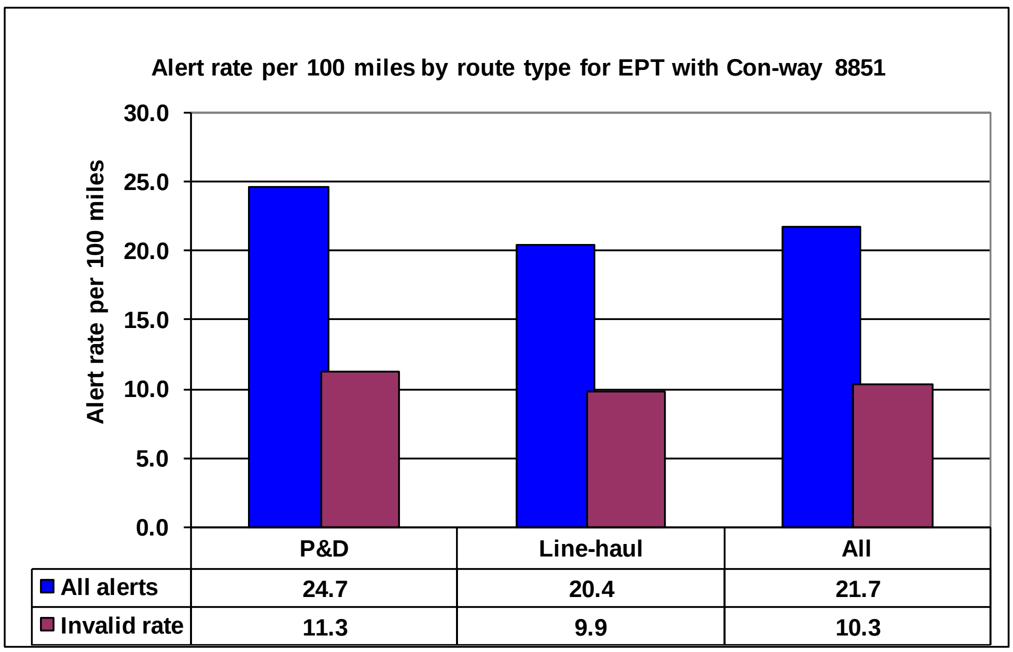


Figure 12. Total and invalid alert rate per 100 miles by route type

[4] To classify alerts as valid or invalid, each alert was reviewed by a researcher who used the on-board video archive to investigate and summarize their findings. This approach was subjective in the sense that these judgments where made by simply looking at video rather than a more rigorous approach that would combine video review with numerical data analysis to identify and understand more explicitly the nature of each alert. Furthermore, two alert categories is a narrow classification and does not encompass the nuances of alert interpretation by the driver, that is, a valid alert could be considered invalid if the driver is vigilant.

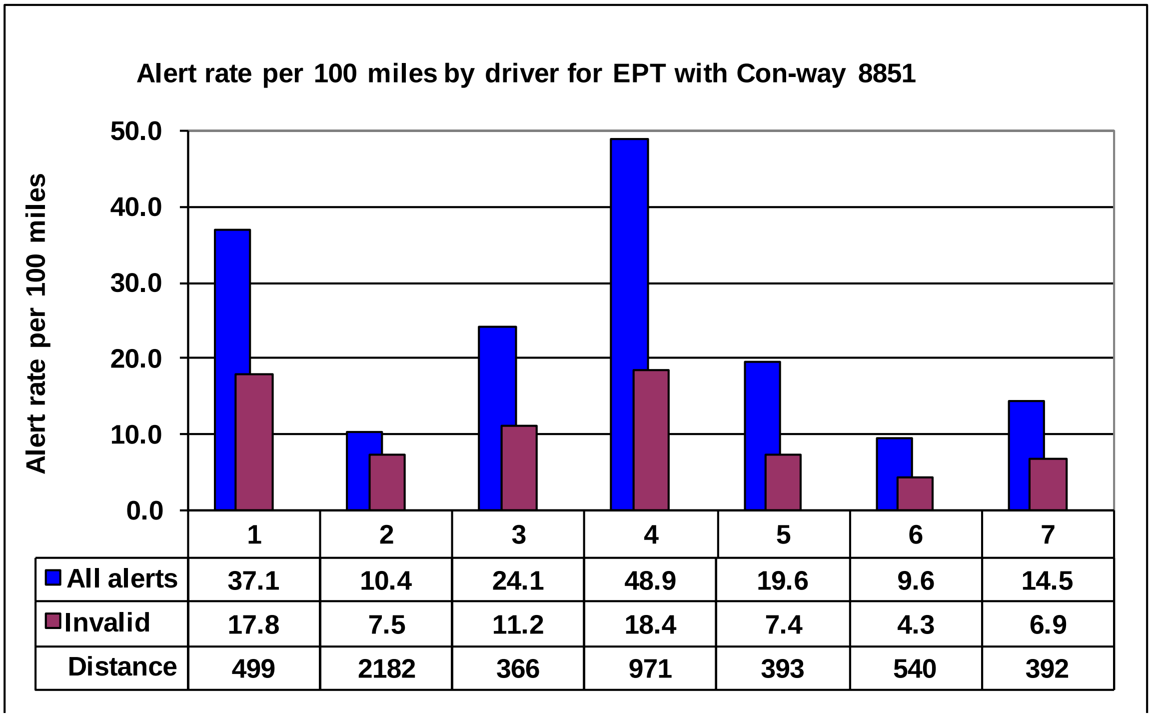
[5] Above 25 mph, the average speed for the EPT was 24.2 m/s (54.1 mph).

