Publication No. FHWA-OP-04-061
Sponsor No. FTA-TRI-11-2003.2

U.S. Department
of Transportation

ITS Joint Program Office
Federal Transit Administration

Evaluation Report: Driver Experience with the Enhanced Object Detection System for Transit Buses

Final Report
December 12, 2003

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
12-12-2003

2. REPORT DATE
Final

3. DATES COVERED *(From - To)*
January 2003-December 2003

4. TITLE AND SUBTITLE
Evaluation Report - Driver Experience with the Enhanced Object Detection System for Transit Buses

5a. CONTRACT NUMBER
DTFH61-96-C-00077

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER
Publication No. FHWA-OP-04-061
EDL No. 13930

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Battelle
505 King Avenue
Columbus, Ohio 43201

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Federal Transit Administration
400 7th Street SW
Washington, D.C. 20590

10. SPONSOR/MONITOR'S ACRONYM(S)
FTA

11. SPONSORING/MONITORING AGENCY REPORT NUMBER
FTA-TRI-11-2003.2

12. DISTRIBUTION AVAILABILITY STATEMENT
No restrictions.
This document is available to the public.

13. SUPPLEMENTARY NOTES
Authors: *Battelle **CJI Research Corporation ***Transportation Resource Associates, Inc.

14. ABSTRACT
An evaluation that measured driver acceptance of the Enhanced Object Detection System (EODS) for transit bus side proximity warning was performed in conjunction with a 100-day Field Operational Test (FOT), conducted during April to July 2003 on buses equipped with Intelligent Vehicle Initiative (IVI) technology, at the Harmar Division of the Port Authority of Allegheny County, Pennsylvania (Pittsburgh metropolitan area). The EODS technology was designed as a driver assistive tool to provide bus drivers with information about detected objects in close proximity to their vehicles. The objects of primary concern are other vehicles and stationary obstacles during in-service operations such as close-maneuvering situations, slow speed turns, lane change and merge situations. The EODS FOT assessed technology implemented as retrofit/aftermarket equipment installation on five buses. The EODS was evolved from an earlier-generation side object detection system for which a FOT with evaluation was sponsored by the Pennsylvania Department of Transportation (PennDOT). The results of the EODS evaluation are intended to help guide deployment decisions for the evolving proximity warning technology in public and private fleets.

15. SUBJECT TERMS
Driver acceptance, object detection, proximity alert, collision warning, collision avoidance, transit ITS.

Evaluation Report: Driver Experience with the Enhanced Object Detection System for Transit Buses

for the
U.S. Department of Transportation
Washington D.C.

Contract No. DTFH61-96-C-00077
Task Order 7735

December 12, 2003

By

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EXECUTIVE SUMMARY

Introduction

The United States Department of Transportation (USDOT) established an Intelligent Vehicle Initiative (IVI) as a major component of the Intelligent Transportation System (ITS) program. The intent of the IVI Program is to improve significantly the safety and efficiency of motor vehicle operations by reducing the probability of motor vehicle crashes. These safety improvements could also show secondary benefits such as increased transportation mobility, productivity, or other operational improvements.

The IVI Program consists of four platforms:

- Light vehicles,
- Commercial vehicles,
- Specialty vehicles, and
- Transit vehicles.

Each platform is unique in terms of funding mechanisms, institutional issues, public mission, operator characteristics, and safety concerns. For example, for the same distance of travel, a person is 15 times less likely to sustain a fatal injury riding in a bus compared to riding in another vehicle type[1]. On the other hand, the transit bus is 15 times more likely to be involved in a collision than other vehicle types. In 2002, transit buses were involved in 1,010 major collision incidents involving 4,005 injuries, 39 fatalities, and $5.2M in collision damage nationwide. Of those, side collisions (sideswipe and angle) accounted for 86 percent of the injuries, 65 percent of the fatalities, and 63 percent of the total collision damage[2].

Since 1998, the Federal Transit Administration (FTA), with support from the USDOT's ITS Joint Program Office (JPO), has been partnering with the Pennsylvania Department of Transportation (PennDOT) and various research organizations and technology providers to investigate different ITS technologies that might help reduce the numbers of side collisions involving transit buses. Several studies involve the development and testing of side-mounted object detection systems.

This report presents findings on driver acceptance of a second generation, Enhanced Object Detection System (EODS) that was evaluated during a 100-day Field Operational Test (FOT) conducted between April and July, 2003 in the Pittsburgh, Pennsylvania metropolitan area). It was prepared by a JPO-funded independent evaluation team consisting of Battelle and subcontractors Transportation Resource Associates, Inc. (TRA) and CJI Research, Inc.

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[1]Presentation by R. Snyder of the Port Authority of Allegheny County at the APTA Best Practices Workshop, Chicago, Illinois, October 18, 2002.

[2]*Transit Accident Analysis Using the National Transit Database*, presentation by C.Y. David Yang, Ph.D., the Volpe Center, June 27, 2003.

FOT Background

The EODS FOT was carried out by the Harmar Division of the Port Authority of Allegheny County (hereafter called "Port Authority") with support from the system developer, Clever Devices, Inc. The technology for the EODS evolved from an earlier-generation side object detection system (ODS) that was designed, installed, tested, and evaluated in the period 1999-2002.

This first generation (Gen1) Transit IVI Side ODS used off-the-shelf proximity detection technologies that had proven useful for the trucking industry. They were provided and installed by Collision Avoidance Systems, Inc. on 100 full-size transit buses that operated in normal revenue service at the Port Authority's East Liberty Division. The field test was carried out over a nine-month period in 2001, during which an evaluation was conducted[3].

That evaluation was designed to determine whether there was a reduction in collisions that could be attributed to the Gen1 side ODS and to conduct an analysis to determine whether it was economically viable to install the system on the entire Port Authority bus fleet. While there was an apparent reduction in accidents and associated claims during this FOT period, it was difficult to establish a cause and effect relationship, except perhaps for the evidence that the presence of the ODS increased the drivers' awareness.

During the FOT, drivers identified several features of the ODS that required future enhancements. They felt that if improvements could be made to the ODS, they would find the system more useful and acceptable. Among the enhancements that were considered as a result of the Gen1 FOT were:

- Reducing the frequency of unwanted warnings,
- Improving the security of the ODS to reduce vandalism and improve its availability,
- Improving the driver-vehicle interface to make the warnings more effective and acceptable,
- Allowing for graduated warnings based on the severity of the collision risk, and
- Providing information to the driver on the proximity of the bus to objects.

Clever Devices, the developer of this second-generation (Gen2) system, used this information in designing an improved version which they named the Enhanced Object Detection System, or EODS. PennDOT commissioned a limited FOT of the EODS retrofit on five buses from the Port Authority's Harmar Division. FTA and the JPO supported an independent evaluation to evaluate driver acceptance of the EODS. The EODS evaluation focused on driver acceptance because a larger-scale deployment over a longer test period was needed to provide conclusive information on accident reduction and overall safer driving. That type of test was conducted with the Gen1 in 2001-2002 and will possibly be conducted again as the technology evolves.

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[3] *Final Evaluation Report-Revised, Side Collision Warning System Operational Test Evaluation,* Thomas J. Luglio, Jr. P.E., Transportation Resource Associates for the Pennsylvania Department of Transportation, March 2003.

The results of the EODS evaluation of driver acceptance will also help guide deployment decisions for object detection and collision warning system technology in other public and private fleets. In particular, the results will be useful to the USDOT in designing the Integrated Collision Warning System (ICWS) being developed through a partnership involving principally the Pennsylvania and California Departments of Transportation (PennDOT and CALTRANS), Carnegie Mellon University (CMU) Robotics Institute and the University of California – Berkeley/PATH, and the Port Authority and San Mateo Transit (SamTrans, in the San Francisco Bay area). The technical objective of the ICWS program is to integrate a frontal and side CWS with a CWS synthesizer for the driver-vehicle interface (DVI). One of the FTA's key goals on the ICWS program is to field a commercially-available CWS by 2005.

EODS Description

The EODS is a driver assistive tool designed to reduce the number of side collisions by enhancing the driver's awareness of nearby objects. The EODS technology is neither a collision warning nor avoidance system; rather it was designed to provide bus drivers with information about detected objects in close proximity to their vehicles. The objects of primary concern are other vehicles and stationary obstacles during in-service operations such as close-maneuvering situations, slow speed turns, lane change and merge situations. The EODS consists of three subsystems:

1. Twenty ultrasonic sensors installed on the exterior of the bus, to detect objects in the required detection zones,
2. A controller to manage input and output data, and
3. A set of operator interfaces to alert the driver to the presence of any objects in the detection zone(s).

When an object was detected in a predefined zone, the EODS presented visual and/or audible signals to the bus operator. The visual warning signals were in the form of two flashing or solid amber light-emitting diodes (LEDs), and the system status lights were a single blue LED. These amber and blue LEDs were located in compact display clusters within 15 degrees of the operator's line of sight to the left and right-side side-view mirrors and at a third location on the dashboard to the right of the operator. The audible warning (a "chime" consisting of two double tones – i.e., one double tone rapidly followed by another of the same characteristics for each close object detection) indicated when a detected object was considered to be too close for normal maneuvering. The chime sounded through a single speaker in close proximity to the operator's seat. The chime was triggered by the same conditions as the solid light, but only sounded if the turn signal was activated. The visual and audible signals were provided through a synthesis of vehicle speed, threat levels, and modes and zones.

Alert Criteria

As shown in Table ES-1, driver alert criteria varied according to proximity zone and operating modes. There were three threat levels (low, medium, and high) when a bus was operating below 45 mph and a single high threat level when operating above 45 mph. In the low threat level, the

LED flashed two times per second. At the medium threat level, there were four flashes per second. At the high threat level, the LED had a solid display (i.e., lit but not flashing) and the chime sounded (see Table ES-1).

Table ES-1. Driver Alert Criteria under Various Operating Conditions

Mode	Vehicle Speed*	Zone			Amber LED Flash Rate			Chime
		Near	Middle	Far	Near	Middle	Far	
Stopped	0 mph	1 ft.	2 ft.	4 ft.	Solid on	Fast	Slow	Silent
Urban Slow	<15 mph*	1 ft.	2 ft.	4 ft.	Solid on	Fast	Slow	If object in near zone with turn signal on
Urban Fast	15 - 45 mph*	2 ft.	4 ft.	8 ft.	Solid on	Fast	Slow	If object in near zone with turn signal on
Highway	45 – 50 mph*	0 – 8 ft.			Solid on			If object in zone with turn signal on

* A transition range occurred when going from Urban Slow to Urban Fast mode between 10 and 15 mph and when going from Urban Fast to Highway mode between 45 and 50 mph.

Operating Modes and Proximity Zones

There were four operating modes. In the stopped mode, low threat was defined as an object that was in a zone equal to or greater than four feet away, medium was two to four feet, and high was less than 1 foot. If the bus was operating in the urban slow mode (i.e., below 10 mph), the zones were four feet, two feet, and one foot respectively. If the bus was operating in the urban fast mode (i.e., more than 15 mph but less than 45 mph), the zones were eight feet, four feet, and two feet. If the bus was operating in the highway mode, there was only one detection zone, from zero to eight feet (see Table 1-1). The zone sizes were based upon prior operator feedback and were capable of being changed through software adjustments, although they were not changed during the FOT.

Warning and Status Lights

The Amber LED warnings flashed two times per second (slow) if an object was detected in the far zone; four times per second (fast) if an object was detected in the middle zone; and a solid "on" if the object was in the closest zone. The blue LED status lights flashed only if there was a problem with the system and never extinguished unless the system diagnosed itself as "unreliable." After the object was no longer detected in the respective zone, the amber LEDs only were extinguished. If a system failure occurred (which included the event of one sensor not being able to operate reliably), there was a warning code set to the blue LEDs and they would flash a code for two seconds, then all of the LEDs (including the amber) would go blank. The LEDs were designed to be visible in direct sunlight and were designed to be easy to see at night. They were focused and mounted so as to make them of little or no distraction to the driver while he or she was looking straight ahead.

FOT Design

The FOT was performed with five retrofit/aftermarket EODS-equipped buses that were driven on five regular urban routes during day-to-day operations of the Port Authority's Harmar Division. The five test routes were selected for their variety of characteristics – including traffic volume, speed limit, and geometry – and ranged from tight urban-slow operations to highway driving. Fifteen drivers, four instructors, and three maintenance staff were trained to use the system volunteered to participate in data collection activities, including two rounds of personal interviews. Driver ages ranged from 31 to 54 years and years of service ranged from 3 and 24 years. The average age was 43.8, and the average years of service were 11.5. These 15 drivers represented approximately six per cent of Harmar Division's 268 drivers and one per cent of the Port Authority's nearly 1600 drivers. The Port Authority was responsible for selecting the drivers and routes to be included in the study. The FOT lasted 100 days beginning on April 7, 2003.

Evaluation Goals and Objectives

The primary goal of the evaluation study was to assess the extent to which the EODS was accepted by drivers. Seven general objectives were established and each was defined in terms of several testable hypotheses. Findings (below) are presented according to these objectives and hypotheses.

Although the ultimate goal of the EODS technology is to reduce the number of crashes involving transit buses, this evaluation did not attempt to quantify the safety benefits. USDOT chose not to focus on accident reduction, since providing conclusive information on that requires a much larger test, involving many more buses and drivers and a much longer test period – such as the 100-bus test that preceded this FOT. The USDOT intends to perform additional tests to assess safety benefits sometime in the future.

Evaluation Methods

The evaluation was based primarily on information gathered from personal interviews with the drivers, maintenance personnel, instructors, and managers associated with the FOT; daily questionnaires and logs; Internet surveys; Quality Circle meetings; and supplemental data. During the FOT, participating drivers covered more than 14,000 miles in service and completed 135 daily questionnaires and 63 maintenance reports. The buses were not equipped with electronic data acquisition systems, nor were they equipped with cameras.

Findings

Findings related to driver acceptance of the EODS are presented below. We begin with some observations concerning drivers' pre-test attitudes and expectations toward this new technology; then present the findings associated with each of seven evaluation objectives. For each objective, we list the hypotheses that were tested and classify our findings according to whether the drivers' reactions were generally positive or negative. Qualified findings are noted and explained.

Drivers' Pre-test Attitudes and Expectations

- Drivers initially had a wait-and-see attitude toward use of high-tech equipment.
- Initially, some drivers were cautious about embracing EODS because of shortcomings with the Generation 1 (Gen1) side collision warning system from which EODS was evolved, and which had been tested on buses at another Port Authority division.
- Situations that drivers perceived to be high-risk were the same situations for which they expected the warnings would be useful to them.
- Drivers viewed EODS as an assistive tool and expected marginal but positive results.

Objective 1: Determine Usability of EODS under Normal Driving Conditions

Hypothesis	Negative Reaction	Qualified	Positive Reaction
Easy to learn			☺
Training adequate			☺
Easy to use and control		√	😐
Capabilities understood		√	😐
Signals recognizable		√	😐
DAS* information understood			☺

*Driver Assistive System

In general, the drivers reported that the EODS was easy to learn, the training was adequate, and they understood how it worked. However, there was evidence that many drivers did not understand the limitations of the system and often mistook such limitations as a system failure.

Additional observations related to this objective are as follows:

- Drivers felt that the association of the chime with the turn signal was a positive feature because it would reduce false positives.
- Drivers found it easy to distinguish the chime from other sounds and suggested that it should differentiate between warnings for the left and right sides of the bus.
- Drivers perceived rapidly flashing lights were more useful than slowly-flashing lights and felt it is was easier to notice a solid light than to notice whether a light was flashing fast or slowly.

Objective 2: Determine How EODS Affects Driving Environment and Workload

Hypothesis	Negative Reaction	Qualified	Positive Reaction
Reduces driving workload	☹		
Reduces stress or fatigue	☹		
Does not distract or interfere with other tasks		√	😐
False positive alarms irritating	☹		
False negative alarms degrade confidence	☹		
False positive alarms excessive	☹		
Passenger questions distracting			☺

As a driver assistive system it was anticipated that the EODS would help reduce driving workload and stress. However, for most of the drivers the EODS either made no difference in mental workload or was perceived to increase it. It did not reduce stress. With the exception of certain aspects of the chimes, the drivers did not feel that the EODS was distracting or interfered with driving tasks. The frequency and nature of false positive alarms was a concern to most drivers.

Additional observations related to this objective are as follows:

- Drivers perceived workload varies with the speed of the vehicle.
- Drivers felt that the characteristics of the chime itself were not distracting, only the frequency of false alarms.
- Drivers were concerned about the slow response of the EODS to vehicles, especially to those approaching from the rear or in their blind spots.

Objective 3: Determine if Driver Behaviors Affected by Use of EODS

Hypothesis	Negative Reaction	Qualified	Positive Reaction
Take fewer risks		√	
More vigilant		√	
Dependent on system in detrimental way			☺
Modify behavior in response to EODS		√	😐

Most of the drivers consistently rejected the notion that the EODS had any impact on risk-taking behavior and vigilance. The qualification is that they believe that they were already safe, risk-averse drivers. This is neither a positive nor a negative reaction because, from the drivers' perspective, the EODS could not have improved risk-taking behaviors or vigilance. There is no evidence that the drivers became dependent on the system. Drivers reported that use of the EODS did not affect their speeds or braking behaviors, but some felt that lane-keeping behaviors and turn signal usage did change somewhat.

Objective 4: Determine if Drivers Value EODS and Believe it Improves Safety

Hypothesis	Negative Reaction	Qualified	Positive Reaction
Enhances drivers' abilities		√	😐
Effective under specific (not all) driving conditions		√	😐
Helps avoid accidents		√	😐
Drivers trust the system and find it useful	☹		
Increases job satisfaction	☹		
Preferred by drivers	☹		

Although the drivers rejected the notion that the EODS made them safer drivers, approximately half reported that it helped them detect objects that would not be detected in the mirror; and thus, enhanced their abilities during lane-change maneuvers. Two drivers reported that the EODS helped them avoid accidents, one pulling out from a stop and the other pulling in. However, in general, the drivers were neutral about the overall usefulness of the EODS, mostly due the frequency of false alarms.

Objective 5: Determine Drivers' and Mechanics' Perceptions of System Quality and Recommendations for System Improvement

Hypothesis: Drivers made recommendations related to…	Recommendations Provided
Performance or functionality	√
Ease of use or learning	√
False alarm rates	√
Component reliability	√

Although not unanimous, drivers and maintenance staff made recommendations that included:

- reducing the double chime to a single chime,
- replacing the 3-level light system with a 2-level system that would include only solid and fast-flashing lights,
- creating a system of differing chime tones to clarify which side of the bus is making the detection of an object,
- making the system response time faster,
- reducing the systems' response to environmental factors such as rain and wind,
- providing an ambient sensor for the warning lights that can automatically dim the light-emitting diodes (LEDs) at night to reduce the strobe effect some drivers reported,
- better educating drivers as to the level of false alarms to expect and what constitutes a malfunction vs. a system limitation, and
- improving diagnostic techniques.

Objective 6: Determine if Driver Acceptance is Affected by Maintenance Requirements

Hypothesis	Negative Reaction	Qualified	Positive Reaction
Failure rate too high	☹	√	
Failures degrade confidence	☹	√	
Failures under certain conditions	☹	√	

Although there were relatively few equipment malfunctions during the 100-day test, many drivers reported equipment problems because they perceived the rate of false alarms was too high. It was apparent that many drivers mistook system limitations for malfunctions. Thus, our findings relative to these hypotheses are qualified because they are based on the drivers' reactions to the perception of maintenance problems rather than to actual maintenance requirements.

Objective 7: Identify Institutional Barriers and Benefits to Driver Acceptance

Hypothesis	Negative Reaction	Qualified	Positive Reaction
Invasion of privacy			☺
Communications between drivers and management			☺
Public's perception of Port Authority		√	😐
Driver training			☺
Testing and deploying other new technologies			☺

Due to the excellent communication with the drivers and mechanics during the planning and conduct of this FOT, no institutional issues arose. The drivers had a very positive attitude toward the test. There was insufficient evidence during the FOT to make a determination concerning the public's perception of the Port Authority; however, national exposure resulting from demonstration of one of the five EODS-equipped buses in conjunction with the June 2003 National IVI Meeting in Washington, D.C. was very favorable.

Additional observations related to this objective are as follows:

- The Port Authority's organization and implementation of the FOT were excellent, especially in the areas of communication and stakeholder involvement.
- The EODS training program that was implemented at the Harmar Division should improve both future training and the deployment and testing of future technologies.

Conclusions

1. **The test produced useful information for the system developer.** The developer of the EODS, Clever Devices, was actively involved throughout the design, installation, and operational phases of the FOT. They were constantly assessing the functionality of the five retrofit bus systems based on their own observations and the comments received from drivers and mechanics. While this FOT was not specifically designed to make comparisons between the Gen1 system (as tested in 2001) to the current Gen2 system, Table ES-2 summarizes the observed results of selected enhancements tested on the EODS FOT as a result of the lessons learned from the 100 bus Gen1 FOT.

Table ES-2. ODS Evolution from Gen1 to Gen2 and Driver Reactions

System Characteristic	Gen1 Limitation	Gen2 Change	Driver Reaction to Gen2
Audible tone	Annoying	Changed tone and frequency	No complaints about Gen2 audible tone
Frequency of audible alerts	Too often	Many situations used only visual alerts	Drivers appeared to appreciate change
Alert algorithm	Large percentage of unwanted alerts – did not give driver useful or new info.	Differentiated alerts based on speed and distance of object from bus	A much smaller percentage of warnings appeared to be unwanted
Alert levels	Only one level	Three levels based on speed and distance of object from bus	Accepted by drivers but two levels recommended
Proximity to objects	No capability to differentiate	Three zones implemented	Drivers appeared to see as favorable
Enhance proximity detection at corners	No capability	Additional sensitivity added at corners	Drivers appeared satisfied with changes
Variation of alert mechanisms	None	Several based on flashing lights and audible alarms	Drivers liked having both lights and audible alarms. Prefer single chime.
Security of systems from vandalism	Poor	Enclosure durability improved	No apparent vandalism
Suitability for low speed operations	Not good	Additional sensors and granularity	System performed better at low relatives speeds
Effect of weather	Not identified – too many other issues	Sensors embedded in "beauty strip"	Wind and rain, including sensor water intrusion, degraded system performance

Just as the limitations of the Gen1 ODS were addressed by the Gen2/EODS design (as illustrated in Table ES-2), Clever Devices, the system developer, plans to continue to explore ways to improve on the limitations of the EODS for the next phase of this technology. Thus, lessons learned from this incremental improvement process will benefit both the evolving EODS-based technology as well as the ICWS developmental efforts.

2. **Drivers used the EODS as a tool, not as a system designed to give warnings of imminent collisions.** Initially, drivers tended to think – erroneously – that the EODS might be a collision warning or avoidance system. As the FOT progressed, drivers became more aware of the EODS' true design and grew more comfortable using it as a driver assistive aid.

3. **<u>Drivers found the system easy to learn but needed a better understanding of system limitations</u>.** For example, many drivers initially believed EODS should detect all objects around them, including stationary objects such as lampposts. Consequently, when a bus passed such an object at a relatively fast speed and no detection registered, they concluded that the EODS was not working correctly. That initial misperception about the EODS' design limits proved difficult to reverse.

4. **<u>The majority of the drivers perceive the benefits of the EODS technology (once it is fully developed)</u>.** EODS did not reduce the drivers' workload (many drivers found that the technology presented them with additional demands in an already hectic environment). But drivers valued it and saw its great potential for safety improvements, particularly if the rate of false alarms and the adverse effects of weather were reduced. Two of the drivers felt that EODS had helped them avert accidents, including one potentially serious collision.

5. **<u>The EODS FOT was pioneering work that produced much useful information, particularly about the DVI</u>.** That information will benefit development of the ICWS. It will advance transit community knowledge on how to successfully implement applied research, train transit operators in the use of high-tech systems, and facilitate the collaboration between transit agency and research team.

Epilogue: The Next Steps

To place the findings of this evaluation in the context of current ITS development and deployment activities, representatives from PennDOT and the Port Authority were invited to prepare the following comments. Also provided is a synopsis of comments from research staff at Carnegie Mellon University who are involved in the development of the ICWS.

<u>Comments from Chris Johnston, PennDOT Assistant Deputy Secretary of Transportation for Local and Area Transportation</u>:

"The Intelligent Vehicle Initiative is providing significant advances in object detection for transit operations. The approach of working directly with operators and assuring that all lines of communication are open and dynamic has proven valuable in creating what will soon be a very comprehensive system that enhances safety by providing drivers the tools necessary to eliminate common accidents.

"The future of this technology development is promising. It is hoped that in the future, FTA – coupled with active DOTs, transit agencies, and private partners – can use this applied research approach to continue to deliver meaningful and acceptable research and innovative solutions to the Public Transportation industry. The latest version of this technology merges two specific features: (1) close maneuvering assist at low speeds, and (2) the ability for the system to adjust to higher vehicle speeds by warning the operator of pending dangers that are detected farther away from the bus.

"The advances to date would not have been possible without the operators' willingness to provide feedback to the team's developers and evaluators based on their hours of experience behind the steering wheel. It could not have been achieved without the private partner's commitment to develop a practical solution to improve public transportation. Finally, the good work that continues to advance the system design could not have been possible without the support of the FTA, the willingness of the Port Authority, and the support of PennDOT. Our hope is that the continued support and energy that has been expended for this technology is making transit safer."

Comments from Dan DeBone, Director of Special Services, Port Authority of Allegheny County, Pennsylvania:

"As a result of our participation in Phase II of the Intelligent Vehicle Initiative (IVI), Port Authority supports the continued development of driver-assisted technology as an important objective for the transit industry. The operators participating in this project, while recognizing the limitations of the tested system, consistently stated that an enhanced system would be valuable if it could prevent just one accident. The success of this project resulted from involving the operators, mechanics and their union representatives as partners early in the process, and ensuring that open channels for communication were created and known by all employees participating.

"The active role that Harmar operators, maintenance employees and Instructors played in developing the design for the next generation of system was achieved through a variety of methods. Operators completed Daily Questionnaires and Maintenance Feedback forms to describe their experiences with the systems, and kept the Instructors informed of recurring issues. The Instructors worked to coordinate issues between the operators and the maintenance department. The Instructors and maintenance staff were often in contact with representatives from Clever Devices to discuss issues with the systems' operation. This effective line of communication resulted in two engineering redesign actions for the systems during the 100-day FOT.

"Quality Circle meetings were held every month with operators, maintenance employees, Instructors, management and representatives from Clever Devices to discuss how the systems were working and what the operators felt would make them a more effective tool. The meetings provided project updates for the group, but more importantly, served as an open discussion with operators about their experiences with and recommendations for the object detection system. In fact, as a result of strong operator opinion about the value of audible warnings, the next phase of the project was modified to provide for testing of Neoplan buses with modified systems containing visual and audible warnings, as well as the planned testing of Gillig buses with original equipment manufacturer (OEM)-installed systems containing only visual warnings.

"Generally, it is felt that an enhanced object detection system could improve safety and prevent accidents, provided that the technology advances to the point where operators can feel confident that it provides accurate information without being too distracting. Two operators participating in the FOT actually had experiences where the audible warning alerted them to a vehicle and they were able to take action to avoid a possible collision. However, operators felt that there needs to be a greater reduction in the number of false warnings and the degree to which inclement weather affects the system. If not, operators said that they will eventually ignore the system. Additionally, the type of warning; audible, visual or a combination of both, is an issue that requires further study. The majority of operators felt that a system with audible warnings can be more successful in increasing safety and preventing accidents. This opinion was shared by the Instructors, who felt that the visual warning actually diverted the operator's attention away from their mirrors, whereas the audible warning brought their attention back to their mirrors."