When route type is considered, the figure shows that overall there is a higher rate for P&D than line-haul at 24.7 and 20.4 alerts per 100 miles, respectively. This result was somewhat surprising since the expectation was for much higher alert rate for P&D drivers when considering the different environment for each route type. More specifically, P&D routes are driven predominantly during the daytime, on surface roads, with more traffic and intra-vehicle kinematic range as compared to line-haul. However, line-haul is driven predominantly at night, where the effect of driver fatigue is more likely to be a factor, and on limited access roadways.

A further breakdown of the alert rate as a function of individual driver is given in Figure 13. This figure shows considerable variability in the alert rate across the seven EPT drivers with a maximum alert rate per 100 miles of 48.9 for Driver 4 as compared to 9.6 for Driver 6, both line-haul drivers. The magnitude of this difference, five-fold, was surprising. When considering only valid alerts (the difference between all and invalid alert rates in the figure) the difference between drivers is even more pronounced. Although the influence of route, weather, and load condition may help explain some of this difference, the primary factor leading to this difference is almost certainly attributable to differences in driving style and the prevalence of secondary behaviors (eating, talking on a CB radio, etc.). Previous work by UMTRI (Sullivan et al, 2004) has shown that the influence of confounding variables (weather, load, time of day, etc.) on the lateral performance of heavy truck driving are all markedly less than the effect of driving style of the operator. Differences in alerts rate due to driving style, although not objectively measured in the analysis of EPT data except by the alert rate, was subjectively supported by researchers in their classification of alerts.

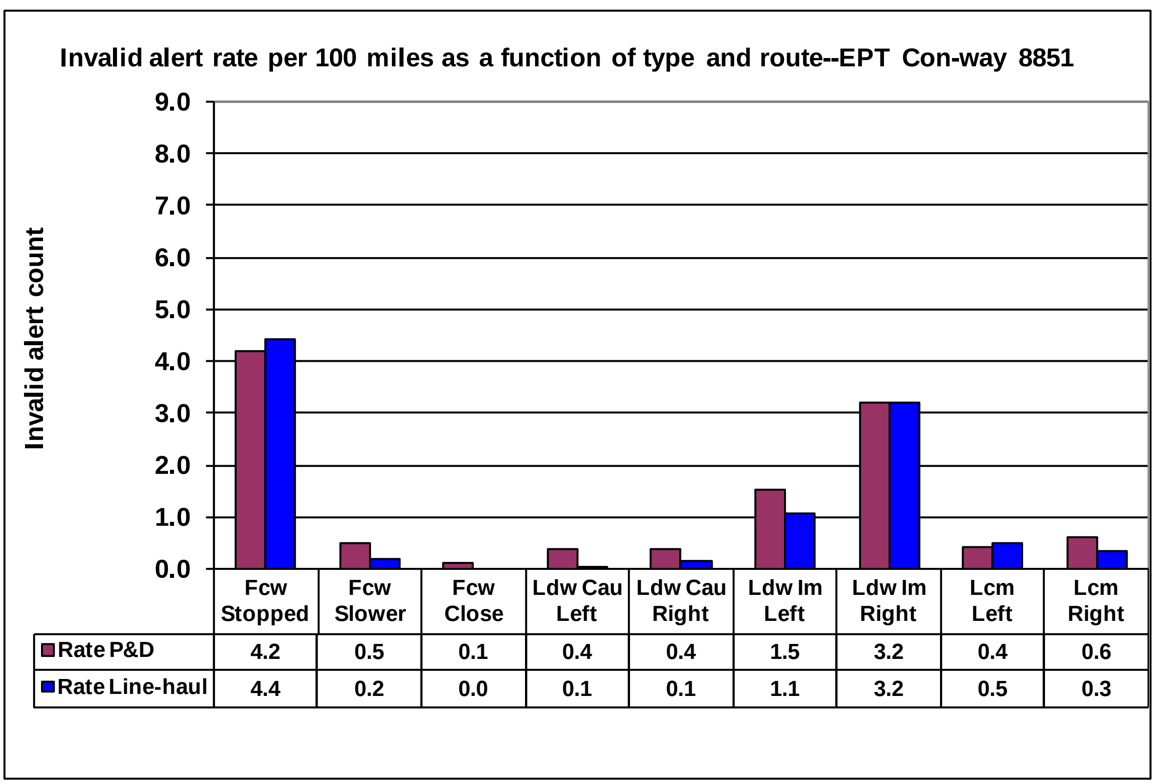
The total alert rate distribution for P&D drivers (1, 3, 5 and 7) did not vary as much as alert rate for line-haul drivers (2, 4 and 6). Out of all of the EPT drivers, P&D Driver 7 had the lowest overall alert rate of 14.5 per 100 miles with an invalid alert rate of 6.9 per 100 miles. Only Drivers 1 and 4 had total invalid alert rates that exceeded the goal identified by the design team of 15 alerts per 100 miles.

Figure 14 shows the distribution of invalid alert rates as a function of subsystem alert and route type. Invalid alerts were dominated by FCW alerts in response to stopped objects and imminent LDW alerts, mostly to the right. Of these categories, the FCW stopped object alerts constituted approximately 4.3 invalid alerts per 100 miles for either route types, or 42 percent of all invalid alerts. Invalid LDW imminent alerts on the right occurred at a rate of 3.2 per 100 miles, or 31 percent of all invalid alerts. For both of these invalid alerts categories route type, line-haul vs. P&D, alert rate did not appear to vary.



	1	2	3	4	5	6	7
All alerts	37.1	10.4	24.1	48.9	19.6	9.6	14.5
Invalid	17.8	7.5	11.2	18.4	7.4	4.3	6.9
Distance	499	2182	366	971	393	540	392

Figure 13. Alert rate per 100 miles by EPT driver



	Fcw Stopped	Fcw Slower	Fcw Close	Ldw Cau Left	Ldw Cau Right	Ldw Im Left	Ldw Im Right	Lcm Left	Lcm Right
Rate P&D	4.2	0.5	0.1	0.4	0.4	1.5	3.2	0.4	0.6
Rate Line-haul	4.4	0.2	0.0	0.1	0.1	1.1	3.2	0.5	0.3

Figure 14. Invalid alert rate per 100miles as function of alert and route type

To analyze the affect of invalid alerts, the fraction of invalid alerts to all alerts as a function of alert and route type is illustrated in Figure 15. This figure clearly shows that nearly all the FCW alerts in response to stopped objects were judged invalid for both route types. Figure 15 also illustrates that that 80 percent of FCW alerts in response to slower moving objects (lead vehicle is less than 80 percent of the subject vehicle speed) in the line-haul routes were also deemed to be invalid as compared to only 10 percent of similar alerts on P&D routes.

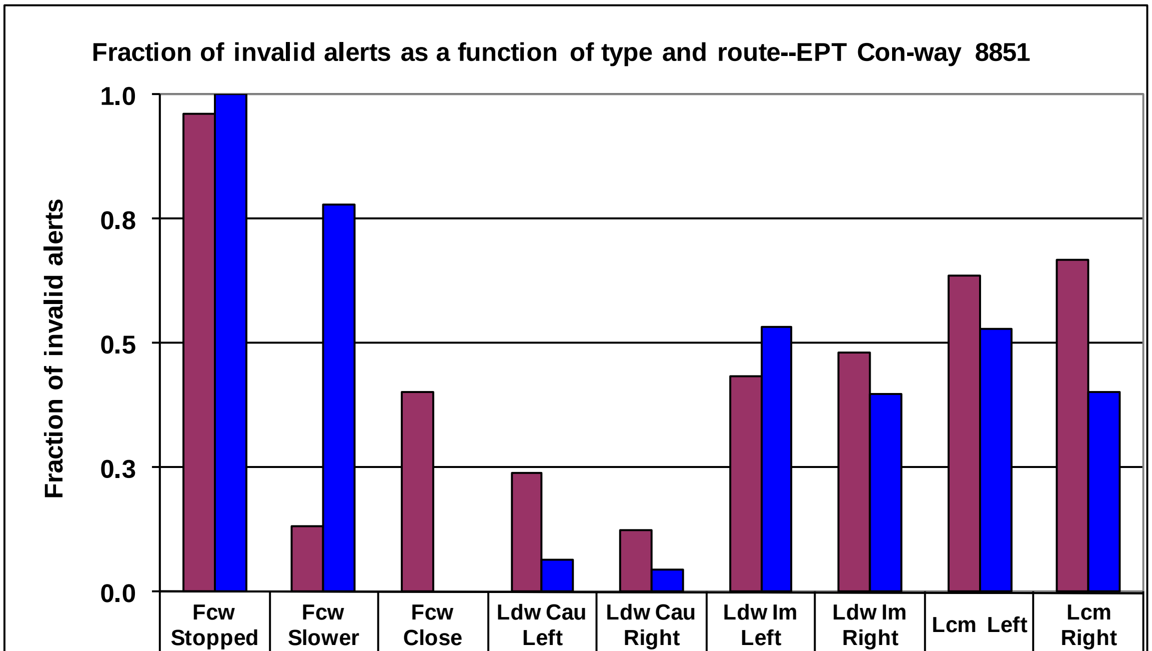
The route type played a significant role in the validity of FCW alerts for events involving slower moving objects. This outcome is not unexpected, given that the tractor is speed-governed at 62 mph, which is slower than most free-flowing highway traffic (i.e., the likelihood of approaching a slower moving vehicle is far greater on P&D routes, which spend significantly more time on lower-speed surface roads).

Also illustrated in Figure 15 is the effect of route type on invalid LDW cautionary alerts. Since this alert type depends on lane-boundary markers, there is a significant increase of invalid alerts on P&D routes, where line markings are generally of poorer quality, as compared to line-haul. However, this does not hold true for LDW imminent and LCM alerts. Here the effect of route type is mixed, especially for LDW imminent alerts. For LCM alerts, P&D drivers were more likely to experience invalid alerts. However, as a category LCM alerts are relatively infrequent due to the fact that they only occur when the driver has the turn-indicator on—which constitutes only 5 percent (4.12 of 93.8 hrs) of the time spent above 25 mph during the EPT.