Synopsis of comments from Carnegie-Mellon University representatives who are participating in development of the ICWS:

Nuances in the transit environment lead to unique DVI requirements compared to other vehicle platforms. The evolving EODS has provided key insights on visual and auditory DVI features for safety assistance systems in transit vehicles. It has provided valuable insights on side detection issues that the ICWS has or will encounter, such as prevalence and effects of water spray, hardware robustness for transit applications, DVI placement, processing of information on stationary objects like parked cars and roadside poles, and commercialization requirements for transit. Feedback on how well certain EODS features worked are impacting the way the ICWS will be designed, built, fielded and tested. Finally, the EODS implementation has primed the Port Authority staff to be more effective collaborators with the ICWS research team. As a result of this project, the Port Authority staff are more knowledgeable of technical details and more willing to test safety assistance systems.

ACKNOWLEDGEMENTS

The principal authors of this report were Bill Tate and John Orban of Battelle and Hugh Clark of CJI Research, Inc. Other major contributors included Tom Luglio of Transportation Resource Associates, Inc. (interviews, evaluation planning and liaison) and Battelle staff Chris Cluett (questionnaire and Internet survey development) and Mark Nemeth (database management). Vince Brown and KyLynn Slayton of Battelle assisted in the preparation of this report. The technical task coordinator was Bill Tate and the evaluation leader was John Orban. Battelle's program manager was Jerry Pittenger.

The authors are grateful for the cooperation and contributions of key individuals and their organizations in supporting the evaluation of this Intelligent Vehicle Initiative Field Operational Test. In particular, we would like to recognize Brian Cronin of the FTA; Chris Johnston of PennDOT; Dan DeBone of the Port Authority of Allegheny County, Pennsylvania; Robin Rochez of the Port Authority's Harmar Division; and Kris Weeks of Clever Devices, Inc. for their instrumental roles on the project.

We also sincerely appreciate the superb support and cooperation of the many Harmar Division drivers, instructors, and maintenance staff who participated in the Field Operational Test. Other participants in the project who we would like to recognize are Kathy Radkoff and Richard Snyder of the Port Authority, Lloyd Miller of Clever Devices, and David Duggins and Aaron Steinfeld of Carnegie-Mellon University, who were the liaison to the Intelligent Vehicle Initiative Integrated Front- and Side-Collision Warning System Program.

ABBREVIATIONS

APTA:	American Public Transportation Association
CALTRANS:	California Department of Transportation
CJI:	CJI Research Corporation, Inc.
CMU:	Carnegie-Mellon University
CWS:	Collision warning system
DAS:	Driver assistive system
DVI:	Driver-vehicle interface
EODS:	Enhanced Object Detection System
FOT:	Field Operational Test
FTA:	Federal Transit Administration
Gen1:	Generation 1
Gen2:	Generation 2
IO:	Input-output
IPAS:	Independent Program Assessment Support
ITS:	Intelligent Transportation Systems
IVI:	Intelligent Vehicle Initiative
LED:	Light-emitting diode
OEM:	Original equipment manufacturer
PATH:	Partners for Advanced Transit and Highways
PennDOT:	Pennsylvania Department of Transportation
SAMTRANS:	San Mateo Transit
TRA:	Transportation Resource Associates, Inc.
USDOT:	U.S. Department of Transportation

1.0 INTRODUCTION

The United States Department of Transportation (USDOT) established an Intelligent Vehicle Initiative (IVI) as a major component of the Intelligent Transportation System (ITS) program. The intent of the IVI Program is to improve significantly the safety and efficiency of motor vehicle operations by reducing the probability of motor vehicle crashes. These safety improvements could also show secondary benefits such as increased transportation mobility, productivity, or other operational improvements.

The IVI Program consists of four platforms:

- Light vehicles,
- Commercial vehicles,
- Specialty vehicles, and
- Transit vehicles.

Each platform is unique in terms of funding mechanisms, institutional issues, public mission, operator characteristics, and safety concerns. For example, for the same distance of travel, a person is 15 times less likely to sustain a fatal injury riding in a bus compared to riding in another vehicle type (Snyder, 2002). On the other hand, the transit bus is 15 times more likely to be involved in a collision than other vehicle types. In 2002, transit buses were involved in 1,010 major collision incidents involving 4,005 injuries, 39 fatalities, and $5.2M in collision damage nationwide. Of those, side collisions (sideswipe and angle) accounted for 86 percent of the injuries, 65 percent of the fatalities, and 63 percent of the total collision damage (Yang, 2002).

Since 1998, the Federal Transit Administration (FTA), with support from the USDOT's ITS Joint Program Office (JPO), has been partnering with the Pennsylvania Department of Transportation (PennDOT) and various research organizations and technology providers to investigate different ITS technologies that might help reduce the numbers of side collisions involving transit buses. Several studies involve the development and testing of side-mounted object detection systems.

This report presents findings on driver acceptance of a second generation Enhanced Object Detection System (EODS) that was evaluated during a 100-day Field Operational Test (FOT) conducted between April and July, 2003 in Allegheny County, Pennsylvania (Pittsburgh metropolitan area). It was prepared by a JPO-funded independent evaluation team consisting of Battelle and subcontractors Transportation Resource Associates, Inc. (TRA) and CJI Research, Inc.

1.1 The EODS Field Operational Test

The EODS FOT was carried out by the Harmar Division of the Port Authority of Allegheny County (hereafter called "Port Authority") with support from the system developer, Clever Devices, Inc. The technology for the EODS evolved from an earlier-generation side object detection system (ODS) that was designed, installed, tested, and evaluated in the period 1999-2002.

This first generation (Gen1) Transit IVI Side ODS used off-the-shelf proximity detection technologies that had proven useful for the trucking industry. They were provided and installed by Collision Avoidance Systems, Inc. on 100 full-size transit buses that operated in normal revenue service at the Port Authority's East Liberty Division. The field test was carried out over a nine-month period in 2001, during which an evaluation was conducted (Luglio, 2003).

That evaluation was designed to determine whether there was a reduction in collisions that could be attributed to the Gen1 side ODS and to conduct an analysis to determine whether it was economically viable to install the system on the entire Port Authority bus fleet. While there was an apparent reduction in accidents and associated claims during this FOT period, it was difficult to establish a cause and effect relationship, except perhaps for the evidence that the presence of the ODS increased the drivers' awareness.

During the FOT, drivers identified several features of the ODS that required future enhancements. They felt that if improvements could be made to the ODS, they would find the system more useful and acceptable. Among the enhancements that were considered as a result of the Gen1 FOT were:

- Reducing the frequency of unwanted warnings,
- Improving the security of the ODS to reduce vandalism and improve its availability,
- Improving the driver-vehicle interface to make the warnings more effective and acceptable,
- Allowing for graduated warnings based on the severity of the collision risk, and
- Providing information to the driver on the proximity of the bus to objects.

Clever Devices, the developer of this second-generation (Gen2) system, used this information in designing an improved version which they named the Enhanced Object Detection System, or EODS. PennDOT commissioned a limited FOT of the Gen2 system retrofit on five buses from the Port Authority's Harmar Division. FTA and the JPO supported an independent evaluation to evaluate driver acceptance of the Gen2 EODS. The FTA wanted to evaluate the EODS in order to gather more information and lessons learned from the implementation of object detection technologies. They decided to have the EODS evaluation conducted under the auspices of Battelle's Intelligent Transportation Systems (ITS) Program Assessment Support (IPAS) contract. Battelle had performed or was performing the independent evaluations of the IVI commercial vehicle and specialty vehicle FOTs.

The Battelle evaluation team included two subcontractors: TRA, who had performed the evaluation of the Gen1 100-bus FOT, and CJI Research Corporation, Inc. The evaluation team's mission was to determine driver acceptance of the EODS by concentrating primarily on the drivers' responses to it. The evaluation focused on obtaining data with which to record drivers' perceptions and gauge their acceptance. It was also important to understand any driver-related and garage-related issues with implementation of the object detection system.

Clever Devices installed the EODS as a retrofitted after-market device on five Neoplan 5000 buses belonging to the Port Authority and garaged at its Harmar Division. The retrofit was completed on January 29, 2003 and was followed by tests to debug and assure proper operation of the systems.[4] Prior to operational testing, Harmar Division and Clever Devices personnel conducted test runs with the EODS and performed system debugging during the week of February 3, 2003. A period of driver instruction followed.

Then the FOT's operational testing got underway. This testing consisted of the five EODS-equipped transit buses making daily runs, each on its regular route in the Pittsburgh area, for a 100-day period. During this time, drivers completed daily questionnaires that captured pertinent driving information from their daily runs, and they filled out Maintenance Evaluation Survey forms if they thought the EODS was not working or not working correctly (or not working to the level of their expectations, which was more consistent with the findings). Other evaluation instruments such as interviews, Internet surveys, and a special series of Harmar Division meetings of a group known as the Quality Circle were employed to capture drivers' perceptions and acceptance of the EODS.

1.2 Background

In 1998, the Federal Transit Administration (FTA) and Pennsylvania Department of Transportation (PennDOT) started looking at transit vehicle collision avoidance as a possible application of advanced technology. FTA and PennDOT initiated two concurrent efforts in conjunction with the Port Authority of Allegheny County, Pennsylvania (Pittsburgh metropolitan area) and Carnegie-Mellon University (CMU) Robotics Institute. PennDOT's approach was to advance the science of collision warning systems (CWSs) through research, explore the use of commercially-available technology, and build a core of professional operators familiar with collision warning systems.

In 2002, USDOT initiated a program to integrate and test a combined forward- and side-collision warning system. One of FTA's goals for this integrated system was to field a commercially-available CWS by 2005. Carnegie-Mellon University Robotics Institute began developing a side CWS to integrate with the frontal CWS and driver-vehicle interface for the integrated CWS. Their host transit agency for bus testing is the Port Authority.

PATH (University of California-Berkeley) began developing the frontal CWS to integrate with the side CWS and will also provide the CWS warning synthesizer for the driver-vehicle interface (DVI). PATH's host transit agency for bus testing is San Mateo Transit (SAMTRANS) in California, supported by the Bay Area Advisory Committee. PennDOT and CALTRANS jointly

[4] While this evaluation was in progress, five Gillig buses were being fitted with a significantly different configuration of the EODS using six sensors in a "blind spot" paradigm, but they were not part of this evaluation.

coordinate communications and project updates from all partners, oversee contracts with selected major players in their locations, and define parameters and responsibilities related to advanced warning system prototype testing.

Using PennDOT matching funds, Collision Avoidance Systems, Inc. – a private vendor among this group – was the supplier of a commercial ODS. PennDOT and the FTA arranged to have the Port Authority conduct the 100-bus FOT in 1999-2000 utilizing the Gen1 ODS, in which they trained 325 operators and gathered feedback. This original test was followed by the PennDOT and FTA decision to have the Gen2/EODS designed, prototyped, and tested in an FOT at the Harmar Garage.

Clever Devices, the designers of the new prototype system, responded to all maintenance issues during the FOT and was a partner in ongoing planning and operations. Clever Devices had the lead role on technical support and design advice, and they supported the driver training and other preparations for the FOT and its evaluation. The Port Authority's Heinz Office provided project administration, and the Manchester Office provided technical support for the FOT. The Harmar Division Director of Service Delivery oversaw and coordinated the FOT. Two on-site union representatives were directly involved with the FOT. Other Harmar staff managed maintenance, quality assurance and technical support and supervised instruction for the bus drivers. The Harmar Garage provided 15 drivers, along with the five EODS-equipped buses for the FOT. The drivers and day-to-day operations of the FOT buses on their assigned routes were under the control of the Harmar Division, where they were garaged.

1.3 Organization of this Document

The remainder of this evaluation report is divided into five parts. Section 2 describes the technical systems that were tested, the research plan for deploying these systems, and some operational issues that affected the evaluation. Section 3 contains a comprehensive discussion of the evaluation goal and objectives and presents specific hypotheses that were tested. The evaluation technical approach in Section 4 describes the data that were collected and the analyses that were performed to test specific hypotheses and achieve the goal and objectives. Section 5 describes the evaluation findings and relates them to the objectives. Section 6 discusses conclusions as well as recommendations for EODS enhancements and future field tests.

2.0 DESCRIPTON OF THE EODS AND THE FOT

The ultimate objective of the EODS was to provide appropriate information and effective warnings to the bus operator during normal in-service situations such as tight maneuvering and lane change operations. The FOT was performed to determine whether the drivers found the system to be helpful, and the extent to which they accepted it. In particular, the FOT focused on determining whether the enhancements built into the Gen2/EODS achieved what they were designed to do and resolved some of the problems that were identified in the Gen1 system.

The results of the FOT will be used to provide the Federal Transit Administration, PennDOT, and the independent evaluator with data, and to inform decision makers and the general public of the potential for the EODS technology to improve the safety and productivity of the transit bus system. The following subsections describe the system tested; present the research plan used, including information on the FOT design, drivers and vehicles, routes, and scheduling system; and identify operational issues that affected the FOT evaluation.

2.1 Description of the Technologies Tested

The EODS was meant to increase safety by communicating to trained operators a "detected object" condition, thereby raising their level of awareness. These objects were detected in the "blind spots" or pre-determined danger zones near the vehicle where operators had blocked or limited visibility, or where the object/vehicle was at greatest risk. The object detection system was not operational when the engine was not running.

The EODS was designed as a driver assistive tool, not a collision avoidance system (i.e., the bus makes no automatic reactions such as steering or braking in response to objects detected). The EODS can be divided into 3 subsystems: sensors, controller, and operator interfaces. Ultrasonic sensors detected objects in the required detection zones. The controller performed various required Input-Output (IO) functions. The operator interface alerted the driver to the presence of any objects in the detection zone(s). The cycle time of the system was 350 milliseconds.

Five Neoplan 5000 buses were retrofitted with the EODS for use in the FOT. These were model AN440L buses that were 40 feet long, 9 feet wide, and 11 feet high. They were approximately 2-1/2 years old. Passenger seating capacity was 37. Each bus was powered by a 320 horsepower diesel engine. They had a wheelchair ramp. In general, a bus went in for inspection and repair (I&R) every 45 to 60 days based on its "fuel mileage."

In addition to the EODS displays and the usual cluster of switches and lights associated with environmental and safety features, there was a bank of light-emitting diodes (LEDs) that displayed information such as maintenance alarm condition, air conditioning stop indicator, and various temperature indicators. There was also a fire suppression system control panel and an automatic passenger information system, which provided automatic stop announcements inside the bus and automatic route and destination announcements outside the bus.

2.1.1 Visual Warnings

Visual warnings served as the primary informational display. The visual warning was conveyed via light-emitting diodes (LEDs) that flashed at two different rates. The more rapid flash rate was correlated to increased (or "Zone 2") proximity. The visual displays also indicated to the driver the side of the bus on which the object was detected, through placement of the displays. Figure 2-1 illustrates placement of the LEDs. There was a single LED for displaying detection of objects on the left side. That LED was mounted on the roof pillar near the left edge of the windshield and was just to the right of the driver's line-of-sight to the left side view mirror.

There were two display clusters that displayed identical information on object detections that occurred on the right side of the bus. One was on the roof pillar near the right edge of the windshield, just to the right of the driver's line-of-sight to the right side view mirror. There was another display cluster that was on the dashboard at the lower right corner of the windshield. These right side clusters flashed identical messages. The dual amber LED on all clusters was added for redundancy in the event of an amber LED failure. The reason that two clusters were used on the curb side (right side) was so the driver would not have to change his or her normal glance positions in order to take in system information. Only one cluster on the left was required because if the operator were to glance at the mirror *or* in the direction of the left corner bumper, the single display cluster was visible without inducing a secondary glance position.

Warning (amber) and status (blue) | Mounted in single place on left | Mounted in 2 places on right (below circular mirror and at corner of numbered placard)

Figure 2-1. Placement of LEDs

The status lights were blue LEDs. The warning lights were amber LEDs. The amber warning lights flashed:

- Two times per second (slow) if an object was detected in the farthest of three detection zones (see Figure 2-4 and Table 2-1 for the characterization of the zones),
- Four times per second (fast) if an object were detected in the middle detection zone, and
- Solid "on" if the object were in the closest detection zone.

The blue status lights flashed only if there was a problem with the system; solid blue indicated normal system function. After they flashed, all lights (amber and blue) were extinguished.

2.1.2 Audible Warning

In addition to a visual warning, an audible warning was also used. The audible warning (a "chime" consisting of two double tones – i.e., one double tone rapidly followed by another of the same characteristics for each close object detection) indicated when a detected object was considered to be too close for normal maneuvering. It duplicated the warning of the LEDs' solid light display. The chime was sounded by a single speaker located in close proximity to the driver's seat. The audible signal was used to convey a degree of relative threat, but the signal (chime) did not indicate the location of the threat to the driver. The chime did not sound when the bus was stopped. Figure 2-2 shows the position of the speaker on the left side.

Figure 2-2. Audible Sensor Placement – Left Side

2.1.3 Sensors

There were a total of 20 ultrasonic sensors mounted on the outside of each instrumented bus.[5] All except the front corner and far aft sensors were installed in a "rub rail" (or "beauty strip") along the side of the bus (Figure 2-3) so as to be less conspicuous than the sensors on the 100 vehicles in the Gen1 FOT, which was one of the EODS design criteria. They were designed to be easily replaced. Ten of the sensors were on the right side and ten on the left side (Figure 2-4). Included in the 20 was a sensor located at each of the right and left front corners, respectively (Figures 2-5 and 2-6). The sensors formed an ultrasonic network of detection around most of the periphery of the vehicle (Figures 2-4 to 2-8). The sensors emitted at 40 KHz/second, which is the same frequency of transducers used in the automotive industry as rear parking aids, assuring good availability if the systems were to go into production for transit.

Figure 2-3. Sensor in Rub Rail

[5] Two of an original 22 sensors, one on each side, were judged to be redundant and removed prior to the FOT.

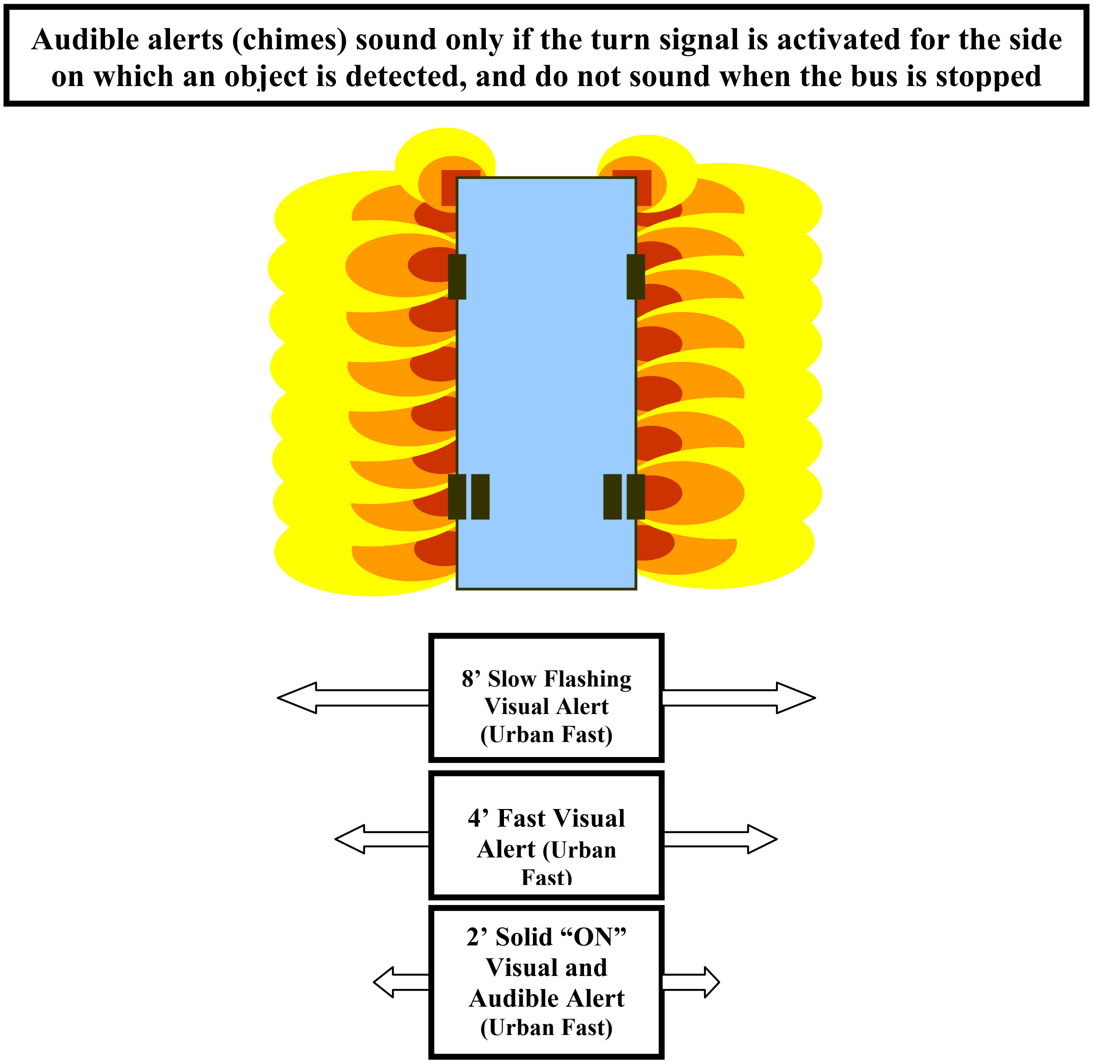

Figure 2-4. EODS Ultrasonic Sensor Array and Coverage Zones

The sensors detected fixed as well as moving objects within pre-determined danger zones or blind spots that surrounded the right and left sides of the bus. They were also positioned to help operators, particularly where there was blocked or limited visibility, or where the object/vehicle was at higher risk. The five FOT buses each had bicycle racks on the front, but the front corner sensors were mounted in such a way that the racks did not interfere with their detection performance (see Figure 2-5).

Figure 2-5. Bicycle Rack Did Not Interfere with Front Corner Sensor

Figure 2-6. Right Front Corner Sensor (on Right) and First Right Side Sensor

Figure 2-7. Right Side Sensor Belt Prior to Rub Rail Installation

Figure 2-8. Rear-most Right Side Sensor and Rub Rail

2.1.4 Operation

The system was designed to give information in the form of lights and (with the most threatening detections) an audible alarm in the form of a chime during in-service close-maneuvering situations, slow speed turns, lane change and merge situations. The system was designed for forward speeds or stopped conditions; there was no provision for warnings while backing. The system was not designed, nor were the sensors arranged specifically, to detect pedestrians; the object detection system was never intended to be the primary means for determining presence of humans or animals around the bus.

The audible part of the alert (chime) was sensitive to what the driver is doing. For example, if the vehicle was stopped (bus speed zero), no chime was given. The audible alert was activated if the bus was moving and an object was detected in the closest zone on the side to which the turn signal was activated. The chime did not repeat as long as the same zone remained occupied. If the object went away and then came back, it triggered a new event.

2.1.5 Alert Criteria

As shown in Table 2-1, driver alert criteria vary according to proximity zone and operating mode. There are three threat levels (low, medium, and high) when the bus was operating below 45 mph and a single high threat level when operating above 45 mph. In the low threat level, the LED flashed two times per second, in line of sight with the object detected. At the medium threat level, there were four flashes per second. At the high threat level, the LED had a solid display (i.e., lit but not flashing) and the chime sounded twice.

Table 2-1. Driver Alert Criteria under Various Operating Conditions

Mode	Vehicle Speed*	Zone			Amber LED Flash Rate			Chime
		Near	Middle	Far	Near	Middle	Far	
Stopped	0 mph	1 ft.	2 ft.	4 ft.	Solid on	Fast	Slow	Silent
Urban Slow	<15 mph*	1 ft.	2 ft.	4 ft.	Solid on	Fast	Slow	If object in near zone with turn signal on
Urban Fast	15 - 45 mph*	2 ft.	4 ft.	8 ft.	Solid on	Fast	Slow	If object in near zone with turn signal on
Highway	45 – 50 mph*	0 – 8 ft.			Solid on			If object in zone with turn signal on

* A transition range occurs when going from Urban Slow to Urban Fast mode between 10 and 15 mph and when going from Urban Fast to Highway mode between 45 and 50 mph.

2.1.6 Operating Modes and Proximity Zones

There were four operating modes. In the stopped mode, low threat was defined as an object that was in a zone equal to or greater than four feet away, medium was two to four feet, and high was less than 1 foot. If the bus was operating in the urban slow mode (i.e., below 10 mph), the zones were four feet, two feet, and one foot respectively. If the bus was operating in the urban fast mode (i.e., more than 15 mph but less than 45 mph), the zones were eight feet, four feet, and two feet. If the bus was operating in the highway mode, there was only one detection zone, from zero to eight feet (see Table 2-1). The current zone sizes were based upon prior operator feedback and were capable of being changed through software adjustments, although they were not changed during the FOT.

2.1.7 Warning and Status Lights

Amber LEDs were warning lights that flashed two times per second (slow) if an object was detected in the far zone; four times per second (fast) if an object was detected in the middle zone; and a solid "on" if the object was in the closest zone. Blue LEDs (see Figure 2-1) were status lights; they flashed only if there was a problem with the system and never extinguished unless the system diagnosed itself as "unreliable." After the object was no longer detected in the respective zone, the amber LEDs only were extinguished. If a system failure occurred (which included the event of one sensor not being able to operate reliably), there was a warning code set to the blue LEDs and they would flash a code for two seconds, then all of the LEDs (including the amber) would go blank. The LEDs were designed to be visible in direct sunlight and were designed to be easy to see at night. They were focused and mounted so as to make them of little or no distraction to the driver while he or she was looking straight ahead; this was thought to be least disruptive to normal, safe driving habits.

2.1.8 Errors

There were several types of recoverable errors. Examples were check-sum errors, a blocked sensor, and high ambient noise. Examples of non-recoverable errors included a dead sensor or a broken communications line. The system was designed to perform in bad weather, within reason. Extreme winds at highway speeds could theoretically whip rain around and degrade system operation. Should that situation occur, the system was designed to flash the blue status lights on the displays to let the driver know it was unreliable. Then it resumed normal operation as soon as possible.

2.2 Research Plan

The research plan was designed to obtain information on the extent to which bus drivers found the EODS acceptable and useful under normal driving conditions. The test was performed on five EODS-equipped buses that were operated by 15 trained drivers over five primary and several secondary routes. The evaluation was based primarily on information gathered from interaction with the drivers, maintenance personnel, instructors, and managers associated with the FOT and did not include equipment such as a data acquisition system (DAS) or camera(s) to help correlate driver reaction with driving data or sensor detection outputs. The Port Authority was responsible for selecting the drivers and routes to be included in the FOT. The following discusses how the selections of both were made and provides information on the characteristics of the participating drivers and routes.

2.2.1 Driver Selection and Demographics

It was decided early in the FOT planning that the number of drivers trained and utilized for operations during the FOT would be kept to a reasonably small group. The evaluation team desired to restrict the number of drivers participating in the study in order to ensure that several drivers would have adequate experience during the relatively short three-month evaluation period. From a pool of volunteers, the Port Authority selected 15 drivers to be trained on the EODS and participate in the study. Two of the drivers were trained on the EODS but were in a standby category with respect to the FOT; they did not operate an EODS-equipped bus on a designated route during the 100-day period and thus did not participate in significant data collection activities. As shown in Table 2-2, the 15 drivers included ten males and five females between the ages of 31 and 54 who had between three and 24 years of service. Most of the drivers were members of Harmar Division's forum known as the "Quality Circle," which met periodically to discuss operational issues. The drivers from the Quality Circle accumulated the greatest experience and number of miles with the system on an individual basis.

Table 2-2. Driver Demographics

Driver Number*	Sex	Age	Years of Service	Member of Quality Circle?
1	F	48	3	Y
2	F	40	3	Y
3	M	43	4	Y
4	M	37	4	Y
5	F	31	5	Y
6	M	50	20	Y
7	M	54	22	Y
8	M	46	14	Y
9	M	42	13	Y
10	F	46	22	Y
11	M	47	10	Y
12	M	46	10	Y
13	M	41	10	Y
14	M	33	9	Y
15	F	53	24	Y
	10 male, 5 female	Average age: 43.8	Average service: 11.5 Years	15 of 15

*This numbering system is used instead of payroll number in order to protect the drivers' identities. This numbering system, using the same numbers for the drivers, is used in other tables.