Based on the results illustrated in

Figure 14 and Figure 15, it is clear that FCW stopped alerts are more likely than any other category to be invalid. This category has the highest invalid alert rate for both route types, as compared to the other categories, and 98 percent of all stopped object alerts were classified as invalid. Furthermore, stopped object alerts were evenly distributed across all EPT drivers (Std. Dev. of 1.3 alerts per 100 miles) unlike other alert subcategories like LDW Imminent Right in which 79 percent of the alerts were from two of the seven drivers.[6]

[6] Drivers 1 and 4 had 320 of the 407 LCM-Imminent Right alerts. Driver 4 had 247 alerts (61 percent).



	Fcw Stopped	Fcw Slower	Fcw Close	Ldw Cau Left	Ldw Cau Right	Ldw Im Left	Ldw Im Right	Lcm Left	Lcm Right
P&D	1.0	0.1	0.4	0.2	0.1	0.4	0.5	0.6	0.7
Line-haul	1.0	0.8	0.0	0.1	0.0	0.5	0.4	0.5	0.4

Figure 15. Fraction of invalid alerts as function of alert and route type

Finally, to investigate the issue of driver experimentation with the integrated crash warning system (the act of intentionally soliciting alerts during the early stages of a driver's exposure), alert rate as a function of distance traveled was examined. Figure 16 illustrates the alert rate per 100 miles as a function of normalized distance for each driver. For all drivers except driver 4 the alert rate is fairly constant across their exposure period, suggesting that for these drivers there was not much experimentation—nor did the system change their driving style, at least as indicted by their alert rate. Driver 4 had a steady, almost linear, decline in his alert rate. A closer look at the type of alerts that Driver 4 had showed that they were predominately lateral in nature, with over 87 percent of all alerts coming from the LDW subsystem (125 Cautionary and 290 Imminent LDW). These alerts tapered off over the course of his five-day exposure, which may suggest the driver changed his driving style to reduce the number of alerts.

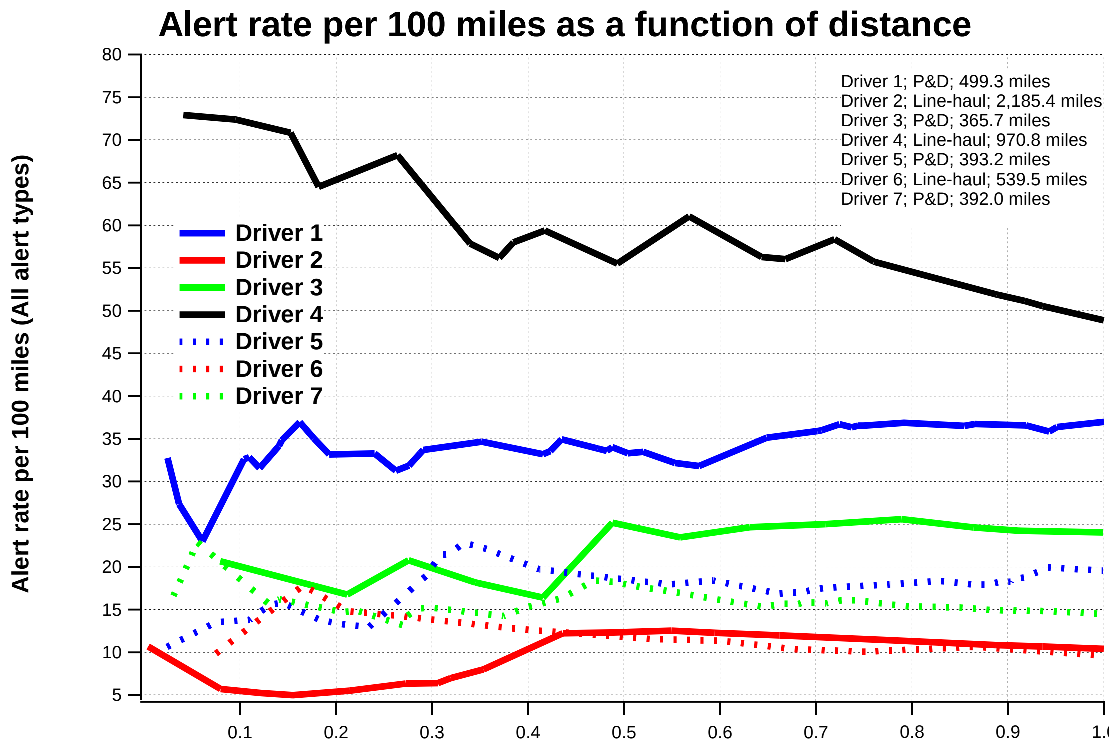


Figure 16. Alert rate as a function of normalized distance

4.3 Subjective Results

After participants had driven the tractor for five days, each was asked to complete a post-drive questionnaire regarding their experience with the integrated crash warning system. The following section is a summary of their subjective feedback obtained from the completion of the questionnaire. The questionnaire is presented in its entirety in Appendix A of this report.

4.3.1 Overall Impressions of the Integrated System

When asked about the integrated crash warning system overall, drivers in general responded positively. The mean responses to these overall questions are presented in Table 2. All four of these questions received mean scores of 4.0 or higher, indicating somewhat positive opinion of the system. Question 6 (mean score= 5.6) received the most favorable score of any question on the questionnaire, indicating drivers felt they received a specific benefit in terms of increased awareness of the road environment and their position in the lane when driving with the integrated crash warning system. A relatively large standard deviation in responses to Question 5 illustrates the difference in opinion drivers had in terms of the perceived increase in safety when driving with the integrated system. Responses to Question 5 resulted in the lowest mean score in this section, with two drivers commenting about their dissatisfaction with invalid alerts.

Table 2: Mean subjective responses regarding the overall system acceptance

Q#	Prompt	Mean	St.Dev
5	“Overall I think the integrated system is going to increase my driving safety.” (1=strongly disagree, 7=strongly agree)	4.3	2.1
6	“Driving with the integrated system made me more aware of traffic around me and the position of my truck in my lane" (1=strongly disagree, strongly agree)	5.6	1.5
7	"Overall, I felt the system was predictable and consistent." (1=strongly agree, 7=strongly disagree)	4.0	1.6
9	"Overall, how satisfied were you with the integrated system? (1=very dissatisfied, 7=very satisfied)	5.0	1.3

4.3.2 Warning Frequency and Comprehension

Mean responses to questions regarding the frequency of warnings, and their comprehension, are presented in Table 3. Of this group, only Question 10 received a mean score under 4.0. The low mean on Question 10 is likely a response by drivers to invalid alerts. Comments to this question included five drivers responding that they received too many FCW’s, two drivers responding that they received too many LCMs and one driver responding that they received too many LDWs. Only two drivers indicated that they received too few warnings from any specific subsystem (one FCW, one LCM).

Only one driver responded to Questions 11 and 12 with a “1,” indicating that he appears to have received a number of warnings that he did not understand. Other drivers reported having a better understanding of why they received warnings. The more favorable scores on Question 11, in contrast to Question 7 (mean=4.7 vs. mean =4.0), might indicate that while drivers did get some warnings that they found to be inconsistent, they were usually able to determine what led to the warning being issued.

Table 3: Mean subjective responses regarding warning frequency and comprehension

Q#	Prompt	Mean	St.Dev
3	"How helpful were the integrated system's warnings?" (1=not helpful, 7=helpful)	4.4	0.8
8	"I was not distracted by the warnings" (1=strongly disagree, 7=strongly agree)	4.1	1.6
10	"Overall, I received warnings..." (1=too frequently, 7=never)	3.1	1.3
11	"I always understood why the integrated system provided me with a warning." (1=strongly disagree, 7=strongly agree)	4.7	1.9
12	"I always knew what to do when the integrated system provided a warning" (1=strongly disagree, 7=strongly agree)	4.3	1.6

4.3.3 Auditory and Visual Warnings

Mean responses to questions regarding the auditory warnings are presented in Table 4 and questions regarding the visual warnings are presented in Table 5. In general, responses to questions regarding the auditory and visual warnings tended to be favorable. Questions 15 and 18 asked whether the auditory or visual warnings, respectively, were "annoying," with both questions receiving only positive or neutral responses.

Table 4: Mean subjective responses regarding auditory warnings

Q#	Prompt	Mean	St.Dev
13	"The auditory warnings got my attention" (1=strongly agree, 7=strongly disagree)	5.6	0.8
14	"I always understood why the integrated system provided me with an auditory warning" (1=strongly agree, 7= strongly disagree)	4.4	1.0
15	"The auditory warnings were not annoying" (1=strongly disagree, 7=strongly agree)	5.0	1.2

Table 5: Mean subjective responses regarding visual warnings

Q#	Prompt	Mean	St.Dev
16	"The visual warnings got my attention" (1=strongly agree, 7=strongly disagree)	4.4	1.6
17	"I always understood why the integrated system provided me with a visual warning" (1=strongly agree, 7= strongly disagree)	4.3	1.1
18	"The visual warnings were not annoying" (1=strongly disagree, 7=strongly agree)	5.4	1.3

The finding that drivers rated the visual warnings as slightly less annoying is consistent with the DVI design strategy employed to make the auditory warnings most conspicuous to drivers. When similar questions were asked regarding both alert modalities from a perspective of how conspicuous the warnings were (Questions 13 and 16), drivers gave responses consistent with the visual warnings being less obtrusive. However, driver responses to the auditory warnings were generally quite favorable.

4.3.4 Invalid alerts

When drivers were asked about invalid alerts (i.e., overall for the integrated system as a whole) their responses were more negative than positive. Mean responses to questions regarding invalid alerts are presented in Table 6. Five of the seven drivers disagreed with Question 20, but only two out of the seven drivers thought the invalid alerts came too frequently.

When drivers were asked about invalid alerts for the individual subsystems, driver responses indicate they received invalid alerts from the FCW subsystem most frequently (Question 22). The LDW and the LCM subsystems received neutral responses in terms of the prevalence of invalid alerts (Questions 23 and 24, respectively).