Drivers were represented by the Local 85 Amalgamated Transit Union. Two operators represented the union on the FOT, one on the transportation side and one on the maintenance side.

2.2.2 Route Selection

The manager of the Harmar Garage selected the following routes to be assigned to the FOT buses:

- 71A Negley (59 mile run, starts 4:16 AM). Note: The Negley run is Harmar's auxiliary route for the FOT,
- 500 Highland Park-Bellevue (55 mile run, starts 4:57 AM),
- 74B Highland Park (59 mile run, starts 5:37 AM),
- 1A New Kensington (268 mile run due to continuous nature, starts 4:42 AM),
- 91A Butler Street (66 mile run, starts 4:42 AM).

They were selected to represent a variety of driving conditions, ranging from "urban slow," often with many turns, to "highway." Maps of these routes are provided in Appendix A. In addition to these routes, the buses were assigned as needed to alternate routes. This often occurred when drivers were assigned to split or multiple routes. Table 2-3 describes the characteristics of the primary and alternate routes to which the test buses were assigned.

Table 2-3. Route Characteristics

Route	Description
71A	Hills, turns, long stretches with no turns, then several tight turns. A fast-paced route through urban areas, with lots of patrons including some who use the bike rack. Must hustle to stay on schedule.
500	Long route with a lot of variety in characteristics, including a through route through a couple of neighborhoods.
74B	A lot of turns.
1A	Generally straight, not too many turns.
91A	Long, straight, a few tight areas.
91S	Similar to 91A, a few more turns.
73B	Express, generally straight.
NP	Express, straight in Parkway.
GC	Straight, express on Parkway, a few turns.
P/PG	Express on Busway, a few turns, frequent starts with a few turns on a hilly topography.

2.2.3 Driver and Route Assignments

Drivers were assigned routes by seniority in accordance with their preferences during the "pick" process. The drivers who operated EODS-equipped buses during the FOT drew their assignments as a result of the picks conducted on March 23 and June 15, 2003. During the March 23 pick, the Port Authority gave the drivers the yearly opportunity known as the "system pick," to transfer to a different Port Authority Division or to different routes within the Harmar Division. The drivers also had a chance every three months to pick runs within the same Port Authority division, and occasionally management requested some drivers to transfer to another division due to seniority issues. During the June 15 pick, which was the only one conducted during the FOT, only two drivers who had been trained decided to select non-FOT routes, so there was minimal lost experience as a result.

The same drivers did not operate the EODS-equipped buses throughout the entire 100-day FOT. This was largely due to the pick system, which was a pre-existing and fair arrangement for the drivers. The resulting turnover was very small and did not adversely affect the evaluation. Drivers on the FOT did not drive the same vehicle during the FOT nor did they drive the same route. These factors were not evaluated as adverse to the evaluation goal and objectives, however. Several drivers were assigned to each of the five runs identified for the FOT. A driver might operate an EODS-equipped bus one day and operate a non-equipped bus the next day. The driver could be on a different route from one day to the next, but generally remained on that particular run for the duration of the FOT. Table 2-4 shows the number of days on which each driver was assigned to a particular route during the FOT. The average speed of each route is also presented along with the designated driving mode.

The routes were selected because they contained a mixture of features, ranging from urban corridors to more rural areas, flat and hilly sections, straight and curving roads, and heavy stop-and-go traffic as well as highway speeds. These FOT runs were regular (not specially-configured) Harmar routes. The buses typically covered about 60 miles during a run, which was typically eight to 10 hours long. Some runs were "split runs," meaning for example that they may have operated four hours in the morning and five in the afternoon. Some runs were "straights," meaning they operated all day. There were also runs that started early and finished early. Some drivers worked a split route, in which they would operate on an FOT route half of the day and on a non-FOT route the other half.

The most challenging of the five FOT routes was considered to be 71A (Negley). This route was the most congested of all, with many vehicles and many pedestrians on the route. Its geometry was also challenging. Many passengers rode 71A buses, which were dispatched every four minutes as opposed to much longer intervals with some other FOT routes.

Table 2-4. Route Assignments

Driver	Route											Total Days
	71A	500	74B	1A	91A	91S	73B	NP	GC	P/PG	other	
1	3				3							6
3											1	1
4	8										2	10
7		7	27									34
8									6		8	14
9	2	8			12		20				1	43
10				27							1	28
11	12	10										22
12					10	6		5			1	22
13	6	3			5					3		17
14		9		17							2	28
15	26											26
Others											24	24
Total Trips	57	37	27	44	30	6	20	5	6	3	40	275
Avg Speed (mph)	13	14	13	18	25	25	27	27	23	27		
Driving Mode	Urban Slow			Urban Fast			Highway					

2.3 Operational Factors Affecting the FOT

While every consideration was given to exercising control over variables in the evaluation's experimental design, there are always operational issues that can affect the day-to-day conduct of an evaluation and its eventual outcome. A number of factors that were part of the operational setting of this evaluation are discussed below, including the efforts of the host agency, the drivers' selection and training, route characteristics and assignment, and weather.

2.3.1 Harmar Division and Port Authority Support of the FOT and Evaluation

The Harmar Division is located approximately 12 miles northeast of downtown Pittsburgh, along the Allegheny River in the community of Harmarville. At the time of the FOT, the Harmar Division garaged 202 buses and their buses accumulated nearly 550,000 miles per month. There were 268 drivers, both male and female, at the Harmar Division and they varied widely in age and experience. There was very little turnover within their ranks, with perhaps only 10 of the 268 Harmar Division drivers leaving the Port Authority in a year.

After the FOT routes were selected, Harmar Management advertised the opportunity for drivers to participate in the FOT. They put together a training plan and instructor team, and they ensured that the drivers selected received both classroom as well as hands-on operational training. They made drivers, instructors, maintenance personnel, and their own management available for evaluation needs. They supplied facilities for the Quality Circle meetings and took minutes which they later published. They provided private rooms in which the drivers and maintenance personnel were interviewed. They also provided access to two computers on which the drivers and maintenance personnel took the Internet surveys.

2.3.2 Driver Training

The training plan included having two Harmar Division instructors train other instructors in the operation of the system. The instructors in turn trained the drivers. The Harmar Division printed handouts for the drivers that gave an overview of the object detection system technologies (with diagrams and pictures), covered key aspects of their operation, and anticipated frequently asked questions about the technologies by providing answers to those questions. They also prepared laminated cards for the drivers with color pictures and text that described the audible operation, modes and zones description, and LED operation. Harmar management produced a training video that covered the background of the FOT as well as the placement, characteristics, and operation of the EODS.

Clever Devices representatives and Harmar instructors took one of the EODS-equipped buses for a test ride on March 31. Instructors qualified the selected operators and maintenance personnel on the EODS during April 1-2, and qualified management on April 3. The EODS system was put into service the following day.

2.3.3 Rain

There was heavy rain early in the FOT. Drivers perceived that the rain caused the system to make false detections, especially at highway speeds. As a result, Clever Devices staff realized that a change in the operational code had allowed the front corner sensors to remain enabled at highway speeds. They re-programmed the controller so that the two front corner sensors would be desensitized when the bus was traveling 45 mph or faster. As will be seen in Section 5, there was not unanimous agreement among the drivers whether this design change reduced the level of false detections due to rain. However, the wind-induced problems generated from these two front-corner sensors at highway speeds was verified by Harmar maintenance and Clever Devices staff.

3.0 EVALUATION GOAL

The USDOT requested that the scope of this evaluation effort be limited to achieving a single goal: *Assess driver response to and acceptance of the EODS.* Although the evaluation addresses topics such as driver training, outreach, institutional issues, safety, and system performance - from the drivers' perspective – the principal evaluation tools were driver interviews, focus groups, and questionnaires. The evaluation did not include system validation or performance assessment, nor did it include a quantitative assessment of safety benefits. Supplemental data such as reports of accidents involving the test vehicles and maintenance information were incorporated into the evaluation if they were available; however, quantitative assessments of safety benefits and maintenance requirements were not conducted as part of this evaluation. With the limited number of vehicles and relatively brief test period, USDOT realized they could not obtain sufficient accident data or cost information, so they focused on driver perception.

3.1 Process of Establishing and Prioritizing FOT Objectives

The evaluation planning process officially began in December 2002 with a series of conference calls with the FOT partners and site visits to the Harmar Garage. On December 18, 2002 members of the Battelle evaluation team attended a meeting of the EODS Quality Assurance Circle. Battelle's Evaluation Task Leader gave a presentation that described Battelle's role as the Independent Evaluator, an overview of the evaluation planning approach, and what should be expected from the Battelle/TRA/CJI Evaluation Team. An evaluation workshop was held on January 9, 2003. Key stakeholder groups involved in the FOT participated.

The evaluation workshop was conducted to achieve a common understanding of the technology being deployed, define roles and responsibilities, clarify the research design and schedule, reach a consensus on evaluation goals and priorities, and identify sources of data. The remainder of this section summarizes the results of the workshop, which are provided in Appendix B.

Workshop participants included 13 individuals from the Port Authority; three from the Battelle Evaluation Team; and one representative each from Mitretek (representing the Federal Transit Administration), Clever Devices, and CMU. Table 3-1 lists the workshop participants along with their respective roles in the FOT. The Port Authority did an outstanding job of bringing together a group of individuals that represented diverse perspectives on issues affecting the FOT.

Following introductions and a brief discussion of logistical issues by Robin Rochez, Director of Service Delivery at the Harmar Garage, an educational video on the EODS was played for the participants. Lloyd Miller of Clever Devices joined the meeting via conference call to describe key features of the EODS. Particular attention was given to describing the algorithms by which the EODS provided alerts to the driver under different driving conditions. Mr. Miller also described the errors that might occur and how the drivers would know if the system was not working. He concluded with an update on the schedule for deployment and training.

Table 3-1. Participants in the January 9, 2003 Evaluation Workshop

Organization	Participant	FOT Role
Battelle	Bill Tate John Orban	Evaluation Task Leader Evaluation Technical Leader
Transportation Research Associates (sub to Battelle)	Tom Luglio	Evaluation Coordinator
Clever Devices	Lloyd Miller (by phone)	Technology Developer
Port Authority	Dan DeBone Kathy Radkoff Rick Snyder Robin Rochez Scott Kovaly Lisa Arenth George Radich Mike Zamiska Joe Paradise Tim Murray Mike Sedlacek Tim Gates Nicole Ford	Project Administrator Deputy Project Administrator Technical Support Director – Project Coordinator Maintenance Manager Supervisor, Instructor QA Specialist Safety Director Operator, Union Represent. Operator Operator Operator Operator
Mitretek	Jim Foley	Representative of FTA
Carnegie-Mellon University	Aaron Steinfeld	Technology Support, Liaison to Integrated CWS Team

Battelle's Evaluation Technical Leader gave a brief overview of what to expect from the evaluation, including roles and responsibilities of the independent evaluator and the partners. The rest of the evaluation workshop was divided into three parts aimed at answering the following questions:

- What are the expected outcomes of deploying EODS?
- What are the desired evaluation objectives related to driver reactions? (i.e., what do the participants/partners want to learn from this FOT?)
- What are the data requirements and proposed evaluation methods?

With regard to the expected outcomes, each participant was asked to describe any benefits, problems, issues, or changes in operations that might occur with the deployment of EODS. Participants took turns listing one or two items. The purpose of this exercise was to promote discussion and bring out different perspectives on the possible positive and negative impacts of deploying the system. This led to the next workshop exercise, which focused on identifying evaluation objectives and discussing what could be learned from the evaluation. Again, the participants were asked to contribute ideas one at a time. Results of these exercises were posted on the walls of the conference room for everyone to see.

The next phase of the discussion involved organizing these ideas into logical categories that were used to define evaluation objectives. The following categories of topics were suggested:

- System usability (including issues related to understanding, training, and perceptions of usefulness)
- Driver workload and stress
- Driver behavior and risk-taking
- Value of the system to the driver
- Driver perceptions of quality and how the system can be improved
- Effect of system reliability and maintenance on driver acceptance
- Institutional issues and public perceptions

An attempt was made to establish relative priorities for these topics; but after some discussion no one area emerged as being more important than the others. Besides, the general consensus was that all of the topics could be addressed within the scope and resources of this evaluation. The specific objectives related to these objectives are presented in the following section.

The remainder of the workshop focused on the research design, identification of data sources, schedules, and roles and responsibilities. Following the workshop, Battelle prepared a detailed evaluation plan (Battelle, 2003) that was reviewed and approved by all stakeholders. A summary of the proposed approach is presented in Section 4.

3.2 FOT Objectives and Measures

The single goal of this evaluation was to assess driver reactions to, and acceptance of, the EODS under normal transit operations. Seven objectives were identified. Each is discussed below. Driver responses to interviews and questionnaires were the key measures used to determine whether these objectives were met. Supplementary measures derived from maintenance data were used in conjunction with interview data to address certain objectives.

Objective 1. Determine the Usability of the System Under Normal Driving Conditions

This objective focuses on how the EODS is used and understood by the drivers. In particular it assesses the drivers' understanding of the system's audio and visual signals, perceptions of consistency and robustness, how the information is presented to the driver, ease of use, and adequacy of training. Specific hypotheses to be tested are:

- Drivers find the EODS and components easy to learn.
- Drivers believe that they are adequately trained to use the system.
- Drivers find the EODS and components easy to use and control.
- Drivers understand the EODS capabilities.

- Drivers perceive that the EODS signals are recognizable and easy to see or hear.
- Drivers understand how to use information from the EODS.

Objective 2. Determine How the EODS Affects the Driving Environment and Driver Workload

This objective focuses on how the EODS affects the driving environment. Of particular interest are the effects of false alarms and the impacts on driver workload. Specific hypotheses to be tested are:

- Drivers perceive that the EODS reduces their driving workload.
- Drivers perceive that the EODS reduces their levels of stress or fatigue.
- Drivers perceive that the EODS does not distract them or interfere with their other tasks.
- Drivers perceive that the EODS false positive alarms are a nuisance.
- Drivers perceive that the EODS false negative alarms degrade their confidence in the systems.
- Drivers perceive that there are too many false positive alarms
- Questions about EODS from riders will create distractions for the drivers.

Objective 3. Determine if Driver Behaviors are Affected by the Use of EODS

This objective is concerned with learning whether drivers using EODS perceive a change in driving behaviors, especially those related to risk taking and vigilance. Specific hypotheses to be tested are:

- Drivers using EODS are aware that they take fewer risks than drivers without the system, because they have a greater awareness of potential safety hazards.
- Drivers using EODS are aware that they are more vigilant in their driving behavior, because of the feedback provided by the system.
- Drivers perceive that they become dependent on the EODS over time, which degrades their safety-related driving performance when driving vehicles without the system.
- Drivers are aware that they modify their driving behavior (speed, braking, lane keeping, turn signal usage) for particular reasons (to be determined) in response to the EODS.

Objective 4. Determine if Drivers Value the EODS and Believe that it is Effective for Improving Safety

This objective addresses driver perceptions of effectiveness and, therefore, their degree of satisfaction with the system. Specific hypotheses to be tested are:

- Drivers perceive that the EODS is effective under specific (if not all) driving conditions.
- Drivers trust the EODS and perceive it is useful.
- Drivers perceive that the EODS will help avoid accidents.
- EODS enhances drivers' abilities.
- EODS increases job satisfaction of drivers.
- Drivers prefer to use the system.

Objective 5. Determine Drivers' and Mechanics' Perceptions of System Quality and Recommendations for System Improvement

Information on the perceived quality, value, and maturity of the EODS from the perspective of the drivers and mechanics will be obtained. Specific hypotheses to be tested are:

- Drivers have recommendations for changes that might improve the performance or functionality of the EODS. (Examples include location, brightness, flashing rate, and size of lights; and duration, type, uniqueness, and loudness of chimes).
- Drivers have recommendations for changes that might make it easier to use or learn how to use the EODS.
- Drivers have recommendations that might reduce false alarm rates.
- Mechanics have recommendations for improving the reliability of components.

Objective 6. Determine if Driver Acceptance is Affected by Maintenance Requirements

This objective addresses whether system reliability and maintenance requirements affect driver acceptance. Maintenance data collected by the Port Authority will be compared with driver interview and survey results. Specific hypotheses to be tested are:

- Drivers perceive that the failure rate of the EODS is too high.
- System failures degrade the drivers' confidence in the system.
- System failures occur under certain conditions.

Objective 7. Identify Institutional Barriers and Benefits Related to Driver Acceptance

Institutional issues that might create barriers to deployment or produce indirect benefits will be identified. Specific hypotheses to be tested are:

- Drivers perceive that the EODS invades their privacy.
- Testing of this technology will improve communications between drivers and management.
- Drivers perceive that EODS improves the public's perception of the Port Authority.
- EODS will improve driver training.
- EODS will make it easier to test and deploy other new technologies.

4.0 EVALUATION APPROACH

This chapter describes the technical approach that was taken. Section 4.1 contains a brief overview of the methodology, the role of each type of data, and the schedule for data collection. More detailed descriptions of the data collection plans are presented in Section 4.2 and the data analysis and reporting plans are presented in Section 4.3.

4.1 Overview

Consistent with the goal of assessing driver acceptance of the EODS, the principal evaluation tools were personal interviews and Internet surveys. Additional sources of data include daily questionnaires, minutes from the periodic Quality Circle meetings, and maintenance records. Table 4-1 illustrates the role and relative importance of each data sources for obtaining background information and addressing each of the evaluation objectives. These data sources, as well as supplemental/operational data obtained from the Harmar staff, are described below.

Table 4-1. Sources of Data for Addressing Evaluation Objectives

	Data Source					
Objectives	**Baseline Interview**	**Daily Question-naires**	**Internet Surveys**	**Quality Circle Meetings**	**Final Interview**	**Mainte-nance Data**
Background Information	**P**					
1. Usability	**P**	**S**	**P**	**S**	**S**	
2. Driver Workload	**Expectations**	**S**	**P**	**S**	**P**	
3. Driver Behavior	**Expectations**	**S**	**P**		**P**	
4. Perceived Value			**S**		**P**	
5. Perceived Quality			**S**	**P**	**P**	**S**
6. Maintenance Issues		**P**		**P**	**S**	**P**
7. Institutional Issues/Benefits	**Expectations & Concerns**			**P**	**P**	

P = primary source of data for addressing a specific objective
S = secondary source of data

The **Baseline interview** was conducted shortly after training was completed and the EODS was activated on the bus. The purpose of the baseline interview was to obtain background information on each driver, determine their level of comfort with new technology in general and their initial understanding of how the EODS worked, and establish initial expectations on how the EODS would affect their workload and driving behavior. The interviewer's guide for the baseline interviews is presented in Appendix C.

Daily questionnaires (see Appendix D) were used to monitor the perceived frequency of high-level alarms and the conditions under which they occurred. They were also important for characterizing the role of the EODS in helping drivers deal with significant safety events.

Two **Internet surveys** were used to quantify the drivers' perceptions of system usability and its impact on their workload and behavior. The questions were essentially the same between the first and second Internet surveys, in order to characterize changes in driver perceptions during the 100-day FOT. Due to the similarity of the questions, only the pages from the final Internet survey are included in Appendix E.

Three periodic **Harmar Division Quality Circle Meetings** during the FOT, conducted by the Port Authority approximately six weeks apart, provided an opportunity to monitor driver attitudes on a more frequent basis and to obtain valuable information on system performance and institutional issues that developed during the test. The evaluation team attended two of the meetings as observers, participated via telephone conference in one, and received the minutes of each meeting from the Port Authority.

The **final interview** explored in depth the drivers' perceptions of the system's impacts on workload and behaviors and the value that they placed on the system. Perceptions of system quality and driver recommendations for improvements were investigated. Also, drivers were asked to elaborate on any institutional issues or benefits that were identified during the test. The interviewer's guide for the final interview is presented in Appendix F.

If the driver perceived that the EODS was not working properly, he or she completed an **EODS Maintenance Evaluation Survey** (see Appendix G), which resulted in appropriate maintenance action. Even though this maintenance evaluation did not specifically address system performance and reliability, the maintenance data collected by Port Authority were compiled and summarized to help explain driver perceptions of system quality and the impact system maintenance and reliability issues had on driver acceptance.

Supplemental Data Sources included EODS engineering design updates, driver background information, mileage accumulations, and a database of drivers/buses/route numbers that proved very useful for data collection and manipulation.

The data collection schedule for this FOT is shown in Table 4-2.

Table 4-2. Data Collection Schedule

Data Source	Month: April (note 1)	May	June	July (note 2)
Baseline Interview	X			
Daily Questionnaires	→	→	→	→
First Internet Survey			X–X	
Second Internet Survey				X X
Quality Circle Meetings	X		X	X
Final Interview				X X
Maintenance Data	→	→	→	→

Note: (1) The FOT began April 7, 2003.
(2) The FOT's 100-day data collection period ended on July 11, 2003.

4.2 Databases and Data Collection Instruments

This section describes the various types of data that were collected during the FOT. Table 4-3 presents an overview of the activity and amount of data available from each of the 15 drivers participating in the study. For example, the driver/vehicle scheduling databases was used to determine the number of days on which each driver was scheduled to operate one of the five test vehicles. Average route distances were then used to determine the scheduled number of test miles for each driver. Because some of the drivers were designated substitutes, the number of scheduled days and miles may not accurately depict their level of experience with the test vehicles. To supplement this information we calculated the number of "activity days," defined as the number of days on which the driver was either scheduled to operate a test vehicle or completed a daily questionnaire or maintenance report. This information is presented by month.

Table 4-3 also provides information concerning the drivers' participation in the personal interviews, Internet surveys, and quality circles. Each type of data is discussed in more detail below.

Table 4-3. Data Collection Summary

Driver Number	Number of Activity Days*					Number of				Initial Internet Survey	Final Internet Survey	Initial Interview	Final Interview	Took Part in Quality Circle?
	April	May	June	July	Total	Scheduled Days	Scheduled Miles	Daily Questionnaires	Maintenance Reports					
1	4	3			7			7	1	X	X	X	X	X
2										X				X
3	1	1			2	1	75	2	1	X	X	X	X	X
4	1	5	5		11	9	429	4	3	X	X	X		X
5	1				1			1		X		X		X
6										X	X	X	X	X
7	1	9	18	3	31	27	1,998	23	13	X	X	X	X	X
8			8	4	12	11	1,002	8			X		X	X
9	7	9	12	1	29	24	2,614	16	4	X	X	X	X	X
10	3	11	17	5	36	28	1,790	23	19	X	X	X	X	X
11	4	9	4		17	15	1,159	10	1	X	X	X	X	X
12	3	8	4	3	18	15	1,465	10	14	X	X	X	X	X
13	1	4	8		13	13	726			X	X	X	X	X
14	4	10	14	3	31	28	1,939	12		X		X		X
15	5	8	12	4	29	26	1,689	19	7	X	X	X	X	X
Total	35	77	102	23	237	197	14,886	135	63	14	12	13	11	15

* Days for which driver was scheduled to drive or submitted a daily questionnaire or maintenance report

4.2.1 Daily Questionnaires

The Battelle evaluation team in conjunction with Harmar staff designed a questionnaire that was completed daily by each driver (see Appendix D). This questionnaire was designed to capture any significant driving events that occurred during a particular route. In particular, it was used to monitor the frequency of high-level alarms and the conditions under which they occurred, such as what caused the alarm and what the bus was doing at the time. Driver-perceived maintenance issues were also noted on the daily questionnaires. A total of 135 daily questionnaires were completed by 12 drivers participating in the FOT. Guidance for filling out these questionnaires was discussed on-site with lead instructors as part of the scheduled driver training, and the questionnaire forms also had directions.

4.2.2 Interviews

Interviews were conducted by two evaluation team members, Tom Luglio of TRA and Dr. Hugh Clark of CJI Research Associates. Mr. Luglio is experienced in transit operations. He was the evaluation leader for the field test involving 100 buses with the Clever Devices Gen1 object detection system. This test was conducted at the Port Authority's East Liberty Garage in 1999-2002. Dr. Clark is a trained interviewer with extensive experience in the transit industry. He has worked extensively with Battelle on the evaluation of the IVI commercial vehicle FOTs. Dr. Chris Cluett and Dr. John Orban of Battelle assisted with design and QA of the interview outlines and the subsequent analysis of interview data. The interviews were qualitative in nature, which allowed the interviewers to probe a particular point or ask associated questions that were not scripted.

Interviews were conducted in private rooms at the Harmar Garage. Each driver was interviewed privately for approximately 30 minutes, with no observers permitted. The interviewers emphasized that drivers' participation in the evaluation interviews and surveys was voluntary and no participant need feel compelled to take part. Information gathered was and is confidential and is only presented in summary form. The evaluation team audiotaped interviews, but names were deleted and the tapes were not shared with management. The respondents were encouraged to say when they wanted to turn the recorder off (but none did). Interview guides were prepared in advance (see Appendix C for the interview guide designed for the baseline interview); however, interviewers were free to explore important topics that arose during the interview. Most of the questions in the baseline and final interviews were open-ended, which encouraged the drivers to express their feelings openly and without a restrictive structure.

4.2.3 Internet Surveys

The evaluation team developed an Internet survey to obtain more quantitative information on driver attitudes and opinions concerning the EODS. The survey was administered twice: once near the mid-point of the FOT and once at the end. Most of the questions could be answered using an ordinal scale related to level of agreement with specific statements or perceived usefulness of EODS features. Except for a couple of introductory questions, both surveys included the same set of questions in order to evaluate changes in driver attitudes. In developing the questionnaire, the evaluation team conducted pilot tests with a few drivers and others not assigned to the FOT to make sure questions were understood and the Internet communications were working. The Harmar Division arranged for drivers to have access to computer terminals at the garage. The drivers were given instructions on the use of this evaluation tool. Each of the two Internet surveys required approximately 20 minutes to complete. Nearly all drivers completed both Internet surveys.

The interview and Internet survey dates and their purposes are presented in Table 4-4.

Table 4-4. Interviews and Internet Surveys Conducted

Data Collection Method	Dates of Implementation	Purpose
First Interview	April 7, 2003	Gather baseline driver and maintenance person attitudes, perceptions and expectations of the systems.
First Survey	June 2-5, 2003	Gather baseline information from the drivers on their experiences with technology and their expectations of the systems.
Second Survey	July 15 and 30, 2003	Gather information after deployment of the IVSS technologies regarding driver uses of these systems, effects on driving behavior, and perceptions of benefits.
Second Interview	July 15 and 30, 2003	Gather qualitative information on driver and maintenance person acceptance of IVSS, and an understanding of any changes in their attitudes and perceptions.

4.2.4 Harmar Division Driver/Vehicle/Route Scheduling Data

Harmar personnel provided to Battelle a master Access database populated with 301 driving assignments involving the five test buses during the 100-day field test. The database linked driver ID (payroll number), route number, and bus number for each driving assignment. These data were used to characterize the level of experience each driver had with the EODS and on which routes they used the test buses.

4.2.5 Maintenance Data

The evaluation team needed to understand and control for any maintenance factors that may have influenced bus performance or driver performance. In addition to noting any maintenance items on the daily questionnaires, the drivers were instructed to fill out an "Object Detection System Maintenance Evaluation Report" whenever they felt that the EODS required maintenance. Then, for each report submitted, the Harmar Garage maintenance personnel compiled all data related to that entry and its resulting maintenance actions (if any). The information was made available to the evaluation team to help interpret the findings of their maintenance actions. An Excel database was prepared to summarize the maintenance data from a total of 63 maintenance complaints. The reader is reminded that this was a prototype (i.e., non-production-ready) system, and operators tended to submit these reports based on whether the system performed up to their expectations, which may not have coincided with actual maintenance problems).