Table 6: Mean subjective responses regarding invalid alerts

Q#	Prompt	Mean	St.Dev
20	"The integrated system never gave me warnings when I did not need them (i.e. nuisance warnings) " (1=strongly disagree, 7=strongly agree)	2.9	1.1
21	"Overall, I received nuisance warnings…" (1=too frequently, 7 = never)	3.4	1.1
22	"The integrated system never gave me a forward collision warning (FCW) when I did not need one" (1=strongly disagree, 7=strongly agree)	2.6	1.4
23	"The integrated system never gave me a lane departure warning (LDW) when I did not need one" (1=strongly disagree, 7=strongly agree)	4.0	1.6
24	"The integrated system never gave me a side-collision warning (SCW) when I did not need one" (1=strongly disagree, 7=strongly agree)	3.7	1.0

4.3.5 User-Interface

Drivers generally responded positively to questions regarding the user-interface. Mean responses to several of these questions are presented in Table 7. The center display received the most favorable mean response score while the LCM side-indicators and the LDW availability icons also received positive responses.

The volume adjustment for the auditory warnings received a neutral response (Question 30). IVBSS provided drivers the opportunity to adjust the volume of the auditory warnings, or to mute the auditory warnings for a short period. All seven drivers responded that they never used the mute, and only one said that he used the volume adjustment. One driver commented that the center display/control unit was too far away to safely push the mute button while driving. Subsequent drivers were specifically asked about this, but none of them shared this opinion.

Table 7: Mean subjective responses regarding the user-interface

Q#	Prompt	Mean	St.Dev
26	"The center display was useful" (1=strongly disagree, 7=strongly agree)	5.3	1.4
27	"The two side-collision warning displays mounted near the exterior mirrors were useful" (1=strongly disagree, 7=strongly agree)	4.6	1.9
28	"The half circle icons on the center display helped me to understand and to use the integrated system" (1=strongly disagree, 7=strongly agree)	4.6	1.5
29	"The mute button was useful" (1=strongly disagree, 7=strongly agree)	4.4	0.5
30	"The volume adjustment control was useful" (1=strongly disagree, 7=strongly agree)	4.0	0.6

When asked about the usefulness of the LCM warning displays, drivers' responses were mixed. Comments on these displays also widely varied, with some drivers responses being:

-"SCW side boxes need to be more visible"
- "SCM useful, but just left light"
-"Didn't notice light on left."

When the responses were split between line-haul drivers and pick-up and delivery drivers, it became evident that the line-haul drivers found the LCM indicator lights to be more useful. The mean score for Question 27 was just 3.2 for the pick-up and delivery drivers, but 5.3 for the line-haul drivers.

4.3.6Driver Endorsement

Question 31 asked, "Do you prefer to drive a truck equipped with the integrated system over a conventional truck?" Two drivers responded "Yes" to this question, and five drivers responded "No." Question 32 asked, "Would you recommend that the company buy trucks equipped with the integrated system?" The same two drivers responded "Yes," while the remaining five again responded "No."

There is some indication of a discrepancy between drivers' responses to questions such as 6 and 9, and their overall endorsement of the integrated warning system (Questions 31 and 32). While the integrated system appears to be helpful, only a couple of drivers would want to drive a truck equipped with an integrated warning system over one without a warning system. While exposure to invalid alerts, primarily from the FCW subsystem that likely accounts for the majority of dissatisfaction, there may very well be other elements at play – namely, a sense that they as individuals do not need a system to help them avoid crashes; this is not uncommon. Specifically, participants in field tests of crash warning systems almost universally report that crash warning systems are needed by "other" drivers – but not themselves. Another component may be the amount of time a professional driver spends with the system (i.e., total exposure). Simply stated, spending ten hours a day driving with a system that presents warnings may simply have a cumulative effect on professional drivers that isn't regularly experienced by drivers of passenger vehicles. Lastly, this was a new tractor to which each driver had to adapt. While the tractor was generally similar in class, number of gears and operation, it was different from the tractor for which they are familiar. How this familiarity may have affected driver acceptance of the integrated warning system is unknown.

5 Conclusions and Implementation of the EPT Results

During the HT EPT, over 5,300 miles of driving with the integrated crash warning system were logged. From an exposure perspective, test conditions were consistent with the business practices of Con-way Freight, and therefore were similar to the conditions that would be expected in the FOT. Seven drivers logged 459 trips and experienced 1162 alerts from the FCW (313), LDW (759), and LCM (90) integrated warning technologies. Upon review of each of these alerts using data and video, researchers subjectively classified 551 (47 percent) of the alerts as being invalid. This resulted in an overall invalid alert rate of 10.3 alerts per 100 miles of travel. For FCW, 249 (79 percent) of the alerts were invalid, while LDW had 255 (34 percent) invalid alerts, and LCM had 47 (52 percent) invalid alerts. Invalid alert rates were largely independent of route type with overall invalid alert rates of 11.3 and 9.9 for P&D and line-haul, respectively.