Maintenance data from this master database were also associated by payroll number or bus number. This detailed record of which drivers were assigned to which buses and routes on which days and times was needed to be able to catalog and track all "events," including EODS warnings issued, collisions avoided or collisions experienced, and the overall performance of the EODS on each bus. Having the route assignment data helped link the analysis relationships between road events, EODS alerts, and location to driver responses. Thus, this master database proved extremely useful to the evaluation efforts, complementing the data that the Evaluation team derived from the in-person interviews and Internet surveys. For example, Table 4-5 illustrates the breakdown of trip days and maintenance days per bus and by month, with a ratio calculated for maintenance time.

4.2.6 Harmar Division Quality Circle Meetings

The Quality Circle was a planned forum that met three times during the course of the FOT. A typical meeting involved:

- Twelve (12) drivers of the EODS-equipped buses (including a union representative),
- One (1) EODS-trained maintenance representative,
- Director of Harmar Maintenance,
- Four (4) FOT instructors,
- Harmar Division Director,
- Two (2) Port Authority management representatives,
- One (1) Clever Devices representative,
- Two (2) Independent evaluator team representatives, and
- One (1) Integrated Collision Warning System program representative.

The Quality Circle convened during the FOT at six week intervals. They met on April 22, primarily to review vehicle operational and driver questionnaire comments and maintenance feedback forms; June 4, primarily to review vehicle operational and driver questionnaire comments, the Internet survey, and a CMU update on IVI Phase III efforts; and July 16, the final meeting, held one day after the final interview and Internet survey. All participants had the right to voice their opinions and were encouraged to do so. On topics of particular importance, the facilitator would go around the room to get the perspective of everyone involved. Teleconferencing was sometimes used by participants who were outside of the Pittsburgh area. Detailed minutes were recorded and later distributed to all involved.

Table 4-5. Bus Activity and Maintenance Summary

	April		May		June		July		Total		
Bus Number	Trip Days	Maintenance Days	Trip Days	Maintenance Days	Trip Days	Maintenance Days	Trip Days	Maintenance Days	Trip Days	Maintenance Days	Ratio
5152	4	2	12	11	16	6	4	2	36	21	58%
5153	4	3	9	6	19	7	1	2	33	18	55%
5154	5	1	10	4	17	6	3	0	35	11	31%
5156	7	3	14	2	18	3	3	1	42	9	21%
5158	2	1	7	3	1	0	0	0	10	4	40%
Total	22	10	52	26	71	22	11	5	156	63	40%

Trip Days = Number of days on which the bus was scheduled to be operated

Maintenance Days = Number of days on which at least one maintenance report was completed

4.2.7 Supplemental Data Sources

<u>EODS Engineering Design Updates</u>
The two design actions were taken around May 12, approximately one-third into the FOT period. These actions involved (1) installing a muffler on the buses' air brake purge valves to solve the problem of similar-frequency noise causing the EODS to fail, and (2) making a software change that disengaged the sensor readings from the front corner sensors at high speed, to solve the problem of wind-induced detections. Clever Devices provided descriptions of these changes to Harmar management and the evaluation team and provided the engineering diagram for the muffler.

<u>Driver Background Data</u>
Basic demographic and driving history data were obtained for the drivers who participated in this evaluation. These data included such driver characteristics as age, sex, and years of driving experience in comparable vehicles. These data were treated with complete confidence, and after review were maintained in company records, which will be destroyed. Battelle maintained the non-sensitive data in its database, and protected the confidentiality of all data so maintained.

<u>Mileage Accumulation</u>
Mileage records were maintained for all the test buses and for each of the drivers participating in the evaluation. Mileage is a measure of "exposure" to the risk of receiving a warning alert, or being subject to an incident or accident. All other factors being equal, the more exposure the higher the probability of a relevant event occurring during this evaluation. Driver mileage with the EODS system was also a measure of experience, with the assumption that more experienced drivers may have different outcomes with the technology than the less experienced drivers. Driver mileage was derived from the driver logs and daily bus mileage was recorded off the bus odometer at the end of each day. These data were provided to the evaluator by the Harmar Division and maintained in the project database for analysis.

<u>Incidents/Accidents/Police Reports</u>
No incident, accident, or police reports relevant to the FOT were recorded. If such events would have occurred, they would have been recorded and maintained in the evaluation database. Accidents and police reports generally adhered to a common format, but incidents would need to be defined and clear indicators developed and maintained. For example, one driver may consider an incident to be a more ordinary occurrence than another driver would. Only incidents relevant to the side collision warning system would be identified for data collection. Battelle would maintain these records in the project database.

4.3 Analysis Methods

The data on driver acceptance that were collected by the various evaluation tools (questionnaires, surveys, interviews, and focus group discussions) were tabulated, analyzed, and reported in accordance with the evaluation objectives. The analysis merged data from a variety of sources to interpret driver acceptance of this new bus safety technology. Findings from each component of the evaluation were merged into overall analyses addressed to each of the evaluation objectives.

Data from the daily questionnaires and from the Internet surveys were examined for statistical trends and patterns that reflected the effect of such factors as changes in driver experience with the systems, driver attitudes toward new technologies, and contextual factors that included changing daily driving and route conditions. Analysis of the maintenance evaluation surveys were examined to reveal any systematic effects of maintenance issues.

The two Internet surveys provided opportunities to conduct more quantitative analyses of driver acceptance. Because most of the questions on both surveys (nearly all of the questions were identical) produced ordinal responses that represented the drivers' opinions concerning the usefulness of particular EODS components or the level of agreement with a statement, it was possible to apply statistical analyses to characterize the uncertainty of average responses and determine if changes in average responses are statistically significant. We began by assigning a score to each response as follows:

Usefulness Response	Agreement Response	Score
Not at all useful	Strongly disagree	-100
Not very useful	Disagree	-50
Uncertain (Neutral)	Neither agree nor disagree	0
Somewhat useful	Agree	50
Very useful	Strongly agree	100

Although in some cases it is useful to analyze percentages of drivers who responded in a particular manner (e.g., percent that agree or strongly agree), we used the average score as a general measure of drivers' perceived usefulness or level of agreement. This made it easy to look for trends when evaluating driver responses to a series of questions related to specific objectives or hypotheses, or comparing responses to the same question at the beginning and end of the operational test.

Appendix E contains a complete summary of the responses to the two Internet surveys. Results are presented in the same order in which the questions were asked. Because we are interested in comparing driver responses between the two surveys, the analysis is performed only for ten drivers who completed both surveys. One additional driver who completed both surveys was eliminated because it did not appear that the driver had adequate experience using the EODS. (The driver was not scheduled to drive the test buses and did not submit daily questionnaires or maintenance reports.) To characterize the statistical uncertainty in the average score, we calculated a 95 percent confidence interval for each average. A confidence interval, presented as error bars in the figures shown in Section 5 (See, for example, Figure 5-1), represents the range of values that the average score would occur 95 percent of the time if the question were asked of another representative sample of 10 drivers. Thus, for example, if we observed an average score of 75 with a 95 percent confidence interval of 65 to 85, we can conclude that the average response is positive (score greater than zero), even though it was possible that one or more drivers submitted a negative response (i.e., disagreed with the statement). The summary in Appendix E also displays the difference in scores between the initial and final survey, along with an associated "uncertainty" or 95 percent error bound on the estimated difference. If the uncertainty in the estimated difference is less than the absolute difference in scores, one can conclude with 95 percent confidence that was a significant change in driver response. Due to the small sample size (10 drivers) we did not find many statistically significant changes. Nevertheless, it is still important to consider the statistical uncertainty in the data when interpreting the data. Standard Normal distribution methods were used to calculate the confidence intervals. The uncertainties in the estimated differences were determined using a paired comparison approach.

The quantitative results were integrated with the more qualitative findings from the baseline and final interviews and presented in order of the evaluation objectives. The final interview, which was conducted after analyzing data from the daily questionnaires and initial Internet survey, extracted explanatory information related to the statistical summarization. For example, the interviewers asked the drivers to explain attitudes that were expressed in the surveys.

5.0 EVALUATION FINDINGS

We begin the presentation of findings with a background discussion in Section 5.1 on the drivers' general familiarity and comfort with high technology devices and their initial reactions to the EODS. Then, Sections 5.2 through 5.8 present our findings related to the seven research objectives outlined in Section 3.

5.1 Drivers' Technology Experience and Initial Reactions to the EODS

As a group, the bus operators brought to their experiences with EODS no particular bias toward the use of high-tech equipment. They are not early adopters of technology, but neither did they bring a notably anti-high tech bias. At the outset of the test, the drivers tended to take a wait-and-see attitude. The following discussions present important background information on the drivers' general familiarity with high technology devices and their initial reactions to the EODS and its potential usefulness.

Familiarity with High Technology Devices

> The bus drivers are not early adopters of technology, but neither did they bring a notably anti-high tech bias.

The drivers tended to have had limited previous experience with high-tech equipment. One had used computers professionally in a previous job. Most have a home computer, though all but two claimed only a modest knowledge of how to use it. As shown in Figure 5-1[6], the drivers agreed at both the initial and final Internet surveys with the statements that they are comfortable with high technology devices in general and, in particular, with having such devices on their buses. In fact, their level of agreement concerning the use of devices on their bus tended to increase during the test[7], though this difference was not statistically significant. This is an indication that in spite of the developmental nature of the EODS, the drivers were comfortable with having such systems aboard their buses.

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[6] Each bar represents the average rating of agreement with the indicated statement at the time of the initial or final Internet survey. Rating assigned as follows: strongly disagree = -100, disagree = -50, agree = 50, strongly agree = 100. Data provide only for 10 drivers who completed both Internet surveys and had a minimum level of experience using the EODS. Error bars represent 95% confidence intervals on the average rating. See Section 4.3 for a more complete discussion of the data analysis approach.

[7] Initially, nine out of the ten drivers who completed both internet surveys agreed that they were comfortable with such devices on the bus. One driver was neutral. However, in the final survey, eight agreed and two strongly agreed with that statement.

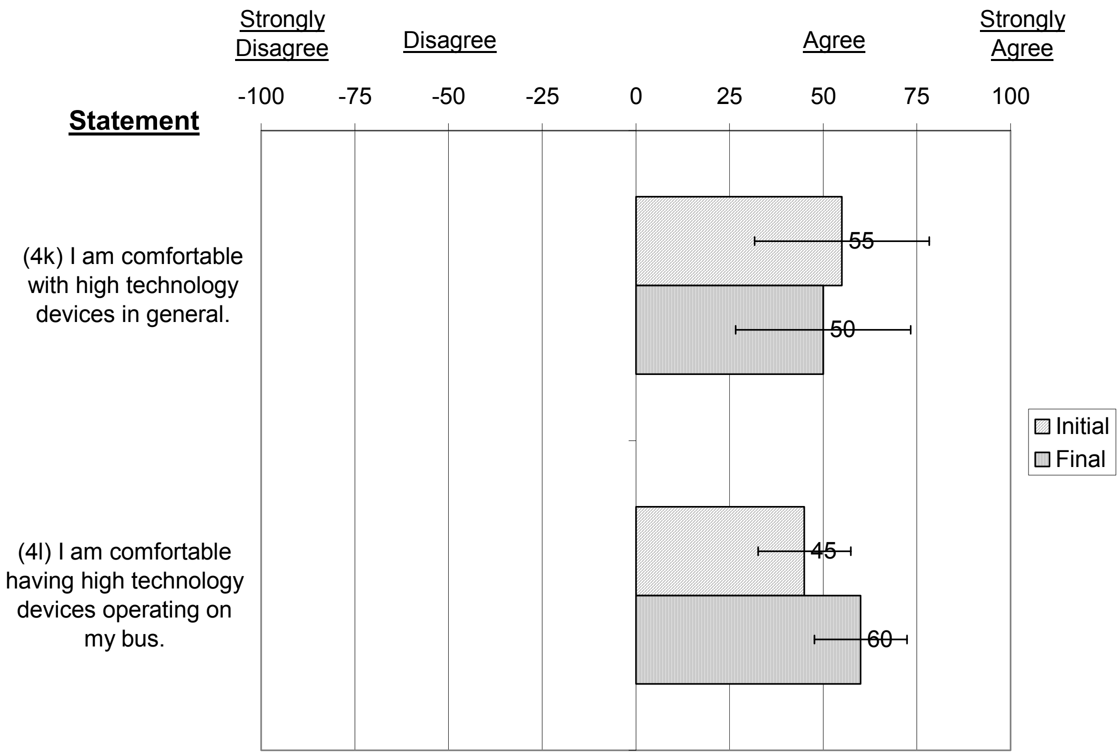

Figure 5-1. Driver Comfort with High Technology Devices

Note: "Initial" and "Final" refer to results from the first and second Internet surveys, respectively.

Thus the operators did not seem to bring to the experiment either a pro high-tech bias or an anti high-tech bias to the field test. The only notable source of potential bias involves the prior use of the "stop-calling" system which is used aboard the Port Authority buses to announce stops in compliance with requirements of the American with Disabilities Act (ADA). Some operators were aware that Clever Devices manufactures the stop-calling system. While some said that that the stop-calling system worked well, several commented that it suffered from maintenance problems, and consequently was shut down quite often. To those who mentioned this device, the fact that Clever Devices also produces the side object detection system made them approach the new warning system with cool deliberation rather than embracing it as a new and "neat" high-tech system. However, their skepticism about the stop-calling system did not appear to bias their opinions of the EODS.

An additional device-related reason for caution on the part of some drivers to embrace the EODS was the issue of the earlier version of the object detection system trial at the East Liberty Garage. Drivers who participated in that test felt that the earlier version suffered from various shortcomings. This resulted in additional caution about embracing the new system among those who drove with the earlier version or who have close friends who did.

Often in groups of persons selected for technology product tests such as this, there are a few who are early-adopters or high-tech aficionados who, in effect if not intent, promote the product among their peers, offering a visionary view of what might be when the system is fully functional as opposed to how it is at the time of the test. We did not find that occurring among this group of drivers.

Only two of the drivers said that they served informally as technical advisors to their peers, and they did not claim comprehensive expertise or interest. For example:

> ***Q***: *Now, when the Port Authority introduces systems like that, in general do other people come to you for advice on how to work them, or do you go to other people for advice on how to work them?*
>
> ***A***: *Well, sometimes people come to me. I've showed a few people how to work them. When they rearranged them, they reprogrammed them a different way and I had to go ask a few people how to do it, but now I can do it myself and I can show other people how to do it.*

Asked about the attitudes of other drivers toward the side collision warning system, one driver who was quite accepting of the test-system, said this:

> ***Q***: *Do you get a sense, in your conversations with other drivers, what they think about the prospects for new safety systems like the side warning systems?*
>
> ***A***: *I'm trying to think of the best way to word it. It's like trying to teach an old dog new tricks. You get mixed emotions. They grumble and growl and what I do is I tell them it's coming, it's here, there's no sense fighting it, it's not a big deal. It's something that will help you. The program that we have right now, we can help fine tune it. It's very mixed. A lot of grumbling; some people, it doesn't matter to them one way or another. A few people were a little up tight about it.*

Are the bus operators thus a group of techno-phobic or techno-resistant persons who would naturally resist any such innovation and find fault with it without justification? No. To say that they are not early adopters or experts in electronic devices, may be somewhat reserved about accepting systems like this, and that moreover they do not rush to embrace every new high-tech system, is not to say that they are highly resistant to them in spite of the alleged grumbling cited above. In fact they appeared to the interviewers to be quite open-minded, neither seeing electronic warning systems as a potential panacea nor rejecting then because of a common reluctance to accept the new and unfamiliar.

Initial Driver Reaction to the EODS and their Perceptions of its Potential Usefulness

After their initial training, but prior to their extended use of the EODS, operators were asked their perceptions of the risk of side collision itself and the situations that would make it difficult to be aware of a potential side-impact without a side collision warning system. In answering, they tended to display their open-mindedness about the EODS.

> *Basically my only perception is certain areas of the city we go on very narrow streets and this system would work well in those areas because you lose sight of one side. You know if you're looking in this mirror, you're looking in that mirror, a lot and we do have those situations a lot.*

Another said this:

> *A situation you could get into, here in the City of Pittsburgh, we have a lot of streets that we operate the buses through that are extremely narrow. The streets are old. They weren't built with the anticipation of larger vehicles. We've got some streets that are over 100 years old. They are very narrow. You've got cars parked on both sides and you've got traffic traveling both directions. ... Your mind is just going 1,000 directions all at one time. Anything that would help to make you aware of a potential and upcoming problems is a plus as far as I'm concerned.*

Having to take Evasive Action

On average, the bus drivers perform one evasive maneuver to avoid a side collision every three days.

The EODS would naturally tend to be considered more useful if drivers say they encounter regular situations in which they must take evasive maneuvers to avoid side collisions. To define how often drivers face this situation, in the first Internet survey the drivers were asked to estimate the number of evasive maneuvers they have made to avoid side collisions in the last 30 days. As shown in Figure 5-2, their responses varied from zero to thirty. The average number of evasive maneuvers in the last 30 days was nine, or about once every three days. The same question was not asked in the second Internet survey because there was no reason to believe the incidence of such events would have changed, but drivers were asked whether they had experienced any change in this regard. They all indicated they had not.

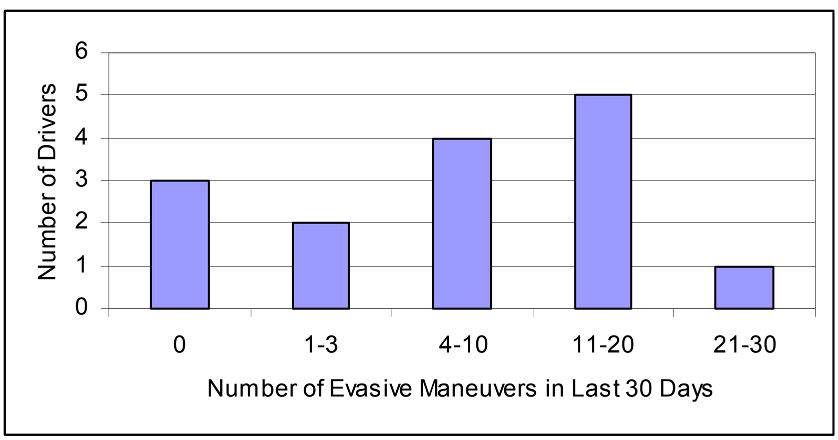

Figure 5-2. Distribution of the Drivers' Estimates of the Number of Evasive Maneuvers to Avoid a Side Collision in the Last 30 Days (from Initial Internet Survey)

When Would the System be Most Useful?

In answering the question of when the system would be most useful, the drivers typically reiterated what they had said about situations in which there is a risk of side collision. In other words, the situations that they perceive to be high-risk are the same situations for which the warnings would be useful to them. However, several drivers included the caveat, "…if it works the way it's supposed to."

For example:

> ***Q***: *In what situation would the system be most useful to you on the route that you generally drive?*
> ***A***: *Well, I do make a lot of turns through a residential area and it's in the early morning, so I'd say my visibility is limited on making turns, so that would be one. Also like making the tight turns, the sound system's on when you're turning so that would help.*
> ***Q***: *What do you consider the most important advantage of having side collision warning on your bus?*
> ***A***: *I kind of look at it, cause I've always said as a driver of a bus you need eyes in the back of your head. You have people crossing here, somebody doing this, doing that, people in the back screaming at you, whatever. But any time that you can enhance their safety or to be aware of something that's beside you, I just think it's a great idea. It's like a set of eyes on each side of your bus if it works properly.*
> ***Q***: *Do you expect there will be any disadvantages?*
> ***A***: *You know what? I really can't see any disadvantages, unless a driver would start depending on that system and not look, not follow your regular driving patterns, then that might be a problem.*

An exchange with one driver illustrates the view that the side collision warning system was seen by all of the responding drivers as being "…another tool…" for helping them drive rather than anything especially revolutionary. The overall expectation was for marginal, but positive, benefit. The driver (quoted below) sounds negative or at most neutral throughout, then he concludes that "…I'll just use it as a tool, like the mirrors…"
This, of course is the objective. The exchanges were as follows:

> Initially, bus drivers viewed the EODS as "another tool" and expected marginal but positive benefits.

> ***Q***: *Considering what is helpful and what is not helpful all together, what is your net conclusion? Do you think the system will help you drive more safely and avoid side collisions or that it will not be worthwhile to you?*
> ***A***: *Right now I'd have to say it probably won't help me a lot, but until I have one and drive it in a couple instances, I'll have a better idea.*
> ***Q***: *Do you think these systems will in any way change your job?*
> ***A***: *No, I don't really think so.*
> ***Q***: *When you're trying to make up time in your schedule because you've been delayed by traffic or some other problem, would a system like this help you in changing lanes or turning tight corners a little faster than you would otherwise, or would it make no difference?*
> ***A***: *It wouldn't make any difference.*
> ***Q***: *Do you think these systems will in any way change the way you drive your bus? Like it will make you less attentive, or maybe more attentive and more sensitive to driving?*
> ***A***: *No, I don't think so. I think I'll just use it as a tool like the mirrors or any other thing.*

In short, at the initial stage, just after training, and just before going on the road full-time with equipped vehicles, the test-subject bus operators felt there were realistic dangers of side-collisions on their routes, and they were neutral to realistically optimistic about the potential benefits of EODS.

5.2 Objective 1: Determine the Usability of the EODS under Normal Driving Conditions

The first objective of the evaluation was to determine the "usability" of the EODS system. Usability is defined for the purposes of this analysis as the ease-of-use of the system under normal driving conditions. For a bus driver, normal driving conditions include variable weather and variable traffic. Ease-of-use will also relate to the ease or difficulty in learning and actually using the system as well as the ease of interpreting the lights and chimes. Specific hypotheses tested were:

- Drivers find the EODS and components easy to learn.
- Drivers believe that they are adequately trained to use the system.
- Drivers find the EODS and components easy to use and control.
- Drivers understand the EODS capabilities.
- Drivers perceive that the EODS signals are recognizable and easy to see or hear.
- Drivers understand how to use information from the EODS.

In some cases, similar hypotheses are considered and discussed together.

Hypothesis: Drivers find the EODS and components easy to learn.

Hypothesis: Drivers believe they are adequately trained to use the system.

These hypotheses are accepted.

The initial training of the drivers taking part in the Harmar Garage test conveyed the purpose of the EODS reasonably well. Operators understood that the EODS system was meant to be an assist for routine operations and not an emergency detection system.

Most of the drivers said that it had taken them only a few days to familiarize themselves with the system. No driver could name any specific elements of the operation of the EODS that had been omitted from the training. All of them said that the training was either somewhat useful or very useful, the duration of training was adequate, and no additional training was needed.

> All of the drivers reported that the training was useful and no additional training was needed.

The drivers found the signals extremely simple with the possible exception of the rate at which the lights flashed, an exception we will discuss further at a later point in this report. Thus, there was no real question of adequacy of the training for understanding the signals.

One driver spoke for all when he had this exchange with the interviewer in the final interview:

***Q**: First I'd like to just discuss things related to training. Prior to going out with an equipped bus, you had training that told you what to expect. Now that you've had experience with the system, remembering back to the training, did the training adequately prepare you for how the system really works?*
***A**: Yes, it did. There was no problem.*
***Q**: How much time in days, or weeks, or months does it realistically take after the training to get used to the system so that it's useful to you as a bus driver?*
***A**: (In) a few days I felt comfortable with it.*
***Q**: How difficult or easy was it to learn to use the system so that it was a benefit to you as a driver?*
***A**: I don't think it was difficult at all.*

Another driver said:

***Q**: How much time, in days, or weeks, or months, does it realistically take after the training to get used to the system so it's useful to the driver?*
***A**: Probably about 3-4 days, maybe a week.*
***Q**: How difficult or easy was it to learn to use the system to your advantage?*
***A**: Very easy, once you got used to it.*

The training accomplished its objectives which were to make the system familiar to the driver in operational terms. They understood the lights and the chimes and the general operation and purpose of each as well as the concept of graduated signaling with varied vehicle speed.

Drivers all said that the training was easy. Under interview questioning at the initial stage, no one mentioned any significant conceptual or operational difficulty with the EODS. Various drivers said that when the system was new to them, they "watched the lights a lot" to see how they acted. One driver mentioned initial anxiety which she quickly overcame:

***Q**: How easy or difficult was it to learn to use the system to your advantage?*
***A**: I think -- at first it's like you're worried about, "Oh, my God is this light going off right?" and you're like geared on to watching those lights. And then after you get comfortable with it, then you notice, well, that light's blinking but I know that nothing's really at a precise danger point. I'd say after about a week or so you settled down. It was pretty easy.*

At both stages of the Internet surveys, drivers indicated that the training was useful, and that they had all the training they needed.

The only dissent involved the fact that the training was intended for ideal operation of the system, whereas the real world of driving created disappointment among some drivers.

For example:

> ***Q***: *Now that you've had experience with the system and you remember back to the training, did it adequately prepare you for what to expect?*
> ***A***: *Yes. Naturally once you get out on the road things are going to happen that are unforeseen by anybody, but, yeah, the training was adequate.*
> ***Q***: *What kind of false readings are you talking about?*
> ***A***: *Just false readings and stuff like that. They tell you this is how it works and stuff like that, but when you get out there, you're going to get false readings. They don't tell you that.*

The drivers all understood that the system was intended to assist them by supplementing their information, and not to replace their judgment or skills. They also understood the warnings provided by the lights and the chime. At the beginning of the test period, and just prior to the first interview, the drivers, having been trained on the system's operation and taken on a training run, had a general familiarity with how the warnings were to work.

They knew, for example, that a side obstacle would result in an amber light flashing while a steady blue light meant the system was functioning[8]. Most drivers knew that the rate of flash represented the severity of the danger, though there was some confusion on two points. First, while in general the drivers understood that the flash-rate was related to speed and proximity, they tended to find it difficult to be precise about the relationship. However, they understood that, in effect, the rate related to level of imminent danger, and practice will probably teach them how this relates to the danger even if they cannot recite the ratios.

Typical remarks about their expectations and understanding of the system at the initial phase are exemplified by the comments of one driver:

> *I understand how it's supposed to work like that, the audible part. And then the rest of the signals in the zones that we have, I know when you're in a highway mode, it'll pick up the furthest zone and you only get a single tone on a highway. Then when it does come into the city mode and you're slower -- urban fast mode -- you get 3 zones. You get an 8', 4' and 2' zone. I understand how that works. And then when you're in the slow mode, you're going to pick up the stuff less than a foot way, you're going to get a solid, 4, 2, and 1' and the 1' zone I understand is a solid light. That's when your senses are heightened their most.*

While this was a rather generic understanding, it was adequate as a starting point.

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[8] Note that in the photographs in this section of the report, two instruments appear on the driver's left side. (See also illustration of the operator's reference card in the Introduction). One is red in color and has no light. That is <u>not</u> the device, rather it is a clock or other instrument. The warning device is just above it, and shows a blue light and two amber lights. The lights are contained in a very small flat-black instrument case which is difficult to see in the pictures against the background of the gray color.

One function almost all were familiar with in specific terms was the chime. For example, all but one knew after initial training that the chime was associated with the turn signal. The drivers uniformly felt that the association of the chime with the turn-signal was a very positive feature of the system because it would reduce false positives. One driver spoke for all about the chime when he said this:

> *The way it was explained to me, we're going to get -- the only time we're going to get an audible tone is while you have a turn signal on, whether it's left or right. And it makes sense, because if you have an audible tone every time you pass something, most times you're going to have the tone going off a lot, the majority of the time you're driving. So I like the idea of it set up that way. I was unaware of that at first, but that's something that they did change from when they first talked to us about it. I think that's a plus, cause that was one of the number one complaints on the first system that came through East Liberty, I was told. I wasn't there, but I was told that that's one of the reasons people didn't like having a bus that had that on it.*

In short, while understandings were not absolutely complete, the training had been sufficient that the drivers could be expected to have a sufficient basis to learn the subtleties of the system quickly when they began driving the equipped buses full time.

Hypothesis: Drivers find the EODS and components easy to use and control.

Hypothesis: Drivers understand the EODS capabilities.

With some qualifications, these hypotheses are accepted. The drivers understood the capabilities of the system to detect objects to the side of the bus, and to vary the range of detection with the speed of the bus. The qualifications involve some apparent lack of understanding of the limitations of the system.

As discussed in the previous section, the drivers generally found the EODS easy to learn and easy to use. However, as shown in Figure 5-3, their perceptions of the ease of learning and ease of use diminished somewhat after using the system for three months. In the initial Internet survey nine of the ten responding drivers agreed (or strongly agreed) that the EODS was easy to learn to use and eight agreed it was easy to use. However, at the end of the test only seven reported that it was easy to learn to use and six said it was easy to use. The change in response concerning ease of use is marginally significant at the 0.10 level of statistical significance. This change in response reflects the drivers' realization that learning to use the system required a bit more effort than they initially thought.

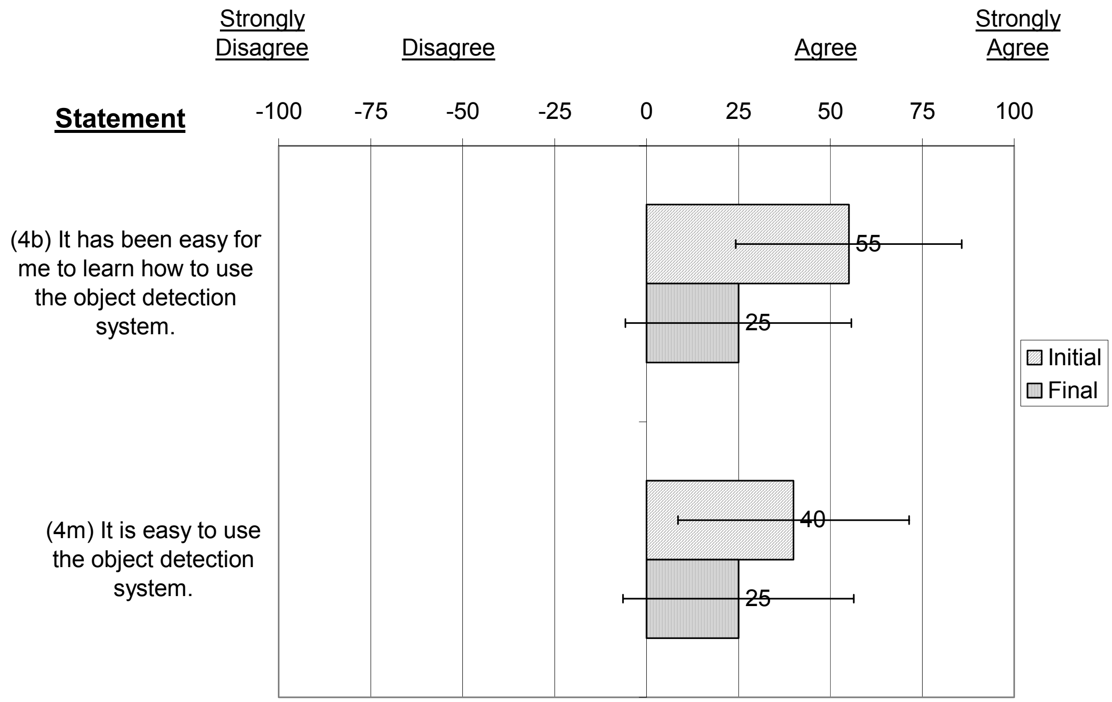

Figure 5.3. Driver Perceptions of the Ease of Learning to Use and the Ease of Using the EODS

> It may be that the training should have gone farther in explaining the limitations of the system.

Although the drivers said they found the training to have been adequate, it may be that the training should have gone farther in explaining the *limitations* of the system, limitations which the operators learned during the test, and which they found disappointing. This observation comes from comments we shall describe later in this report about "slow response time" involved in detecting cars that were passing the buses and certain other types of limitations inherent in the system.

One exchange illustrates this expectation:

Q: *I just want to talk about your expectations with the side warning system. What was your initial reaction to the system in the first week or two that you were using a bus equipped with it?*

A: *Well, I thought that it would be really advantageous for us and it wasn't. It has some problems that need to be worked out and the biggest one is by the time it lets you know that there's something there, half the time you're past it. If you're going to hit it, you've already hit it by the time the light comes on.*

If the initial training ultimately had a flaw, it was not a lack of training in how to understand the system's signals or what they meant. It was rather, that operators tended to have unrealistic performance expectations of the EODS' capabilities. This was most pronounced in the case of a vehicle approaching rapidly from the rear to pass. Bus operators felt that the system failed to detect such objects quickly enough for them to take corrective action. However, detection of that nature would have required anticipatory detection and not detection of an object already next to the bus.

Thus, when operators found fault with the EODS system, it was more often a result of their hoping that the system would match the specific needs of their daily driving than that it failed to live up to the specific description of the system as designed.

We shall return to these themes later in this report.

Hypothesis: Drivers perceive that the basic EODS signals are recognizable and easy to see or hear.

With some qualifications, this hypothesis is accepted.

At the initial stage of the test period, drivers were asked during the in-person interviews if they felt the lights and chime would be effective in getting their attention, and whether there were any downsides to the warnings. All felt that the chime would certainly get their attention as long as it was not issuing frequent false alarms that would lead them to ignore it. They also said that lights were visible even during daylight hours. Only two drivers said that at night, the lights were so bright as to be distracting in the peripheral vision

At the end of the test period, the drivers agreed that the lights are easy to see and the chime can be heard even in heavy traffic and bad weather. Those aspects of the system received high marks and were primary design criteria as defined in the system specification.

Lights

The Internet surveys examined a series of five characteristics of the lights worded in a positive manner (see Figure 5-4). Each characteristic received a rather high mean score. Drivers felt that the amber lights are clearly visible looking in the side mirrors or in the direction of the bumper corners. They felt it was easy to distinguish whether the warning lights were flashing or solid on. They also felt that the brightness of the amber warning lights is adequate during daylight hours, and that it is easy to distinguish the EODS warning lights from other operating lights and displays in their buses. One driver said this:

Q: Well, did the lights get your attention during daylight hours?
A: Yeah, they did pretty good. I thought they were too bright at night.
Q: So they got your attention, but they were too bright?
A: They did unless I'm in a tight situation and I go into like an auto mode. You're looking straight at that mirror and you're watching everything. You're not worried about the lights, cause you can't trust them and they're supposed to help, but you rely on yourself first. So you ignore them at that point. Then once the situation lets up, then you can glance and see them better.

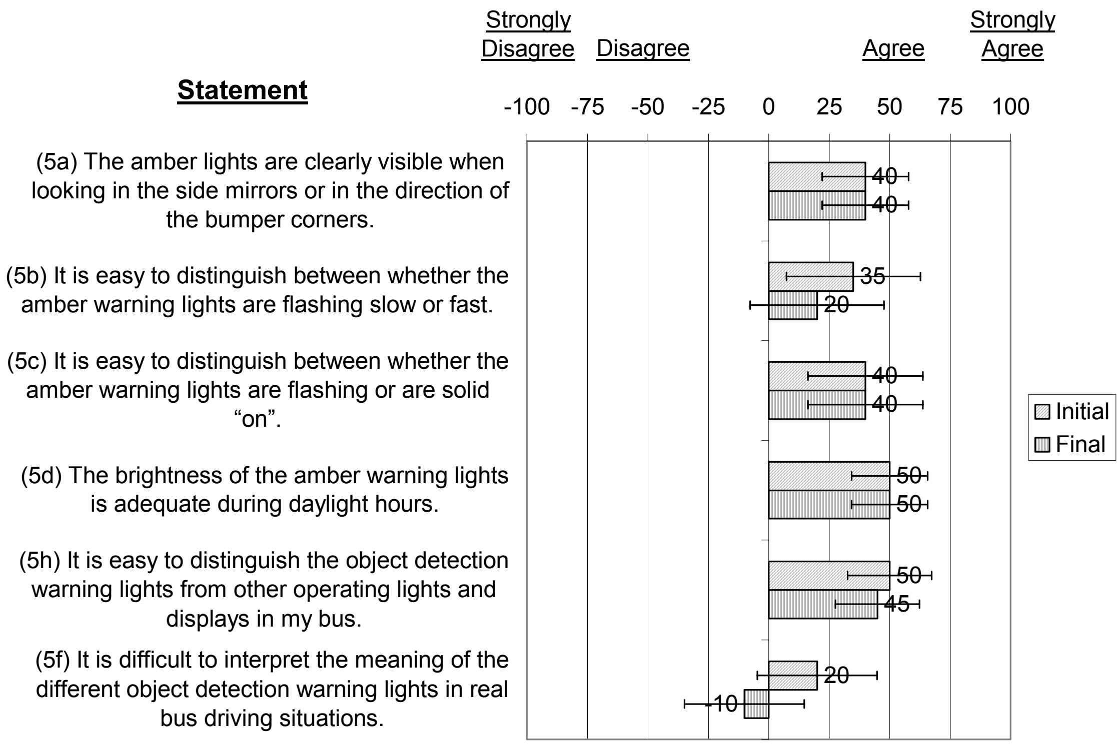

Figure 5-4. Drivers Perceptions of the Visual Effectiveness of the EODS Lights

The problem came, not in seeing the lights, but in distinguishing the different rates of flashing for the lights. Responses in the final in-person interviews split between the lights being easy to interpret (7 drivers) and difficult (5 drivers). In the final Internet survey the mean score for ease of making this distinction declined from 35 to 20, an indication that experience had taught many of the drivers that the distinction was not as easily made as they had initially thought[9].

According to the drivers, it was easy to distinguish the EODS warning lights from other operating lights – but, some had a problem distinguishing the rate of flashing.

[9] Note that in Figure 5-4, most items are worded in the positive, but one item (5f) is worded in the negative such that the driver would have to disagree with the statement to offer a positive evaluation of the EODS. This does not affect the results, but the reader should be aware of the difference in reading the chart.

The lights are intended to flash at differing rates depending on the speed of the bus and proximity of an object to the side of the bus. Driver opinion differed on whether it was easy or difficult to interpret rates of flashing. Difficulty appears to arise because the drivers perceive the lights as competing for their attention with their need to be watching their mirrors and observing through the windshield. For example, consider these exchanges between the interviewers and several drivers:

One driver:

> ***Q***: *How easy or difficult was it to interpret the signals the lights were giving in real driving conditions?*
> ***A***: *Difficult, cause between the slow speed and the faster speed, not the solid, when you glance at them you can't really tell how fast they're flashing. It's too hard.*

Another driver:

> ***Q***: *How easy or difficult was it to determine the signals the lights were giving in real driving conditions?*
> ***A***: *The amount of flashing? It's sort of difficult determining whether it's flashing slow or flashing fast. The solid, you automatically know that it's solid. So I'd say it's difficult, because it's hard to tell if it's flashing slow or fast.*

Another driver:

> ***Q***: *How easy or difficult was it to interpret the signals the lights were giving you in real driving conditions?*
> ***A***: *Too difficult to find the blinking, on steady, because you don't have the luxury of just staring at a light.*

Another driver elaborated, arguing that a dual flash rate is not needed:

> *You don't have enough time to distinguish, okay, it's flashing slow or it's flashing fast. It's not necessary in my personal opinion. It's either flash or solid and whatever speed that they figure works best. Two different speeds of flash I think is very unnecessary.*

Another driver said this:

> *My personal opinion is the rate of flash is a waste of time. There's no reason for three steps in it.*

Those who said the lights were easy to interpret tended to say that one could tell if they were flashing fast or slowly, and this was sufficient information without having to think about the actual flash-rate.

One driver was particularly articulate about the reasons he believed two rates of flash were unnecessary. To him, there was no difficulty in distinguishing the rate. The rate of flash was not relevant to him because he felt that the urgency to check the mirrors was the same regardless of the rate. A slower flash did not mean he could react any less rapidly.

Q: *What about the different rates of flash?*
A: *Two different speeds of flash I think is very unnecessary.*
Q: *Was it difficult to distinguish?*
A: *No, it wasn't difficult to distinguish, but your mind -- you're picking up the flash, okay? It's flashing, so you're trying to process the information. This thing has just warned you of something so you've quit looking at the flashing light and you're looking to see what it's trying to tell you. So whether it's flashing slow or flashing fast doesn't matter to me. I'm looking to see what it's trying to tell me. It doesn't make a bit of difference to me whether it's going slow or fast. <u>It's telling me something and I want to see what it's trying to tell me</u>. Solid means something's right here right now.*

These opinions had not changed much since the initial interviews. At that time several drivers said that they felt they could not watch the lights closely enough while driving to distinguish the flash rate. To them it was a binary situation: either flashing or not flashing. Any subtlety beyond that, they said, was unlikely to be noticed.

This was not unanimous; however, for other drivers felt they could see at a glance whether the rate was fast or slow. Several drivers felt that it was easy to interpret the rates of flash. For example:

Q: *How easy or difficult was it to interpret the signals the lights were giving in real driving conditions?*
A: *Well, you really can't tell how many times they're flashing when you're driving, but I guess you could detect if they're flashing a little quicker.*
Q: *So would you say it was very easy, easy, difficult, or very difficult?*
A: *It wasn't hard to interpret. I think they said it flashed four times. I don't think anybody ever looked to see how many times it flashed, but you could tell if it was fast or slow.*
Q: *So it was easy to interpret?*
A: *Easy.*

Another driver echoed this:

Q: *How easy or difficult was it to interpret the signals of the lights in real driving conditions? Easy, very easy?*
A: *Easy. It wasn't very hard at all.*

In the initial interview, this same driver had also been positive about the rate of flash saying that a driver could roughly distinguish the basic pattern of fast-or-slow just by glancing, but that in slow turns, the rate of flash was easy to detect with confidence:

Q: *Do you notice the difference in rates or did you just notice it flashing?*
A: *You could pick it up. You don't notice it as much when you're moving along in the fast mode, because you're just glancing. You may look in the mirror or look over at the signal when it goes off. You're not sitting there staring at it waiting to count how many times it blinks. But when you're turning, you're looking in the mirror most of the time when you're turning and that sensor is right next to the mirror basically and you can pick it up in your peripheral vision and you can see how many times it's blinking, whether it's fast or slow. You don't have to count it. You can just see how quickly it's blinking.*

The Chime

All drivers agreed that the chime was easy to distinguish from other sounds on the bus and could be heard in all conditions. Most of the drivers were comfortable with the idea that there is no audible chime when the bus is stopped; however, two drivers disagreed with that approach. Figure 5-5 summarizes the drivers' feelings about these issues. Typical feelings about the chime are as follows:

> Drivers found it easy to distinguish the chime from other sounds; but, suggested that it should differentiate between warnings for the left and right sides of the bus.

> ***Q***: *How about the audibility -- could you always hear the chime adequately in normal traffic?*
> ***A***: *Yeah, that's no problem.*
> ***Q***: *And how about in heavy traffic or other noisy conditions?*
> ***A***: *I've not had any problem at all, fast, slow, noise, no noise, with hearing the chime.*

Another driver indicated that the chime was easily heard. He then suggested what some of the other drivers also suggested: that the chimes differentiate left and right sides of the bus. (We will comment further on this under Objective 5.)

> ***Q***: *And could you always hear the chime adequately in normal traffic and in heavy traffic or where there were relatively noisy conditions?*
> ***A***: *Yes, right. They are loud. I wish there was a different sound for each side.*

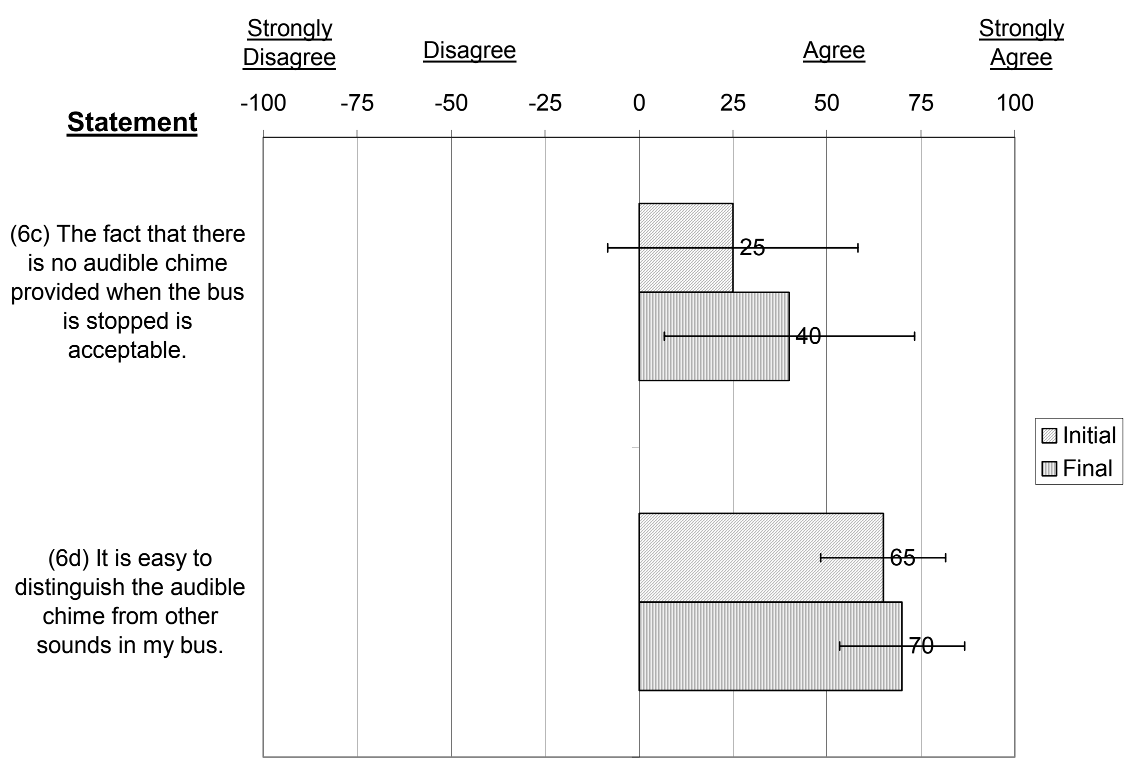

Figure 5-5. Drivers' Perceptions Concerning the Audible Chime

Lights Versus Chimes

At the initial and final stages of the Internet survey, drivers were asked whether they preferred warning lights without chimes or *vice versa* (see Figure 5-6). In both occasions they tended to disagree with both exclusionary options. This finding reinforces our conclusion from the in-person interviews that most drivers prefer a system that uses both. In those interviews, the responses were: five drivers said they prefer lights and no chimes, two prefer chimes and no lights, but five prefer both. In other words, if required to choose, lights win. But a total of seven of the drivers prefer not to give up the chimes, either relying on them exclusively (the choice of only two) or using both lights and chimes.

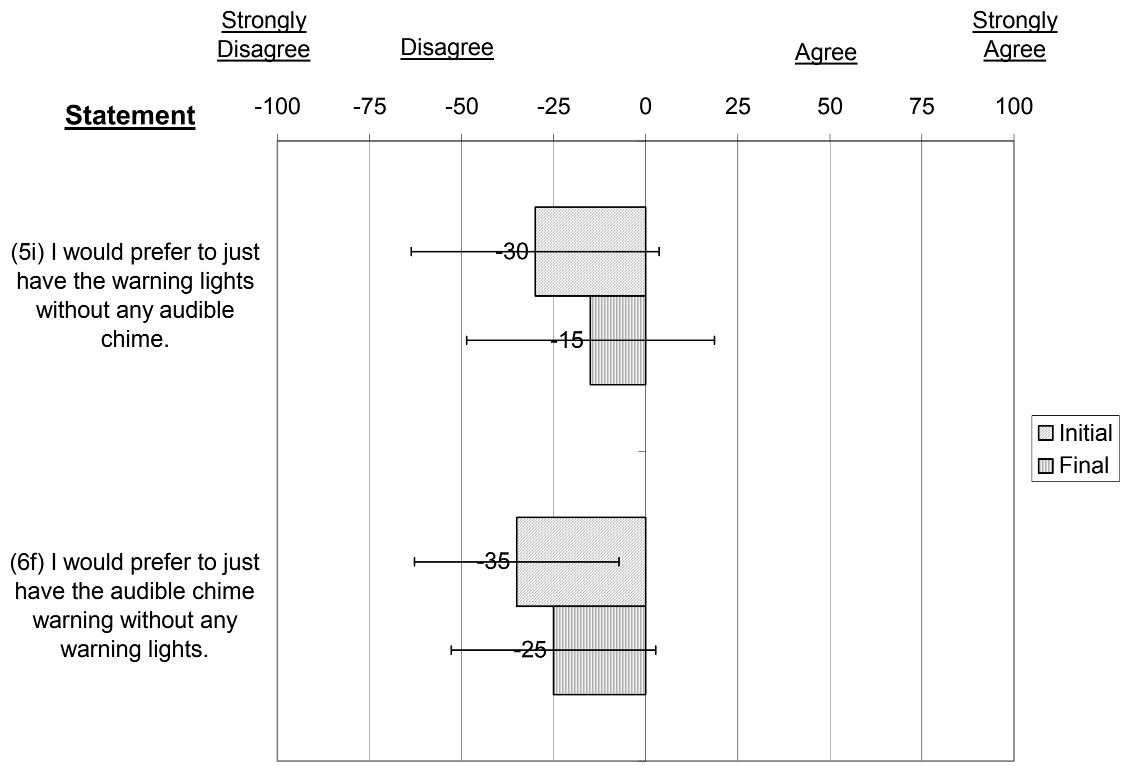

Figure 5-6. Drivers' Attitudes Concerning the Use of Lights without Chimes or Chimes without Lights

Hypothesis: Drivers understand how to use information from the EODS.

This hypothesis is accepted.

Most of the drivers understand in a literal sense how to use the signals from the EODS. Repeatedly, they discussed using the chime to double-check the presence of a vehicle to their left when changing lanes at highway speed. Repeatedly also, they discussed using the lights when making turns. This was especially true in tight turns to the right where the blind spot is more severe than it is to the left. Several drivers pointed out that in a tight turn to the right they could easily see the lights and distinguish the approximate rate of flash, thus knowing whether they were very close to an obstacle.

For the most part, then, there was no real question as to what they should do when receiving a signal from the EODS.

A more significant question to the drivers was whether they needed the supplement of the EODS. Several drivers pointed out that in situations in which the EODS would theoretically be quite useful, for example, in heavy traffic, that they were very busy watching their mirrors and watching traffic and paid little attention to the lights. This was an indication that they perceived the lights as something they actively had to watch rather than observing passively (meaning the lights were catching the driver's attention in peripheral vision).

The chime, of course, was a different matter. Parenthetically, we would add that the chime was not subject to this concern, and therefore had clarity of meaning for some drivers that the lights sometimes did not convey. One driver said:

> Drivers use the chime to double-check for the presence of vehicles to their left when changing lanes on highways, and use the lights when making right turns in the city.

> *I trusted the chime at all speeds. We get the most use out of the chime as we are changing lanes, cause that's when it comes on when you have the turn signals on. So no matter what speed you're at, if it chimes to tell you -- if you don't see what's out there, the chime tells you something's there. At any speed it works.*

One driver said that in "tight" situations, it was difficult to tell from the lights which side of the bus the obstacle appeared on because the lights on either side of the bus would be flashing simultaneously[10]. He drives in very "tight" areas in which there is heavy traffic, and often cars are parked on both sides of the street. Therefore, one who is completely familiar with the EODS would expect that lights on both sides would flash. However, he said this:

> *I noticed that a few times in tight areas, cause I drive in tight areas, they would both be flashing at one time. Now which side do you look on -- it's warning on both sides, so what side do you really look on? I mean it'd take you 2 seconds, a second each side, to look to see where the danger would be. I think that's where the problem was. I don't know if you'd be able to overcome that in the tight areas in the cities and stuff like that, New York City, you know, the major cities with cars parked on both sides, telephone poles, walls. It would be too difficult. The eye can move quicker than the light, I believe.*

Although he was complaining about what he saw as incomplete information from the EODS, he was actually acknowledging that the system was in fact working correctly as designed. It was appropriately detecting obstacles to both sides of the bus in a tight situation. His complaint was, in effect, that the warning may have been accurate but was also without operational meaning to him because it could not give him more information than it was designed to provide – i.e., help him prioritize.

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[10] The lights separately indicate obstacles on the left or right, providing directionality to the warning. The chime does not do this.

His question was which side he should "really look on." In fact the system was accurately telling him to "look on" both sides. It could not prioritize because both sides met its proximity criteria. His implicit assumption was that system was telling him he should take action to avoid an obstacle, but his frustration was that it could not tell him what action to take any better than his instincts could. That is the meaning of his comment that the "eye can move quicker then the light."

This is probably a matter of training in the meaning of the messages of the lights in certain kinds of situations. That is, training should perhaps include situations in which the system will simply confirm the obvious, leaving the driver on his or her own.

> Drivers perceive that the rapidly flashing lights are more useful.

The Internet surveys (See Figure 5-7) tend to confirm what the drivers told the interviewers in person. The perceived usefulness of the lights varies with the speed of the flashing. They perceive that the more rapid the flashing the more useful it becomes. The mean scores of each of the flashing light measurements improved from the initial to the final survey. Because the sample size is so small, the estimated differences are not statistically significant. Nevertheless, it is interesting that there was consistent change in this mean score across the three levels of flashing lights. This is particularly true given the skeptical remarks that many of the drivers made about the utility of the lights.

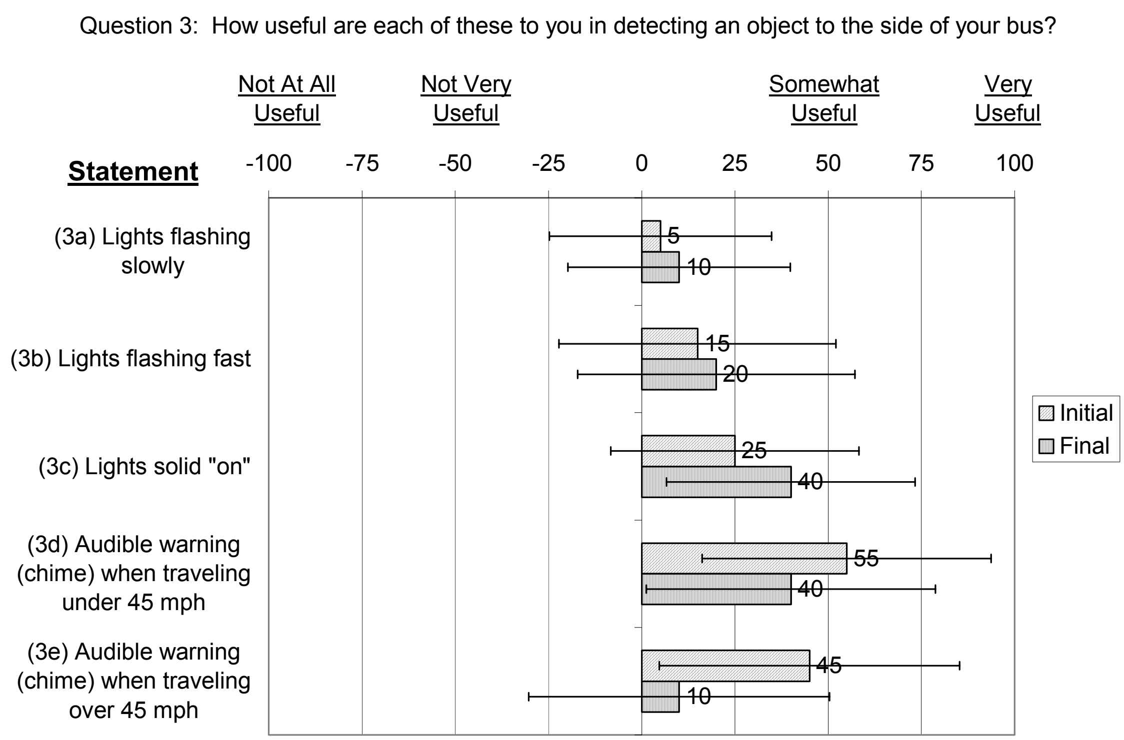

Figure 5-7. Drivers' Perceptions of the Usefulness of the EODS Lights and Audible Warnings (3a-3e)

Regardless of the change, however, the overall measurement appears consistent with what the drivers said in their individual interviews. That is, it is easier to notice a rapidly flashing light than a slowly flashing light. And it is apparently easier to note the urgent warning of a solid light than it is to notice that a light is flashing fast rather than slowly. This may be because the solid light would occur in close traffic situations, and close turns, when the driver would be paying attention to the mirrors, and therefore seeing the light.