A further breakdown of the alert types showed that FCW alerts for stopped objects (234) had a total of 232 (99 percent) categorized as invalid.[7] Based on this finding, the heavy-truck team decided to evaluate two changes to reduce the occurrence of invalid FCW alerts with stopped objects. These changes included the following:

- To address stationary objects when following a POV: In this scenario the software would suppress a stopped object alert for 0.5 s when the following conditions have been met; a) SV has been following an in-path moving POV for at least 3 seconds, b) the distance to the stationary object is greater than the distance to the POV at 3 seconds prior to the alert request, and c) the distance to the stationary object is less than the distance to the POV at the time of the alert request. It is anticipated that this change to the FCW threat assessment will reduce invalid stopped object alerts by 15 to 30 percent.
- To address stopped objects like roadway signs while in a curve: In this scenario, the software would suppress a stopped object alert for 0.5 seconds if the SV has been decelerating for the last 5 seconds. It is anticipated that this rule may reduce invalid stopped object alerts by 20 to 40 percent.

Relative to their subjective impressions, drivers in the HT EPT indicated that they were somewhat satisfied with the integrated system as a whole. While one of the drivers was clearly unhappy with the consistency of the warnings, the remaining six drivers responded that they usually understood why warnings occurred. Specifically, the majority of the drivers felt the system provided the benefit of increased awareness of the

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[7] This is also 74 percent of all FCW alerts

traffic situation around them, and therefore increased their driving safety. Of the three individual subsystems, drivers rated the FCW subsystem lowest, likely a result of the prevalence of invalid alerts. The LDW and LCM subsystems received higher overall scores, but neither substantially out-performed the other.

Drivers seemed satisfied with the user-interface of the integrated system. Regarding the intensity of the warnings, drivers felt they were strong enough to gain their attention without being annoying. Only one driver reported using the volume control, and none of the drivers reported using the mute function or the brightness adjustment. This lack of customization may have partially been a result of the relatively short exposure periods in the EPT. Responses were mixed in terms of the LCM displays. Drivers tended to like the concept, but felt that the location of the displays could be improved to make them more noticeable when checking their mirrors.[8]

In summary, the HT EPT succeeded in assessing system performance and driver acceptance prior to conducting the FOT of the integrated crash warning system. Data gathered from the EPT demonstrated that the vehicle and data acquisition system performed reliably. Subjective assessments suggested that there was no major discontent with the integrated system. However, particularly as it relates to the FCW subsystem and the accurate detection of stopped and slow moving objects, areas for system improvement were identified. These findings led to changes in the FCW subsystem prior to deployment in the FOT.

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[8] The location of the side display LEDs was decided by the fleet management personnel who felt it was important that the lights not be in the drivers' normal field of view where they may distract the driver from the forward scene especially at low ambient light conditions. Hence, despite driver desire for a different location, changing the location of the displays is not being proposed for the FOT.

6 References

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7 Appendix A. Post-Drive Questionnaire and Evaluation

Subject #__________

Date ____________

IVBSS HT 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.

The integrated system consists of three functions. Please refer to the descriptions below as you answer the questionnaire.

Forward Collision Warning (FCW) – The forward collision warning function provided an auditory warning 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 "Collision Alert". Additionally, this system provided you with headway information in the display as you approached the rear of a vehicle (e.g., object detected, 3 seconds)

Lane Departure Warning (LDW) – The lane departure warning function provided an auditory warning whenever your turn signal was on AND you were changing lanes and there was the possibility of a collision with a vehicle in the lane to which you were moving. When you received this type of warning, the display read "Lane Drift" and a truck in the display appeared to be crossing a lane line.

Side Collision Warning (SCW) – The side collision warning function provided an auditory warning whenever there was a vehicle in the truck's blind spot, your turn signal was on, and the system detected lateral motion indicating your intention to make a lane change. A red LED illuminated in the side display on whichever side you were making the lane change. Additionally, if your turn signal was off, and there was no indication that you were intending to make a lane change, but there was a vehicle in the truck's blind spot, a yellow LED was illuminated in the side display.

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

Mean	St. Dev
4.4	0.8

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

Mean	St. Dev
4.3	2.1

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

1 2 3 4 5 6 7

Strongly Disagree — Strongly Agree

Mean	St. Dev
5.6	1.5

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

1 2 3 4 5 6 7

Strongly Disagree — Strongly Agree

Mean	St. Dev
4.0	1.6

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

1 2 3 4 5 6 7

Strongly Disagree — Strongly Agree

Mean	St. Dev
4.1	1.6

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

1 2 3 4 5 6 7

Very Dissatisfied — Very Satisfied

Mean	St. Dev
5.0	1.3

10. **Overall, I received warnings . . .**

1 2 3 4 5 6 7

Too Frequently — Never

Mean	St. Dev
3.1	1.3

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)**

Forward Collision Lane Departure Side Collision

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)**

Forward Collision   Lane Departure   Side Collision

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

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Mean	St. Dev
4.7	2.0

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

Mean	St. Dev
4.3	1.6

13. The auditory warnings got my attention.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Mean	St. Dev
5.6	0.8

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

Mean	St. Dev
4.4	1.0

15. The auditory warnings were not annoying.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Mean	St. Dev
5.0	1.2

16. The visual warnings got my attention.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Mean	St. Dev
4.4	1.6

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

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Mean	St. Dev
4.3	1.1

18. The visual warnings were not annoying.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Mean	St. Dev
5.4	1.3

19. 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

Mean	St. Dev
4.3	1.5

20. 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

Mean	St. Dev
2.9	1.1

21. Overall, I received nuisance warnings . . .

1	2	3	4	5	6	7
Too Frequently						Never

Mean	St. Dev
3.4	1.1

22. The integrated system never gave me a forward collision warning (FCW) when I did not need one.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Mean	St. Dev
2.6	1.4

23. The integrated system never gave me a lane departure warning (LDW) when I did not need one.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Mean	St. Dev
4.0	1.6

24. The integrated system never gave me a side-collision warning (SCW) when I did not need one.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Mean	St. Dev
3.7	1.0

Overall Acceptance of the Integrated System

25. 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:

										Mean	St. Dev
useful	1	☐	☐	☐	☐	☐	5	useless		3.1	1.2
pleasant	1	☐	☐	☐	☐	☐	5	unpleasant		2.6	0.8
bad	1	☐	☐	☐	☐	☐	5	good		3.4	1.0
nice	1	☐	☐	☐	☐	☐	5	annoying		3.1	1.1
effective	1	☐	☐	☐	☐	☐	5	superfluous		2.3	1.1
irritating	1	☐	☐	☐	☐	☐	5	likeable		2.9	1.2
assisting	1	☐	☐	☐	☐	☐	5	worthless		2.4	1.0
undesirabl	1	☐	☐	☐	☐	☐	5	desirable		3.4	1.1
raising alertn	1	☐	☐	☐	☐	☐	5	sleep-inducing		2.0	0.6

Displays and Controls

26. The center display was useful.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Mean	St. Dev
5.3	1.4

27. The two side-collision warning displays mounted near the exterior mirrors were useful.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Mean	St. Dev
4.6	1.9

28. The half circle icons on the center display helped me to understand and to use the integrated system.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Mean	St. Dev
4.6	1.5

29. The mute button was useful.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Mean	St. Dev
4.4	0.5

30. The volume adjustment control was useful.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Mean	St. Dev
4.0	0.6

31. Do you prefer to drive a truck equipped with the integrated system over a conventional truck?

Yes______ No______

Mean	St. Dev
1.7	0.5

32. Would you recommend that the company buy trucks equipped with the integrated system?

Yes______ No______

Mean	St. Dev
1.7	0.5

Forward Collision Warning (FCW) acceptance

33. Please indicate your overall acceptance rating of the forward collision 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.

Forward collision warnings were:

									Mean	St. Dev
useful	1						5	useless	2.9	1.1
pleasant	1						5	unpleasant	3.0	1.3
bad	1						5	good	3.1	1.6
nice	1						5	annoying	3.0	1.0
effective	1						5	superfluous	2.1	1.2
irritating	1						5	likeable	3.0	0.6
assisting	1						5	worthless	2.6	0.8
undesirable	1						5	desirable	3.4	0.8
raising alertn	1						5	sleep-inducing	2.1	0.9

__Lane Departure Warning (LDW) acceptance__

34. Please indicate your overall acceptance rating of the lane departure 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.

Lane departure warnings were:

										Mean	St. Dev
useful	1	☐	☐	☐	☐	☐	5	useless		2.6	0.5
pleasant	1	☐	☐	☐	☐	☐	5	unpleasant		2.4	0.8
bad	1	☐	☐	☐	☐	☐	5	good		3.7	1.0
nice	1	☐	☐	☐	☐	☐	5	annoying		3.0	1.0
effective	1	☐	☐	☐	☐	☐	5	superfluous		2.4	0.8
irritating	1	☐	☐	☐	☐	☐	5	likeable		3.7	0.8
assisting	1	☐	☐	☐	☐	☐	5	worthless		2.6	1.0
undesirabl	1	☐	☐	☐	☐	☐	5	desirable		3.4	0.8
raising alertn	1	☐	☐	☐	☐	☐	5	sleep-inducing		2.3	0.8

Side Collision Warning (SCW) acceptance

35. Please indicate your overall acceptance rating of the side-collision 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 side collision warnings were:

										Mean	St. Dev
useful	1						5	useless		2.6	0.8
pleasant	1						5	unpleasant		2.7	1.0
bad	1						5	good		3.7	1.0
nice	1						5	annoying		2.4	0.8
effective	1						5	superfluous		2.7	0.8
irritating	1						5	likeable		3.3	1.0
assisting	1						5	worthless		2.6	0.8
undesirabl	1						5	desirable		3.7	0.8
raising alertn	1						5	sleep-inducing		2.0	0.6

36. Please indicate your overall acceptance rating of the Two Side-Collision Warning Displays Mounted Near the Exterior 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 two side-collision warning displays mounted near the exterior mirrors were:

	1					5		Mean	St. Dev
useful	1					5	useless	2.6	1.3
pleasant	1					5	unpleasant	2.1	0.9
bad	1					5	good	3.6	1.1
nice	1					5	annoying	2.6	1.4
effective	1					5	superfluous	2.1	0.9
irritating	1					5	likeable	3.7	1.0
assisting	1					5	worthless	2.3	1.0
undesirabl	1					5	desirable	3.6	0.8
raising alertn	1					5	leep-inducing	2.3	0.8