There also may have been another reason for the improved scores of the lights. At the outset, some drivers felt that the lights might be distracting. They came to learn that they could either ignore them or use them, "tuning them out" or using them as they wished. For example, one driver said this:

> ***Q***: *At the beginning of the project we asked if the warnings would be more of a distraction than a help, or more of a help than a distraction. What is your bottom line conclusion now about that?*
> ***A***: *Well, when you first start off, it's a distraction because you know what you -- I know when I first got on there they were a little distracting because I was watching the lights basically to test it to see if they were working properly. But after I got used to it, no, it wasn't distracting at all to me.*

Notice also that the scores for the chime declined from the initial to the final survey. The mean score for usefulness of the chime at speeds under 45 miles an hour declined by 15 points, and the mean score for the chime at about 45 mph declined by a precipitous 35 points. Why did this occur? We will see in the next section, that although the drivers were very hopeful initially that the chime would warn them of vehicles approaching to their side at highway speed, they ultimately found that the system response did not cover certain situations with which they were most concerned, such as a car overtaking them on the highway at high speed. Therefore, although they had said that the chimes were highly audible, and were in some respects more useful than the lights, they were also more intrusive and impossible to ignore (unlike the lights), but also subject to false alarms.

One driver reflected the views of several regarding the chimes when he said the following:

> ***Q***: *Did your views of the system change over the course of the test?*
> ***A***: *Yes, it did. I got a little discouraged at the end because it seemed like the buses that had problems maintained the same problem without being any change and that got a little discouraging, especially the ones that had the audible chimes that were going off all the time.*
> ***Q***: *But over time did you feel that the system got more useful or less useful?*
> ***A***: *I think actually it became less useful.*

Effects of Driving Conditions on Perceived Usefulness of the EODS

During the personal interviews the drivers were asked a series of questions concerning the usefulness of the EODS under various driving situation. A summary of their responses is as follows:

- In close maneuvering in the city most (six of ten responding) found it useful
- Eight drivers found it much more useful at low speed versus high speed.

- Five drivers who perceive a difference in usefulness between curved and straight roads said it would be more effective on curves.
- It is considered very useful when changing lanes by ten drivers.
- It is considered very useful when merging into traffic from a passenger stop by eight of the nine drivers responding to this question.
- It is considered very useful when making turns. Five drivers indicated that it was more useful in making right turns than left turns, while four said there was no difference between left and right turns in its usefulness, or lack of usefulness, and one said it was more useful in left turns.

Two exchanges with drivers who were relatively positive regarding the usefulness of the EODS illustrate why they thought its usefulness varied with conditions:

> ***Q***: *In your case, in what way did the system help you most?*
> ***A***: *The highway speeds was the most. Lane changing, merging, stuff of that nature. I think what it did it protected my blind spots to detect -- I don't care if it was a tree, a car, or a wall, whatever, at least something was there whenever -- it did go off sometimes when there was nothing there, but that's something you guys can work on later.*

Another driver:

> ***Q***: *Is it more useful in light traffic or heavy traffic?*
> ***A***: *I would say lighter traffic, because when you're in heavy traffic you're there. Everything's all around you. You know it's there. You don't need something to tell you that something's there because you already know it's there. When you get into a lighter traffic situation, you see a few vehicles in front of you, it might pick up something behind you, that's when you can be surprised because somebody can sneak up on you. In heavy traffic, nobody's sneaking.*
> ***Q***: *So is it more useful at low speed or high speed?*
> ***A***: *I would say equally as useful either speed.*

On the other had, not all drivers were so positive about the EODS. Some rejected the idea that it varied in usefulness because they felt it was not at all useful. For example:

> ***Q***: *In your case what way did the system help you most?*
> ***A***: *I really don't think that the system helped me at all.*
> ***Q***: *Then can you give any specific example of a time when the system was helpful to you?*
> ***A***: *No, I don't think the system was helpful, not to me.*
> ***Q***: *In what ways was the system a problem for you?*
> ***A***: *The lights constantly going off, all the false readings, the false readings in the rain, the false readings when the wind blows hard. You could drive down the road and there's nothing on either side of you and the system's going off. It's constantly flashing.*

Notice that this driver's objection was not to the concept of an object detection system, but the way it, in his opinion, provided misleading information at this stage of its development.

Summary of Objective 1

The drivers found the EODS and its components easy to learn. They believed that they had been adequately trained to use the system. The found the EODS easy to use. Drivers understood the EODS capabilities to some extent, but as we shall discuss at greater length in this report, they had hoped for additional capabilities, which were not part of the system design. This led to some disillusionment, as we have seen. The drivers certainly perceived that the EODS signals were recognizable and were easily seen or heard. The only exception to this is that some drivers felt that the differential rates of flashing were difficult to distinguish in operational settings. Finally, drivers understood how to use the information from the EODS in the sense that they understood the basic fact that a signal may indicate a need to avoid an object.

5.3 Objective 2: Determine How the EODS Affects the Driving Environment and Driver Workload

This objective focuses on how the EODS affects the driving environment. Of particular interest are the effects of false alarms and the impacts on driver workload. Specific hypotheses to be tested are:

- Drivers perceive that the EODS reduces their driving workload.
- Drivers perceive that the EODS reduces their levels of stress or fatigue.
- Drivers perceive that the EODS does not distract them or interfere with their other tasks.
- Drivers perceive that the EODS false positive alarms are a nuisance.
- Drivers perceive that the EODS false negative alarms degrade their confidence in the systems.
- Drivers perceive that there are too many false positive alarms
- Questions about EODS from bus riders will create distractions for the drivers.

Hypothesis: Drivers perceive that the EODS reduces their driving workload.

Hypothesis: Drivers perceive that the EODS reduces their levels of stress and fatigue.

These hypotheses are rejected. For most of the drivers the EODS either made no difference in mental workload, or was perceived to increase it. Similarly it made little or no difference in stress.

The drivers tend to perceive that the EODS does not reduce their driving workload. Typically, the drivers said that the EODS was one more intervening factor in their driving, which requires their attention. Consequently, if anything, it was perceived as increasing the workload slightly. In the initial interview one driver expressed it this way:

> ***Q***: *Do the lights get your attention?*
> ***A***: *As far as the different rhythm, I mean there's no way I'm noticing that. The lights flash in different rhythms for distance. I mean maybe a person sitting in a seat*

watching those lights could see that, but the person that's driving the vehicle, there's no way I'm going to take my eyes off the actual road to focus on something telling me there's something there versus me actually seeing there's something there.

Figure 5-8 shows the drivers' average "mental workload" ratings under a variety of driving conditions. They rated each condition at both the initial and final stages of the test period. In the chart, the scale indicating workload varies from zero to ten, where ten indicates maximum mental workload. For comparative purposes a series of questions were asked having to do with the workload of driving their own automobile under various conditions. Drivers were also asked about driving the buses with and without the EODS system operating.

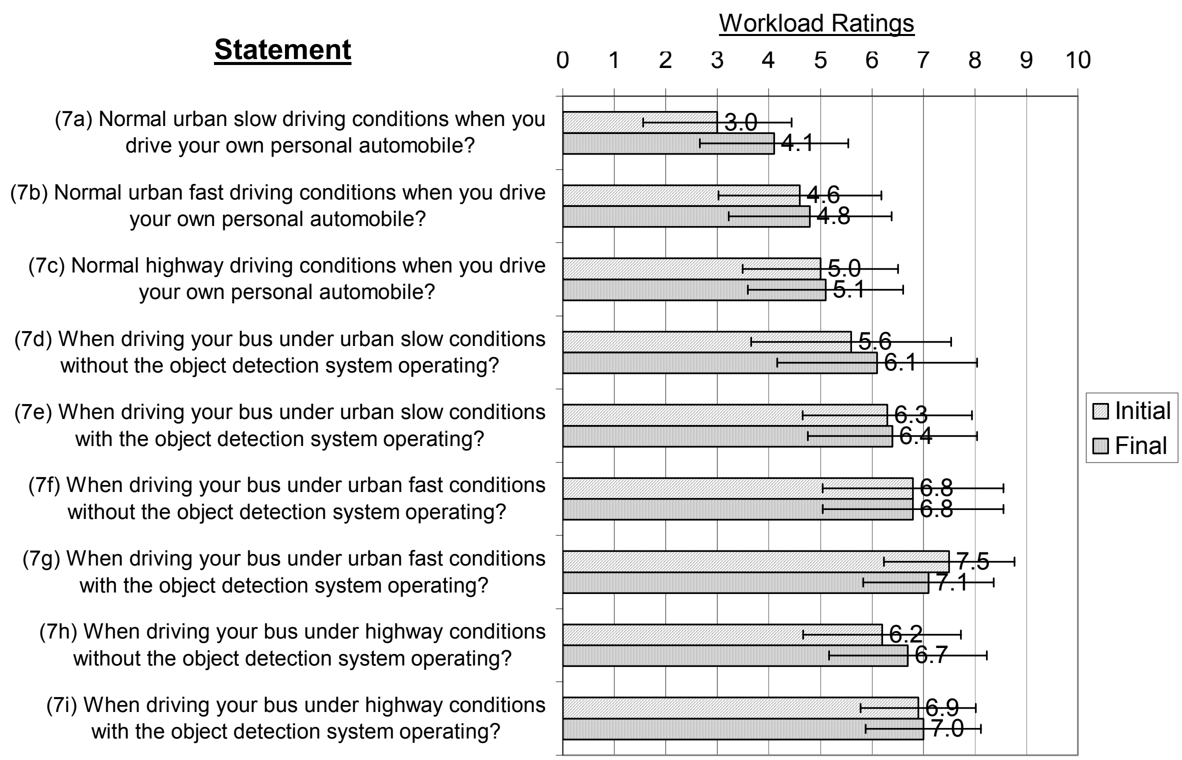

Figure 5-8. Driver Ratings of Mental Workload Under Various Driving Conditions

Considering the perceived workload of driving one's personal automobile, three things are clear:

- Perceived workload varies with the speed of the vehicle.
- Workload is greater for driving a bus than driving a personal vehicle.
- It is also clear that, with one exception, there was no meaningful change in mean scores between the initial and final survey; that exception was with respect to operating the personal vehicle. There was no reason known to the authors to expect a change unless

there was a sudden onset of highway construction or other congestion inducing factor in the area. Consequently, it is odd to observe a change of mean from 3.0 to 4.1 in perceived workload when driving one's own vehicle.

With respect to operating the bus, several aspects of the workload scores are clear:

- First, the range of mean scores at the time of the final survey was only 6.1 to 7.1, in spite of the fact that many driving conditions and combinations of operating with and without the EODS were considered.

- Also, there is a consistent pattern, showing that the workload perceived when the system is operating is greater than when the system is not operating. This observation needs to be considered in the context of the extremely small sample and thus the volatility of the statistics. Analysis of the potential errors in the statistics suggests that there is no statistically significant difference between the situations in which the EODS is operating and in which it is not operating. Three of the ten drivers who completed the first internet survey give higher workload rating with the EODS. In the final Internet survey, two of the ten rated the workload higher with EODS operating. The average rating with EODS is 0.7 higher on the initial survey and 0.3 higher on the final survey. The differences are the same at all three driving speeds. The differences, while small, are consistent across several driving conditions. It is also important to note that the differences are consistent with the findings of the oral interviews.

Further evidence from the Internet surveys that drivers do not perceive EODS as reducing their stress or fatigue is shown in Figure 5-9. In both the initial and final survey the drivers clearly disagree with the statement that the EODS reduces stress and fatigue. Their comments during the in-person interviews indicated that they tend to perceive their jobs as requiring constant attentiveness, and they do not perceive EODS or other systems of automation as significantly reducing that stress level.

Perceptions of Mental Workload as Determined by the In-person Interviews

In the follow-up in-persons interviews, drivers were asked similar questions about workload and the EODS. When asked about the level of mental effort required with EODS compared to non-EODS equipped buses, the results were very similar to the Internet survey results. However, probably because of the option to discuss their answers in-depth during in-person interview, some of them were somewhat more ambivalent. The primary message, however, was that very few said that driving at any speed with the EODS would require *less* mental effort (one said this at urban slow and urban fast and two at highway speed), while all others said either that the effort would be the same or would increase. In other words, the consensus of this small test-group was that it would either make no difference or would increase the mental effort somewhat.

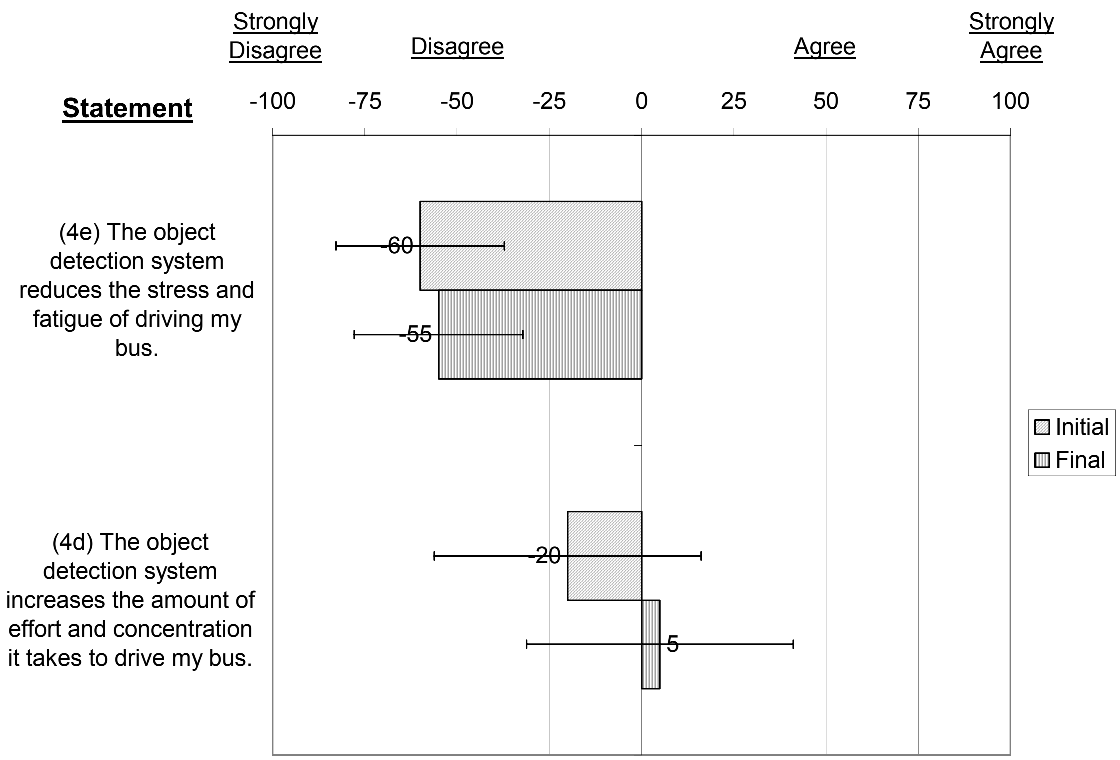

Figure 5-9. Drivers' Perceptions of the Impacts of EODS on Stress and Fatigue and Driving Effort and Concentration with Driving Tasks

Drivers were also asked about their preference for driving with and without EODS. The responses were:

- Two prefer driving with it
- Three say they are pleased when they are given a bus without it because, they say, the EODS often did not work and they did not want to fill out the maintenance report. Also, these respondents said that they will not miss it at all in the slower congested areas.
- Seven say it makes no difference to them whether they drive an EODS-equipped bus or one without EODS.

The views of one driver illustrate the feelings of several of the drivers about how little difference EODS makes in their typical driving pattern:

> ***Q***: *Now I want you to compare your experience with vehicles that had the EODS and those that didn't have it, in terms of what the mental effort is that a driver has to use. Did you find that it took more mental effort or less mental effort to operate a bus with the EODS than one without it in slow urban traffic.*
>
> ***A***: *I feel it's about the same, because, like anything, you can't always trust your system's working to 100%. Look how many things inside the bus that don't work, the*

passenger signal, or there's always something that isn't working. So I drive the bus the same way no matter what. You know what I mean? It's an aid, I believe, but it doesn't take any more mental stress off of me, so it would be the same.

A perception among some drivers that EODS requires somewhat more mental effort is not necessarily associated with a desire to avoid using it. This driver, for example, says that the mental effort of operating with EODS is greater in slow urban traffic, and lesser in faster traffic. But she prefers to have EODS in the slow traffic nevertheless. Perhaps her thought is that although it requires somewhat more effort, the extra effort pays off because this is a situation in which the EODS is quite functional for her. Her views:

***Q**: Now I'm going to ask you about the comparison of the EODS equipped vehicles and the non-EODS equipped vehicles. In terms of the mental effort, did you find that it took more mental effort or less mental effort to operate a bus with the EODS than one without it in the slow urban traffic?*
***A**: A little bit more.*
***Q**: In fast urban traffic?*
***A**: Less.*
***Q**: At highway speeds?*
***A**: I'd say a little less.*
***Q**: When you were driving a bus not equipped with the EODS, did you find yourself wishing you had it or glad that you didn't have it, or did it make no difference?*
***A**: I liked having it.*
***Q**: Under what conditions did you wish you had it? Were there any special conditions under which you wished you had it?*
***A**: In the slower congested areas.*

Another driver also prefers to drive with EODS, but unlike the previous driver, he said it takes the same level of mental effort, not more:

***Q**: I want you to think about driving the buses with the EODS versus driving the buses that didn't have it. In terms of the mental effort that it takes to drive a bus, did you find that it took more mental effort or less mental effort to operate a bus with the EODS than one without it in the slow urban traffic?*
***A**: About the same mental effort.*
***Q**: And with fast urban traffic?*
***A**: It's the same.*
***Q**: And with the highway speeds?*
***A**: Same.*
***Q**: When you were driving a bus not equipped with the EODS, did you find yourself wishing you had it or glad that you didn't have it?*
***A**: I liked it. Like I said, it didn't bother me. I'd ask them if I could have one of those buses. Cause I'm on the extra list, so I'm assigned a different run every day, so I'd go to the shifter and say, "I'm on this run tomorrow. Can I have one of those buses?"*

The comments of one driver reflected the views of several others who consider that using EODS requires greater mental effort:

> ***Q***: *Did you find it took more mental effort or less mental effort to operate a bus with EODS?*
> ***A***: *It takes a little bit more because you're adding another element into the situation. It didn't affect me negatively, but I certainly had to use a little more effort to watch the lights. There's no effort for the chimes. You don't have to worry about that. That's second nature just to hear that. But to actually watch for the lights, you had to put a little more effort for that.*
> ***Q***: *And was that true in slow urban traffic, fast and highway?*
> ***A***: *Yeah. Other than the highway where I told you I'd lock it out, I didn't watch lights on the highway. I didn't even look at the lights. I'm in the right lane, I'm staying in the right lane the whole way. If I'm changing lanes I'm going to be watching the mirrors and using turn signals in case the system* (i.e., the chime) *went off, but I wasn't counting on it.*

In other words, the extra mental effort involved actively checking to see if the lights were providing warnings rather than simply allowing them to catch the driver's attention by flashing within peripheral vision or when the driver checks mirrors. Perhaps he was misusing the system in this sense, but it was his perception, and that of some of the other drivers that a driver ought to be regularly checking the lights just as he or she would regularly check mirrors. Therefore, rather than reducing the mental effort, EODS was perceived to increase it for roughly half of them.

One driver described a method of dealing with the EODS that places the driver in a more passive role, allowing the system to notify the driver of potential problems rather than putting the driver in a position of continually monitoring the warning lights. He said this:

> ***Q***: *So how difficult or easy was the system to learn to use to your advantage?*
> ***A***: *It's easy. It's very easy to learn to use the system. The best thing to do with the system is ignore it and let it get your attention instead of focusing your attention on the system. You cannot focus on something else other than what you're doing and that's driving. You can't direct -- you can't be watching monitors and stuff like that.*
> ***Q***: *Okay, so you let it get your attention.*
> ***A***: *Yeah, you need to let the system get your attention. Right off the bat just from natural curiosity, you're going to be eyeballing the stuff. You'll focus on something down the road knowing that it's coming up to see if the system's working, you know, to see if the system picks it up. At first you'll do that just to see. But my personal opinion is your best bet is just to ignore the system – that is, not really ignore it, but get used to the system being there and not ignore it, but know it's there, but do your job as you normally would do without the system and let the system help you when you need it. More than likely you're not going to be aware that you need it until the system tells you.*

Hypothesis: Drivers perceive that the EODS does not distract them or interfere with their other tasks

This hypothesis is accepted, but with qualifications. Generally, the drivers do not find the lights distracting; however, there are certain aspects of the chimes that the drivers report as being distracting. These factors, along with the degree to which the EODS interferes with driving tasks, are discussed below.

Distractions from the lights

Drivers indicated their disagreement with the proposition that the warning lights were distracting to their driving under normal daytime conditions. The final mean scores of -35 and -40 on the initial and final Internet surveys (See Figure 5-10) are indications of disagreement.

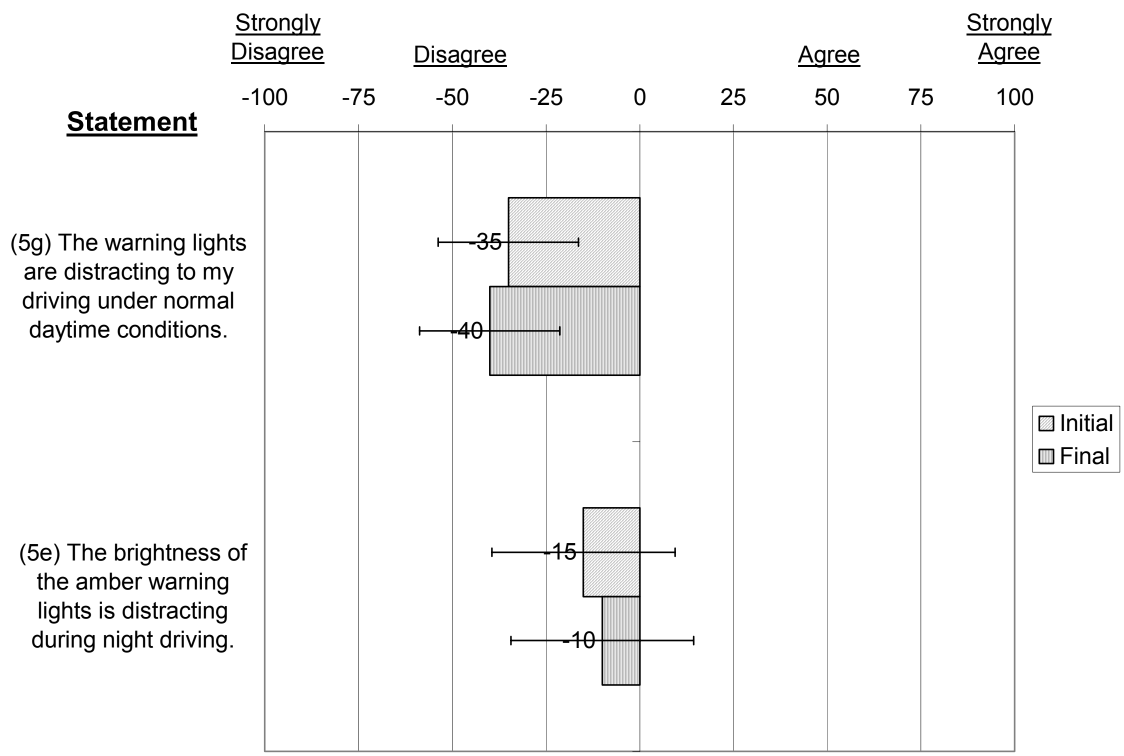

Figure 5-10. Drivers Concerns with Visual Displays

At the initial stage of the interviews, two respondents had indicated that at night the warning lights might become distracting, because they became strobe-like against the black background. Most drivers tended to be neutral or somewhat dismissive of this idea. However, several of the drivers who were neutral on the matter volunteered that they had had no experience with night driving while using the EODS.

Distractions from the chime

Figure 5-11 indicates that the drivers tended to disagree that the chime distracted from their driving. However, they were less adamant in their rejection at the time of the final survey than at the initial survey, an indication that at least some of them were less ready to reject the idea that the chimes could be distracting. One possible explanation for the change in response may be attributable to the frequency of false alarms. Some drivers reported that the false alarms caused the chimes to ring frequently enough to be annoying and to cause the drivers to double-check their mirrors unnecessarily. But, the drivers felt that the chime itself is not distracting, but only the frequency caused by what they interpret as false alarms.

On the other hand, the drivers tended to agree at both stages of the survey that having the chime ring twice was distracting. There were many comments during the in-persons interviews that reinforced this survey finding.

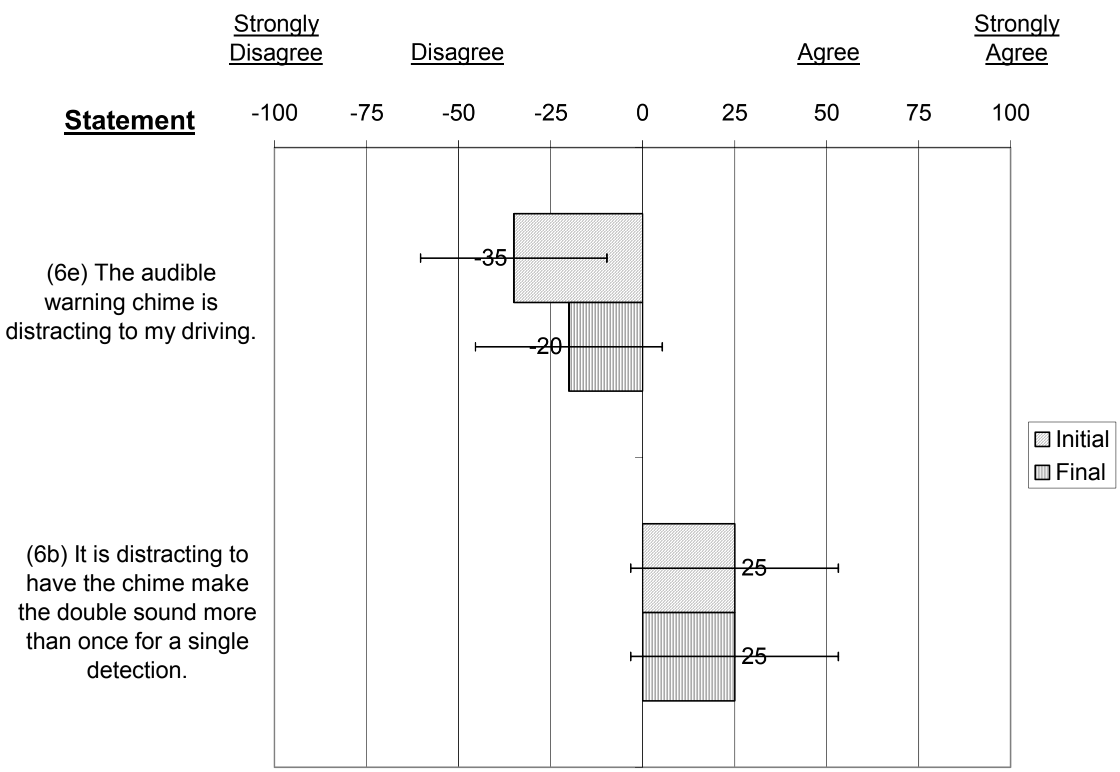

Figure 5-11. Drivers' Concerns with Audible Warnings

Interference with driving tasks

Drivers were asked to agree or disagree with the statement that "the object detection system interferes with my driving tasks." Figure 5-12 indicates that at the initial Internet survey, there was some disagreement with the statement, but that at the second Internet survey the drivers' score on this item had moved to a neutral or very slightly positive response to that statement. Looked at in another way, initially about half of the drivers disagreed with the statement and the other half were mostly neutral. In the final Internet survey, one-third agreed that the EODS interfered with driving tasks, one third disagreed, and one third was neutral. The result was the score of +5 that appears in Figure 5-12. These findings are consistent with the statements of the drivers in the in-person interviews.

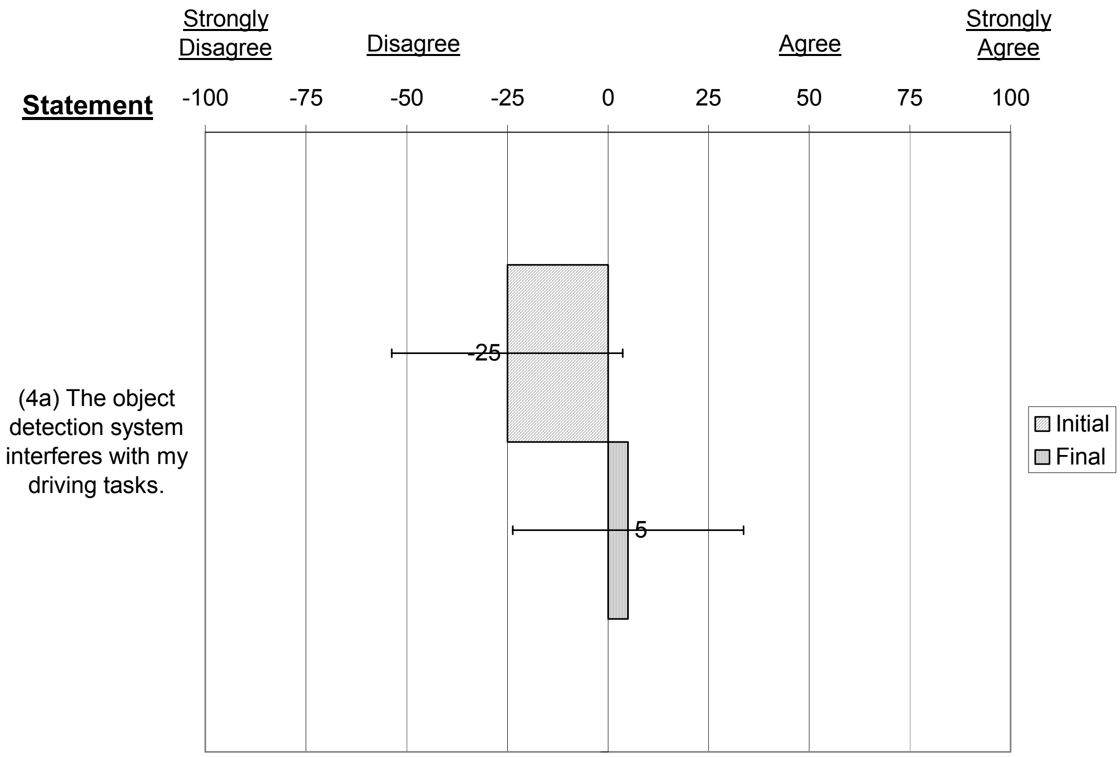

Figure 5-12. Interference with Driving Tasks

Hypothesis: Questions about EODS from riders will create distractions for the drivers.

This hypothesis is rejected. While the drivers reported that some passengers asked them about the lights and the chime, they did not report that this was any more frequent or distracting than the usual banter and questions from passengers. The drivers simply reported that some passengers were curious about the unusual sound and the new lights. They wondered if the chime was part of a game for drivers to play, or if the lights were a kind of detector. These are the types of questions one can expect at any time where visible new technology is added to a bus which has regular passengers. If the EODS were implemented on a large scale, the questioning would end after a short period. Meanwhile it is not sufficiently onerous to consider it distracting.

Another aspect of this question was tested in the survey (See Figure 5-13). Drivers at both the initial and final survey stages disagreed slightly (mean = -10) with the statement that the chime would prove annoying to passengers.

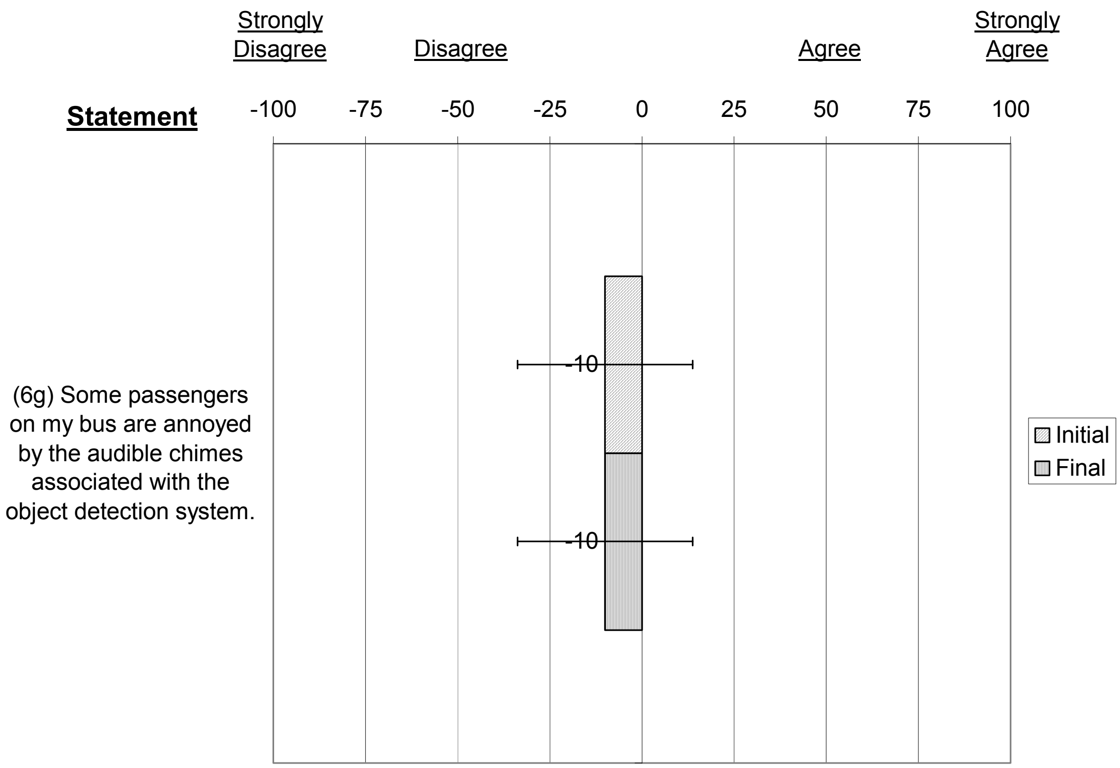

Figure 5-13. Drivers' Response to Statement that Passengers would be Annoyed by the Audible Warning (Chime)

Hypothesis: Drivers perceive that there are too many false positive alarms.

Hypothesis: Drivers perceive that the EODS false positive alarms are a nuisance.

Hypothesis: Drivers perceive that the EODS false negative alarms degrade their confidence in the system.

These hypotheses are accepted.

The perception of false alarms was formally tested primarily in the in-person interviews. However there is also supporting data from the daily questionnaires, equipment condition reports, and minutes from the quality circle meetings.

It was abundantly clear from the in-person interviews that false alarms are a widespread concern of the drivers. Also, we learned that we must distinguish between two types of situations drivers consider to constitute false alarms. The first, which we will call "actual false" is false in the literal meaning in which the alarm appears to be in fact false, not caused by any object near the sides of the bus. The second, to which we will refer as "irrelevant false" is the situation in which there are real obstacles (e.g., retaining wall, heavy traffic, parked vehicles, etc.) and the EODS is appropriately detecting them, but the warning light flashes are so constant that they become meaningless for the driver.[11] The latter is not literally a "false" alarm, but to the drivers, it had the similar effect of causing them to ignore the signal.

When drivers in the in-person interviews were asked how often, if at all, the EODS had given them warnings for "objects" that did not exist or they felt it should not have detected, responses split between rarely (3), sometimes (3), and often (5). No one said "never."

In addition to the Internet surveys and in-person interviews, daily surveys provided useful information related the frequency of alarms and the drivers' perceptions of false positive and false negative alarms. Figure 5-14 shows the distribution of the number of times the audible alert sounded. According to these daily reports, the alarm sounded between zero and 50 times per day, with an average of 12 alerts per day. The drivers report that two thirds of the time when the alert occurred, the bus was traveling at less than 15 mph. Drivers did not always complete a daily questionnaire every day they drove their vehicles during the test. Concerning the false negatives, on 80 percent of the days on which the drivers completed a questionnaire, they reported that they had encountered a situation in which the alert *should have sounded,* but did not.

The kinds of objects the EODS seemed to detect that these drivers felt ought to have been ignored included guardrails, signs, poles, bushes, rain, wind, curb, and even, one driver speculated, the yellow line on the highway.

Many of the drivers attributed the "actual false" alarms to rain. For example

> ***Q***: *Did the EODS rarely, sometimes, or often provide a warning when you felt there was no real cause for it?*
> ***A***: *Sometimes.*
> ***Q***: *What kinds of objects did it respond to that you thought it should ignore?*
> ***A***: *Rain, hard rain. It seemed like when the wind was blowing and the rain was harder, that seemed when the lights were flashing more.*

[11] Initially, prior to the test period, the chime as well as the lights were activated under these conditions. However, the chime was then tied into the directional signal so that this would not occur so often. Thus the warnings were more often from lights than chimes under these circumstances.

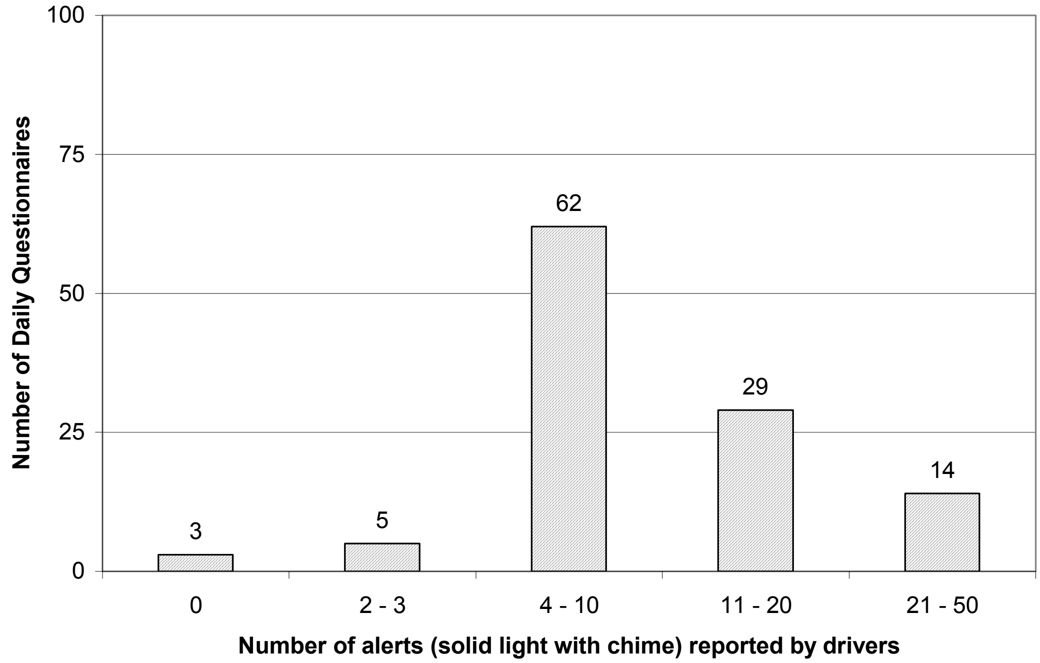

Figure 5-14. Distribution of the Number of Times per Day Drivers Receive an Alert with a Solid Light and Chime

Some, however, felt that these kinds of false alarms occurred regardless of the rain. For example:

> ***A***: *As far as false readings, I got a lot of false readings at highway speed, especially going down 28 here. Three lanes to my left were wide open. There's a Jersey barrier so it's probably about 35-40' to the Jersey barrier, and I was getting a lot of left side signals and there was nothing there.*
>
> ***Q***: *What route is that again, 28?*
>
> ***A***: *Route 28, yeah, the highway. Many times I had that on a couple of the buses. It was something that I brought up in discussion with the Clever Device people when we had our meetings.*
>
> ***Q***: *What did they say about it?*
>
> ***A***: *They first indicated it could have been from weather and I did have one or two days when heavy rain and they blamed it on the spray of the water coming up off the wheels, which actually creates a wall of water next to the bus. That made sense to me. In those couple days that was the case. But I did have a couple days where it was a sunny day like today and it did the same thing. Off hand I can't remember which buses they were. It's been a month or so now when we first started out.*

Another driver said this:

> *I'll tell you the truth, there's times that it seemed like it was just picking up the curb, or the yellow line on the highway. I know it's not possible according to what the guy said, but it just seemed like it was picking up everything sometimes. I mean one day I was going down the busway and it's going off, you know, the lights kept flashing and there's nothing around and on the bus you have at least 8-12' on each side of the bus at that particular point.*

Several drivers commented on receiving false signals on highway 28:

> *Well, you know, when you're driving on 28 going to and off the road, I don't know because of the speed of the bus, but a lot of times there would be nothing on either side of you and it was picking up. I don't know what it was picking up. There was nothing there. I mean even on sunny days without the rain, it would flash or chime on the open road. Everybody's thinking it might be rain. It might be wind that does it.*

Unlike most of the drivers who commented on false alarms and attributed the problem to rain or to the EODS itself, another driver felt that the problem was especially problematic on one bus.

> ***Q**: What about the false alarms you mentioned, did that get better over time, that problem?*
> ***A**: Right off the bat they pulled those buses off and they were working on them for a while, so I didn't have one for a while. When I did get them back, that particular problem I did notice I didn't have any problem except for one bus. There was one particular bus that had been trouble from the beginning and that one still did it. That one still gave you a lot of false readings. But the other ones did seem to work better. I wasn't getting as many false readings on them traveling on the highway. That's the one bus that threw me off the most, going down the highway and there's 35-40' to your left and it's giving you left side bus signals and there's nothing there at all.*

A few drivers maintained that several buses malfunctioned. Whether they are accurate in this assessment or not, the perception that the signals were unwarranted led to a degradation of confidence for some of the drivers. For example:

> ***Q**: And when you were driving a bus that was not equipped with EODS, did you find yourself wishing you had it or glad you did not?*
> ***A**: Glad I did not. Sorry to tell you. There were days I'd come in and I looked on the sheet to see which bus I had, "Oh, good, I don't have one today."*
> ***Q**: What was the main reason?*
> ***A**: Mainly because they -- more of them didn't work the way they should have than did. When I got one I knew I was going to have it all night. I had that thing in the back of my head that if it didn't work right, I was going to have to listen to this thing all night. And then I'd fill out a sheet at the end of the night that didn't work right and possibly have to explain to somebody why it didn't work right.*

A maintenance staff person confirmed that there were problems initially.

> ***Q**: A number of the drivers have told us that only half the buses work and so forth. Was that your observation too, that a high proportion of them were not functioning properly?*

A: *They were functioning I would say erratically at a highway speed and a lot of the drivers, the complaints that came in, were that it was picking up things that weren't there. And then I would take them out, I would look at it from a different perspective like what's causing it to do that, if it's something that I can help with or supply some information. Some of my observations on that were, especially in rain conditions, it seemed like the overspray from the tires when it would kick up and you know how it kind of comes out around the body, it kind of picks that up and that seemed to be more so when the roads were really wet. It seems like wind has a lot to do with it. I know they had made some changes from early on, the two front sensors were on and as you're going down the highway over 45 mph, the wind would be hitting the sensors head on in front. They have made a change to that. It seems to have made it better. It's still there, but it's not as noticeable.*

As noted in Section 2.2, during the FOT Clever Devices personnel desensitized the 2 front corner sensors at speeds of 45 mph or greater (i.e., Highway mode), due to driver reports that the rain was causing numerous false object detections. Several – but not all – drivers confirmed that as the test went on, the changes in the front sensors had alleviated the problem of false object detections considerably.

Of the five buses equipped with the EODS, four were operating on most days of the FOT. Two buses accounted for most of the maintenance reports. Based on vehicle assignments and maintenance reports submitted by the driver, we found that the drivers of two buses submitted maintenance reports on 55 percent to 58 percent of the days the buses were scheduled to operate. Drivers of two different buses submitted maintenance reports on 21 percent to 31 percent of the days. A fifth bus was only scheduled to operate on 10 days and received four maintenance requests.

Drivers mentioned what they perceived to be a general problem with range regardless of the bus they were driving. While the system was intended to operate only within a certain distance of an object, these drivers observed that alarms occurred when the object was out of range. Asked about how well he trusted the accuracy of the chimes, one driver said he did not rely on them to accurately detect objects in urban settings. However, he said he did trust them on the highway:

On the highway, I'd put a little bit more trust in it. It definitely would pick up that car in the left lane, especially in your blind spot on the left side. On the right side it would pick it up. The right side was kind of iffy because sometimes if you -- it would pick up too far a lane. It would pick up more than 8-1/2'.

The attitude of the drivers tended to be that these false alarms caused them to realize they could not rely on the EODS to warn them because it became difficult for them to sort out the valid from the invalid signals. Because the lights are consistently on, the tendency to dismiss the signals as false was more acute with them. The chime, occurring only in conjunction with the turn signals, was less frequent, and was less often dismissed. However, it too sometimes gave signals drivers considered false.

Q: *Okay. In what way was the system a problem for you?*
A: *The constant chimes on turn signals. I had to delay putting my turn signal on till I actually got to the turn so that the chimes wouldn't come on. I couldn't put on my turn signal 150' before the turn, because my chimes would go off. But if I waited*

until I got almost practically to the corner, which was illegal to do, I could put my turn signal on and I wouldn't get any chimes. Now I don't know what caused that or didn't cause it.

This experience did not necessarily cause this driver to dismiss the system as without utility for his driving. He went on to say this:

A couple times -- not that it prevented an accident, but it just picked up that blind spot on my left side on highway speeds, cause I did a lot of highway driving with it and it did pick up those cars in there. If somebody wanted to pass the bus, it picked it up. It didn't pick it up real quick, but quick enough to alert me there was something there. Most of the time I saw it before the system went off, but it was there too.

False alarms can become a nuisance, although consistently drivers argued that in those circumstances they mentally "tuned it out," and that the distraction did not degrade their driving. One driver called the false readings annoying:

As a matter of fact I drove one on Friday and it was giving me false readings. And after about a half hour I ignored the system. That's what happened. I mean if it's going to give me a false reading and I'm going to check out and see what it could possibly be. It's not going to harm my driving in any way, but it would get annoying. Like I said, then I tended to kind of ignore the system after a while.

The irrelevant false alarms were a nuisance to some of the drivers, and caused drivers to ignore the system under various conditions. Even at the initial interview, this was observed to be a problem. As one said at the time:

A lot of the situations, no, you don't need a warning. 'Cause you're coming up on parked cars, the system's going off at parked cars, it's going off at telephone poles, it picks up -- I think it picks up too many things

The repetition involved in driving the same route on many trips during a driver's shift aggravates this problem. One driver pointed out that in evaluating driver reactions to the EODS, it must be remembered that the drivers' tasks are highly repetitious. Therefore the irrelevant alarms become repetitious and drivers become conditioned to ignore them. He said this:

Like with the chimes, it just got a little annoying whenever you hit the turn signal you'd hear the chimes, because you've got to remember we're doing the same thing over and over again. Sometimes it gets -- the noise in certain areas just gets really kind of redundant, like in low speed areas, but in high speed areas it was a little more helpful.

Others echoed this point. Another driver expressed it this way:

***Q**: How about when merging into traffic from a passenger stop?*
***A**: You know when I'm doing that, I'm so -- I may not even hear or pay attention to that, 'cause I'm watching the mirror. I mean I've been doing it for 10 years. You know what I mean? Driving a bus anymore is like breathing.*

Another driver said something similar about the repetitiousness of driving a route, but reached a slightly different conclusion about EODS. He too spoke of the repetitiousness of the drivers' functions, and indicated that a driver comes to the point of not paying attention to the lights or the chimes because they know all of the obstacles, even the cars always parked in the same place day after day. He does, however, nod positively toward the EODS in that he says he regards its ability to pick up something in the blind spot as useful. The difficulty with this, of course, is that if he is no longer paying attention to the lights, he may not perceive the eventual warning of real danger as relevant.

> *A lot of the drivers, we drove the same routes every day, and after doing it every day, every day, every day during the pick[12], usually it's the same cars parked in the same spot. I mean you get used to the route and a lot of times you don't even pay attention to the lights or the chimes or anything, but being that they're there to pick up something in your blind spot I think is useful. But I mean if a lot of the operators do the same route every day, you're making the same turns, you're making the same turns the same way.*

Perhaps the clearest expression of this situation was this exchange:

> ***Q***: *Did you find that at some point you began to ignore the system some or all of the time?*
> ***A***: *Well, once you do the same route all the time like on the 500, there were certain spots on my route that it would chime and I just ignored it because it was the same turn, the same corner, basically the same -- you know what I mean? I started to ignore it. But it's a regular operator that does the same route every day, where someone who works the board[13] is doing something different every day, they wouldn't be used to it. I mean after a pick is over, you can do your route with your eyes closed. And it seemed like the same spot every day.*
> ***Q***: *But the place where you ignored the system was where you knew it was giving you false indications.*
> ***A***: *Right. I knew I had it cleared. Not necessarily false, there was something there, but I knew I had plenty of room. It was picking something up.*
> ***Q***: *False is probably the wrong term. An unwanted warning.*
> ***A***: *Right, right.*
> ***Q***: *Would it be a stationary object it detected all the time that you knew you were far enough away from?*
> ***A***: *Right. I mean I did that four days a week. I knew when it was going to chime and when it wasn't.*

One driver saw the situation somewhat differently. He argued that the chime, though not the lights, would provide a wake-up call to the driver who was becoming bored by the repetition. His reasoning was echoed by those few drivers who argued that the chimes were more useful than the lights and the more dominant view that both chimes and lights were needed in the system that would eventually emerge. He said this:

> ***Q***: *Would you prefer to have only lights and no chimes, or only chimes and no lights?*
> ***A***: *I'd prefer to have both.*
> ***Q***: *Why is that? There's times when each of them could be helpful?*
> ***A***: *Correct. I think that what happens is when you're driving, especially for a longer period of time, if you're in the seat for 4-5 hours, it helps you stay on your toes a little bit more. It helps keep you more alert. It's like an alarm clock going off. Even*

[12] The pick is the driver assignment to a schedule, including the route, during a period of several months.
[13] "Working the board" means operating on various bus routes as a substitute driver.

if there's an object there and you know you've got it cleared and it goes off, at least I think in your inner mind it's going to keep you more alert. It does me, anyhow.

Irrelevant alarms were a result of both the repetitiousness of the situations encountered, but also a consequence of varied traffic situations. In heavy traffic they were more frequent than in light traffic, for example. Therefore, the incidence of this irrelevant kind of "false" alarm would vary by the nature of the route, the time of day, and other factors. The system became irrelevant in heavy traffic situations for two reasons. First, the signals were constant and thus failed to convey the kind of meaning they would have if the warnings were a less frequent event. Second, the traffic was such that the drivers felt they needed to concentrate, using their own skills, and felt they could not afford the moment to check the validity of warnings they knew to be constant anyway.

One driver explained it this way:

> ***Q***: *Did you find that at some point you began to ignore the system some or all of the time?*
> ***A***: *Some of the time, especially in a lot of the urban areas where it's very congested, like the Oakland area where you have tons and tons of traffic, and cars, and people, and poles. I'm more counting on my eyes than the system.*
> ***Q***: *What differences were there in the usefulness of the system in various traffic conditions? Say like close maneuvering in the city in terms of usefulness. I know you kind of touched on this before.*
> ***A***: *I'd rather trust my eyes than to trust that type of system, because there's not going to be too many blind spots in that type of area, because most of it is straight anyhow.*
> ***Q***: *How about between light traffic and heavy traffic in terms of the usefulness?*
> ***A***: *The light traffic would be a little easier because, of course, you'd have a little bit more of a mindset to look at the system. Heavy traffic, I'm not going to look at that system.*

Timeliness of the Warning

Drivers were concerned about the slow response of the system to vehicles approaching at high speed from the rear.

Another significant concern among drivers was not a matter of *false alarms*, but involved what they perceived as the system's slow response. Even at the initial stage of the test, they pointed out that on several occasions during their training runs a vehicle had approached from the rear of the bus to pass at a high relative speed and had passed to the front of the bus (see illustration[14]) before the warning light came on, rendering the warning too little and too late. The perception increased during the test itself.

While this is not a function of system error, it was of concern to the drivers because as a practical matter they felt the sensors could not act quickly enough to meet their needs in some situations in which a vehicle was approaching from the rear at a high relative speed.

[14] When the vehicle pictured at the left was photographed, the amber lights had just ceased, but had not initiated until the vehicle was close to the front of the bus

Thus, this characteristic degraded their confidence that they could rely on it to identify objects in their blind spots. This situation usually would arise at highway speeds on multiple lane highways. Under these conditions, drivers in general had said that the chime warning could be useful to them when changing lanes to the left or to the right.

This issue was widely discussed among the drivers and with the technical team. The arrays of sensors are such that the system as designed simply could not operate quickly enough to warn of a vehicle approaching at a high closing speed. Several drivers who had complained of this perceived shortcoming understood and accepted this explanation, but that did nothing to help them gain confidence.

The problem was not that they would, for this reason, distrust the chime when it sounded. The problem was that they did not trust it always to sound when there was an object in their blind spot. To them, this represented a gap in the alert system that otherwise would have provided a double check on what they were observing in their mirrors.

Between the initial Internet survey and the final survey (See Figure 5-15), there was a major increase in the mean score on the issue of having an audible signal more quickly. The reason for this change was that during the training it had not occurred to most of the drivers that the lag-time in the response would occur. (There was one exception who noticed the phenomenon during training runs.) However, by the time of the final survey, most drivers had experienced it.

One exchange with a driver represented the views of many of them on this issue very clearly:

> ***Q***: *Tell me your understanding of how the system was supposed to work. What kinds of things was it supposed to pick up?*
>
> ***A***: *When you're in slow mode, certainly stationary objects when you're in town, telephone poles, fire hydrants, mailboxes, etc. And urban fast and highway modes, you're certainly looking for vehicles approaching mainly your blind spots, coming up from behind you faster than you are and coming in your blind spot before you get a chance to see them. For instance, somebody coming straight up behind you and then coming over to the left or right of you, coming in on a blind spot. And the system seemed to work okay. It would pick cars up coming up on you. But, like I said earlier, a car coming up from behind you, it may not register until it was up by your front wheel and it was passing you. I think I had a pretty good grasp on how it was supposed to work. At the beginning I did expect it to give me signals a lot quicker and as time went on I found there were a lot of delays in the urban fast and highway modes. In the urban slow it seemed to be pretty -- it was more accurate in the urban slow, going through town and stuff in the 5-10 mph range.*
>
> ***Q***: *So you say a car could be passing you and it would be parallel to your front wheel before the alarm would sound?*
>
> ***A***: *Sometimes. Sometimes that was the case, yeah.*

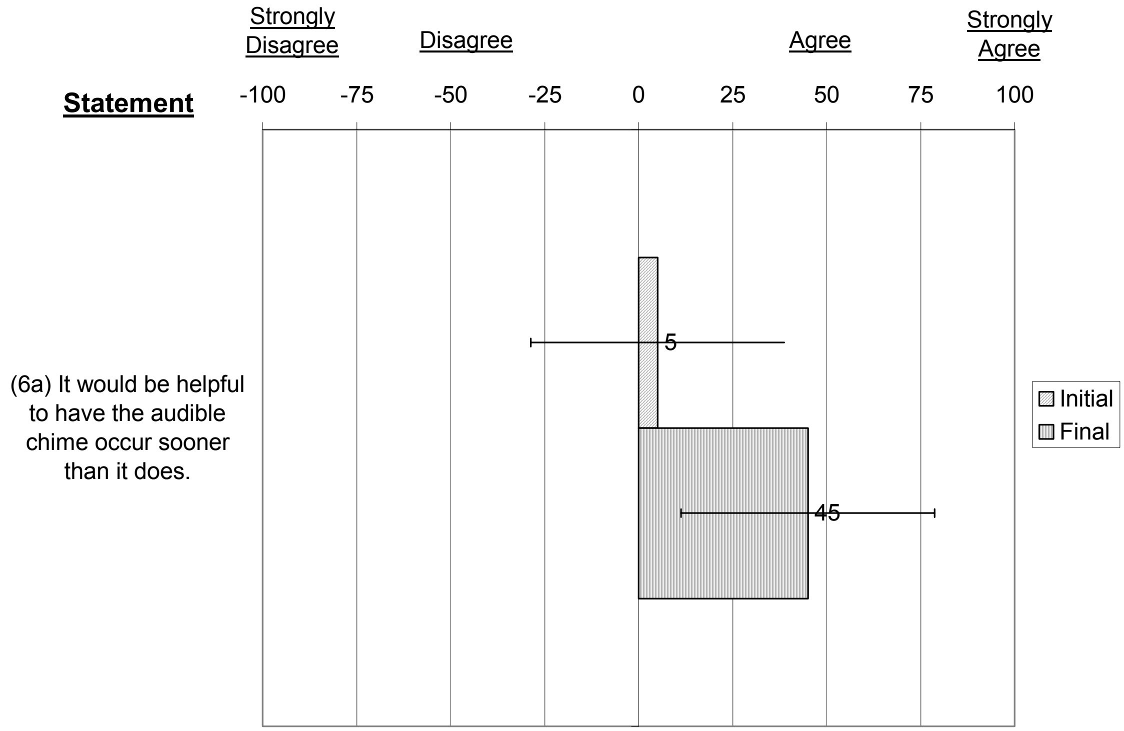

Figure 5-15. Drivers' Opinions Concerning the Timeliness of the Audible Alarm

Q: *Was that because you didn't put your blinker on until then?*
A: *No, you'll still get a light. You'll still get a visual. You won't get any audible unless your turn signal's on…*
Q: *So you wouldn't get a light. You said you complained about that. What did the Clever Device people say about that?*
A: *Well, they said that the number of sensors on the vehicle, I think it was 22, it takes so many seconds for the system to function. It would go around in a pattern, so many sensors would go off at certain periods of time. He says it goes fast, it's milliseconds that it works, but sometimes that reading goes back to the computer and by the time the computer gives the signal it may be half a second, but in half a second time a vehicle traveling 55 mph could be half way down the bus, and that part made sense. Everybody that I talked to and in that meeting felt that it should work quicker. And they said the only way you can do that is to lessen the number of sensors on the bus so it could work faster.*

While the situation of slow response at highways speeds was the most-discussed issue in terms of perceived slow system response, some drivers also cited situations of slow response at lower speeds. One driver in particular cited this as a problem. He was in the habit of testing the system by intentionally driving in a position that should trigger an alarm. In one such situation, he observed:

Q: *But the slow response, how did you -- what specific situation told you this was slower than it should be responding?*

A: *I would have to say urban slow, below 45 -- actually below 25 I believe it was, you're going slow, going through town or something like that, and you're going past a telephone pole is a perfect example and you're -- at that point there's nothing around you, I'm paying attention to the lights to see if they're working correctly. You go past the telephone pole and the pole may be half way back the bus before I get a signal on that side and I'm only this far away from it, only two feet away from the pole. I know it should have -- I'm assuming it should have went off when it broke the plane of the front corner of the bus. That would be my interpretation of it. That was explained to me that that's how it was supposed to work, but there were delayed response times on that. It didn't always do that. Sometimes it did kick -- it did give me a light or an audible tone when it was on the front corner, but there were times, there were many times it wouldn't go off until it was half way back the bus.*

This same driver elaborated on the theme that while the EODS may function as intended at slow speeds, he had hoped it would function to help him also at higher speeds:

Q: *In terms of how fast the system warned you of potential danger, did you find that the lights warned you quickly enough for you to take action?*
A: *No.*
Q: *And the chimes?*
A: *No.*
Q: *So just to clarify, I diagrammed this situation (shows diagram). The big box on the right side is your bus and the little box is the car pulling beside you on your left. You turn your left turn signal on because you're going to change lanes, go around somebody or something, would the chime normally function?*
A: *Yeah. Any time you put your turn signal on if there was anything next to you, the chime did work, yeah.*
Q: *But you said you regarded that as superfluous. But that the way the EODS is supposed to work, right?*
A: *Correct.*
Q: *But to you that was not important?*
A: *It was not important because there were times I'd look in that mirror and I'd see something coming, and I'm going to signal I'm going to move over to the left and sometimes I'll put it on and I would get the audible tone but the car was already halfway down the bus even when I had the signal on. So I did notice a delay. That's why I didn't feel that it was effective. You can't count on it to make your judgment. You can't. That's what I felt. Which I don't think you're supposed to. That's not what the system's designed for. But the delay time on that, I think if you did look, you did put the turn signal, you start going over and then you got the chime, it was already too late. And that's the situation I saw a few times.*
Q: *Well, let's say the bus and the car are moving in parallel, but the car's in the blind spot and the operator checks the mirror quickly and doesn't see anything, puts the blinker on and the chime sounds. You're moving in parallel, so it's not the problem you just described. It's not coming up fast behind you. Isn't that a useful situation?*
A: *Yes, I had that situation and it seemed like it worked okay. There was something right next to the bus traveling the same speed as the bus, I thought that it was working correctly. It was the ones coming by, you're going 55 and there's somebody going 65-70, moving by you a lot quicker, didn't seem like you got a signal soon enough to make a difference in your decision to change lanes. You're not going to change. Your lane's not clear.*
Q: *And your argument is that that may be that the system's working as intended, but that doesn't do you a whole lot of good under those conditions.*
A: *I think so. Yeah, all the slow stuff is the stuff that the system is trying to look for and maybe I was looking for something different. I didn't need enhancement in that*

area. I think as you drive longer and become more experienced, your skills are better. You get a higher level of awareness, and I don't think the system enhances that.

***Q**: In other words you'd pick up those things anyway?*

***A**: Yeah.*

5.4 Objective 3: Determine if Driver Behaviors are Affected by the Use of EODS

Several hypotheses are related to this objective. They are:

- Drivers using EODS are aware that they take fewer risks than drivers without the system, because they have a greater awareness of potential safety hazards.
- Drivers using EODS are aware that they are more vigilant in their driving behavior, because of the feedback provided by the system.
- Drivers perceive that they become dependent on the EODS over time, which degrades their safety-related driving performance when driving vehicles without the system.
- Drivers are aware that they modify their driving behavior (speed, braking, lane keeping, turn signal usage) for particular reasons (to be determined) in response to the EODS.

The first two of these hypotheses are rejected with qualifications and the third is rejected. The fourth is accepted, but with qualification.

Most of the data on which this section is based comes from the in-person interviews. However, two questions from the Internet surveys provided useful information on this issue. First, drivers were asked to agree or disagree with the statement that "my driving habits have not changed for the worse as a result of having the object detection system on my bus." At the time of the first Internet survey, most drivers agreed that this would be the case, as indicated by the score of 80 shown in Figure 5-16. At the time of the second Internet survey, most drivers continued to agree with the statement. However, the level of agreement had slipped somewhat to 65, because three drivers had changed their opinion slightly and were now less likely to agree strongly with the statement. Nevertheless, all but one driver agreed or strongly agreed with this statement in the final survey; thus, rejecting the notion that the EODS degrades driving performance.

The second statement is only indirectly related to the issue of change in driver behavior. Drivers were asked to agree or disagree with the statement that "the object detection system is really only helpful in situations of careless or inattentive driving." Because the drivers consider themselves neither careless nor inattentive, they tended to reject the statement at the time of the initial survey, since some of them thought it might alter their driving habits in their usual course of conscientious driving. At the second Internet survey, the level of agreement had decreased somewhat. During the in-person interviews at the end of the test after they had considerable experience with the system, some drivers offered to comment that the EODS would be especially helpful if driver became bored, or distracted.

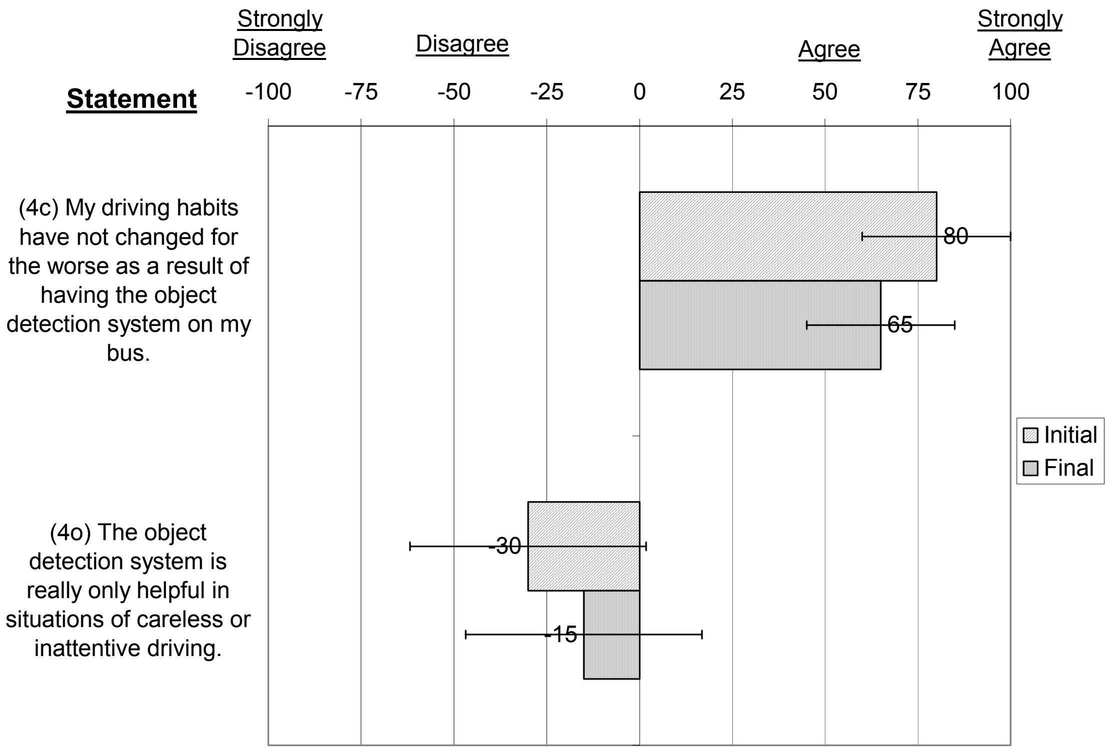

Figure 5-16. Drivers' Perceptions of the Impact of EODS on Driving Behaviors

Hypothesis: Drivers using EODS are aware that they take fewer risks than drivers without the system, because they have a greater awareness of potential safety hazards.

Most of the drivers consistently denied that the EODS had much effect on their driving. They emphasized that they were skilled drivers, and that they relied first on their own judgment. They did not indicate either that they drive more safely or that they take fewer risks because EODS had heightened their awareness of hazards.

However, in certain circumstances EODS clearly did make the drivers more aware of hazards. Yet they did not associate this greater awareness with taking fewer risks because they unanimously said that they were safe, risk-averse drivers to begin with, constantly checking their mirrors, constantly monitoring traffic. Typically, they did not argue that such a system could never improve their driving or reduce the risk inherent in driving, but they implied, or said, that at this stage of EODS' development they lacked sufficient trust in the system to change their driving behavior in any substantial way. This is, of course, self-reported behavior. Without direct observation, we cannot know with certainty that they are reporting correctly.

For example, one driver said this:

> *It all comes down to driver capability. For me it wasn't that useful, because my eyes are moving all the time. It may be very useful for some people.*

Another driver, answering the question of whether the system had been helpful, said:

> ***A***: *Not really, I'm such a good driver. You know what I think it is? If you're in a hurry and you've got this rage attitude, you're going to have all kinds of problems. I don't have them. I stop in plenty of time. I'm aware of what's going on and I react.*
> ***Q***: *Overall, did the system provide greater safety of operation for you?*
> ***A***: *I think any time that they have something that can give you any kind of help, yes.*

Another driver said this:

> *In the beginning I thought it was going to be a unique system. I thought it was going to work well. As time went on, it did not -- I thought it was going to enhance my driving skills, but I found towards the end it did not. I never did have a situation where it helped me avoid a collision or something. So towards the end I just didn't feel it was as useful as I thought it would be from the beginning.*

A third driver said this:

> *It certainly makes you aware of things around you when you're in the slow mode in town, anything under 15 mph I would say it was very useful in picking up objects. It was accurate. Above that when you're rolling pretty good, the accuracy wasn't there that I had expected, so I don't think it enhanced anything*

A fourth driver:

> ***Q***: *Overall, did the system provide greater safety of operation for you?*
> ***A***: *I would say half and half on that. Somewhat. Like I say, I just feel pretty confident about myself out there, so I -- but it does help. I would say somewhat.*
> ***Q***: *Did the EODS help you avoid an accident?*
> ***A***: *No.*
> ***Q***: *If you used it for a year or so, do you believe that it would or would not help you avoid an accident?*
> ***A***: *Well, I'll say sure it can help if the given situation would arise. Fortunately I haven't had it.*
> ***Q***: *And do you think that -- it didn't help you avoid an accident, but do you think it helped you reduce the number of times you had to make evasive maneuvers to avoid an accident?*
> ***A***: *No, I wouldn't say that it did, no.*
> ***Q***: *Did the system provide greater safety of operation for you?*
> ***A***: *No.*

Several drivers were simply ambivalent. The following driver first indicates that the system made no difference in the sense of being helpful. Then he cites how it was helpful, and finally suggests that although it was helpful it did not help him avoid any accident. The exchange was as follows:

> ***Q***: *Did it seem helpful to you or did it seem to be more of a distraction than a help?*
> ***A***: *I'll tell you, it wasn't either. It wasn't distracting to me and it wasn't helpful -- you know I just basically went on about my normal driving.*
> ***Q***: *Okay. Did your views of the system change over the course of the test?*
> ***A***: *Yeah, a little.*
> ***Q***: *Can you explain a little?*

A: *Well, my view of … the chimes really changed from the beginning. I think that's really helpful. It's letting you know what's beside you and even if you are checking -- you know, you have your blind spot, so I think that's (the chime) useful.*
Q: *Oh, so over time you thought that getting the warning chime was useful to you.*
A: *Yeah.*
Q: *And you said it really wasn't distracting, so you didn't have that problem.*
A: *No, it wasn't distracting at all to me.*
Q: *Do you feel that the object detection system helped you to reduce the number of times you had to make evasive maneuvers to avoid an accident?*
A: *No.*

An exchange with another driver produced the comments that the technology is still immature, and that future generations of that same basic technology might produce a different result:

Q: *So overall did the system provide greater safety of operation for you?*
A: *Overall, no. …I don't think it enhanced my driving. I don't think it made me a better driver. If the next generation comes out and it's a little more accurate, that may be a different story. I'm all for technology. I'm willing to give it a shot and it just didn't do what I thought it would do.*

Another driver, citing problems with the technology concluded that it was up to the drivers to rely on their own skills, and not on the new technology:

A: *I've had I think two buses the system just completely went black on me. It completely shut down.*
Q: *Do you have a sense of what the conditions where?*
A: *No. It just completely shut down. One bus the system would shut off for maybe 10-15 minutes and then it would come back, and then it would shut down again. Most of these buses, I've written them up.*
Q: *Did that experience affect your feelings about the system in any way?*
A: *Other than you have to rely on yourself. You can't rely on a mechanical system like that. You have to rely on yourself.*
Q: *Do you feel that the EODS helped you reduce the number of times you had to make evasive maneuvers to avoid an accident?*
A: *No.*

On the other hand, some drivers do find EODS useful, implying that it had altered their behavior. These drivers said that they had not encountered a situation in which it helped them avoid an accident. However, they did speculate that if they used the system for a year, it might help them avoid an accident.

I found it useful. I only been driving for 3 years and I found it very useful going into tight situations, sharp turns, going down Main Street with cars parked on both sides of the road. I think it was very helpful.

Another driver indicated increased awareness of the fact that situations arise unexpectedly, and he credited the EODS system with being able to detect those kinds of situations, implying that this aspect of EODS would reduce the risk:

***Q**: Was there a specific example of how it was helpful?*
***A**: Well, yeah, because you know usually the majority of the time when you're making a turn you look one time and there's nothing there, but you look again and there is someone there or something there and that's where it's very helpful, cause it only takes a split second for something to come up beside you.*
***Q**: So you think the system would help to bridge that gap after you looked the first time and if there was something there it would give you an indication?*
***A**: Yeah. It wasn't there the first time, but all of a sudden it pops up.*
***Q**: Did the object detection system help you to avoid an accident?*
***A**: Knock on wood, so far no. I haven't had any close calls like that.*
***Q**: If you used it for a year or so, do you believe that the object detection system would or would not help you to avoid an accident?*
***A**: It probably would.*

These drivers did not explicitly say that they take fewer risks than drivers without EODS because of having a greater awareness of potential safety hazards. However, some of them probably did have a heightened awareness of hazards because of EODS. In terms of the specific hypothesis, however, the drivers did not indicate that they were <u>aware</u> of taking fewer risks, but rather declared that their normal driving patterns without EODS were excellent. Consequently, the first of the four hypotheses in this section is rejected with the qualification that EODS probably did have some effect of heightened awareness of hazardous situations.

Hypothesis: Drivers using EODS are aware that they are more vigilant in their driving behavior, because of the feedback provided by the system.

Based on the data collected, the hypothesis that drivers using EODS are aware that they are more vigilant in their driving behavior because of the feedback provided by the system, is rejected. We have seen in an earlier section of this report that drivers perceived that their workload actually increased because of having EODS onboard. Again, we reject this hypothesis with a qualification. The qualification is that while drivers may deny awareness of being more vigilant, some drivers appear to have become somewhat more vigilant. This may have resulted from a halo effect[15] of participating in a test of EODS. However, clearly many of these drivers were thinking fairly constantly about obstacles to the side, and appear to have been thinking more about that as part of the test. Whether this would carry forward into an operational use of EODS is an open question. Many drivers were alternating between EODS-equipped and non-EODS buses during the FOT.

Hypothesis: Drivers perceive that they become dependent on the EODS over time, which degrades their safety-related driving performance when driving vehicles without the system.

Additionally, we have rejected the hypothesis that drivers perceive that they have become dependent on the EODS over time, an effect which would have degraded their safety-related driving performance when driving vehicles without the system. Drivers repeatedly indicated that

[15] The halo effect is a generalization from the perception of one favorable trait to an overly favorable evaluation of the whole group of traits.

it made no difference to them in terms of safe driving habits whether they were using a bus equipped with EODS. But again and again in the in-person interviews, drivers denied becoming dependent on EODS, emphasizing, for example, that they abandon EODS in heavy traffic and rely on their own judgment, finding EODS a distraction. We have documented these opinions earlier in this report.

Nevertheless, with any new technology there is always the potential that people will become dependent upon it, and that their normal skills – by using the technology – will be degraded. Therefore to reject this hypothesis is not to suggest that eventually a system such as EODS would not result in such a deterioration of basic driving skills. It is only to suggest that we did not observe such deterioration during this brief operational test.

Hypothesis: Drivers are aware that they modify their driving behavior (speed, braking, lane keeping, turn signal usage) for particular reasons (to be determined) in response to the EODS.

The fourth hypothesis is accepted, with qualification. There was no evidence that they altered their speed or braking as a result of EODS. However, both lane-keeping and turn signal usage, apparently did change somewhat. As has been pointed out earlier in this report, at higher speeds drivers found that they could utilize the chime coupled with the turn signal to double check the safety of changing lanes. Although there were clearly limitations on the success of the chime under these conditions, such as the failure to detect a rapidly passing vehicle quickly enough, and the apparent detection of phantom objects from time to time, when an obstacle did appear in the blind spot, the chime was perceived to provide an accurate indicator of the danger in changing lanes.

5.5 Objective 4: Determine if Drivers Value the EODS and Believe it is Effective for Improving Safety

Six specific hypotheses relate to this objective. In various ways they overlap with hypotheses discussed previously in this report.

- EODS enhances drivers' abilities.
- Drivers perceive that the EODS is effective under specific (if not all) driving conditions.
- Drivers perceive that the EODS will help avoid accidents.
- Drivers trust the EODS and perceive it is useful.
- Drivers prefer to use the system
- EODS increases job satisfaction of drivers.

Figure 5-17 summarizes the drivers' perceptions from the Internet survey concerning the impact of the EODS on driving safety and the overall value that they place on the system. The results are discussed below while addressing the specific hypotheses.

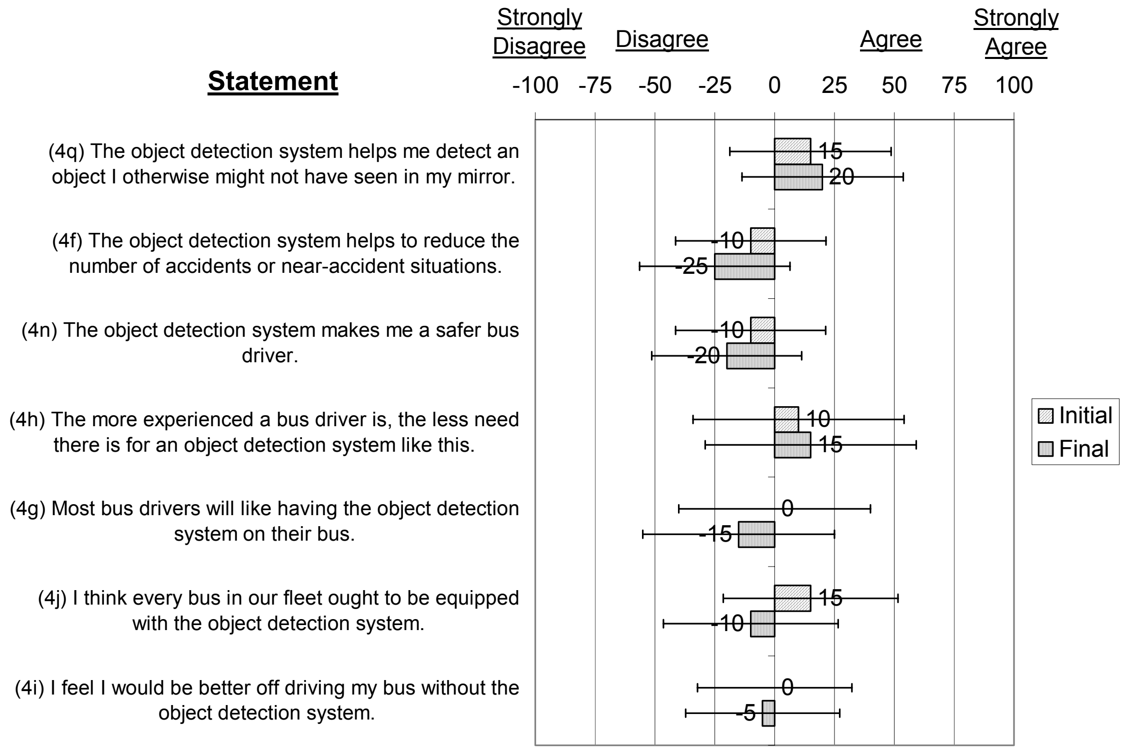

Figure 5-17. Drivers' Perceptions Concerning the Use of EODS as an Object Detection Tool, its Impact on Driving Safety, and the Value they Place in the System

Hypothesis: EODS enhances drivers' abilities.

This hypothesis is accepted with the qualification that it overstates the impact of the system on driver abilities by implying that it has an across-the-board effect. As discussed in Section 5.4 (Objective 3), there is some evidence that the EODS has a positive effect on driver behaviors involving lane-keeping and turn signal usage. Although the drivers have mixed feelings about the degree to which the system changes their behaviors, this hypothesis is accepted by the level of agreement (half of the drivers agreed) with the statement that the EODS helps drivers detect objects that would not be detected in the mirror.

Hypothesis: Drivers perceive that the EODS is effective under specific (if not all) driving conditions.

This hypothesis is accepted with qualifications because most of the participating drivers could identify certain conditions under which the EODS was somewhat useful, when it was operating properly. For example, in the in-person interviews the drivers generally felt the lights were somewhat effective in slower traffic situations and less effective in the faster situations. They tended to perceive the chimes as most effective in changing lanes at speed and detecting vehicles passing a bus when a lane change is needed in an urban slow situation such as pulling away from a bus stop. Some reasons for the qualified support for this hypothesis are noted below.

Several drivers felt the EODS was effective in situations in which a bus has stopped to pick up or discharge a passenger, and needs to pull back in traffic, changing lanes to the left from a full stop. For example one driver said:

> *That's when it worked for me, when I was pulling out from a stop. I was pulling out from a stop and I had my turn signal on to pull out and the chimes went off. I wasn't aware that that car had come up from behind me and was starting around me and it warned me.*

Another driver suggested that EODS was very helpful in travel through intersections. He even suggested that he had avoided a significant accident because of an EODS warning. He said:

> *It helped me avoid that accident that one time. Do you want me to tell you about it? I guess it's the corner of Negley and Center, it's a tricky intersection. You have two lanes coming into the stop and then you have one lane coming from the right. I was pulling into the stop with my turn signal on and I checked my mirror, checked the side, there was nothing coming from the right. I proceeded into the stop and the chimes went off. I looked and there's a guy running the stop sign with no clue that I was even there. So I blew my horn at him and checked my left side mirror, there was no one in the left lane, I swerved to the left. I guess he swerved around me and we avoided each other. I mean I don't even know if I wouldn't have blown the horn and moved, I still don't think he would have seen me. I mean his head was just an inch above the dashboard. And that chime -- I had a standing load. It was rush hour. Somebody would have been hurt.*

Regardless of the specific facts of this case, the driver clearly perceived that EODS had significant potential benefit. In this case that potential benefit related to driving away from the stop at an intersection, and involved a signal provided by the chime.

Hypothesis: Drivers perceive that the EODS will help avoid accidents.

This hypothesis is accepted with qualifications. As discussed above, two drivers reported that the EODS helped them avoid accidents. However, at the time of the initial survey, drivers were in mild disagreement that EODS helps reduce the number of accidents or near accidents, as gauged by their responses (mean score of -10). At the time of the final survey this mean had declined to -25. Several examples have been quoted from the in-person interviews to illustrate the attitude of drivers on this issue. And there is considerable discussion in Section 5.4 concerning changes to risk-taking behavior, general driving behavior, and awareness of safety hazards. Typically, drivers felt that they had avoided no accidents and had taken no additional evasive maneuvers because of EODS. They did not, however, reject the idea that such a result would be possible in the future.

During the in-person interviews several questions were asked which related directly or indirectly to this objective. These are the results:

- **Did EODS help to avoid accidents?** While most (10) reported that it did not help to avoid an accident, 2 reported that the EODS did help to prevent an accident. Asked if in a year of using the EODS, drivers thought the EODS would or could help to prevent an accident, 7 said it would, 2 said it could, and 2 did not think that it would help to prevent an accident.

- **Did EODS reduce evasive maneuvers?** Seven drivers did not think the EODS helped to reduce the number of evasive maneuvers they took to avoid an accident, while three reported that it had.

- **Did EODS provide greater level of safety?** The driver response was evenly split on the question of the EODS providing greater safety of operating (5-yes, 2-nuetral, 5-no).

In their remarks during the in-person interviews, several drivers made it clear that they felt future versions of the EODS had potential to reduce accidents but that the current version did not.

Hypothesis: Drivers trust the EODS and perceive it is useful.

Data presented in a previous section of this report dealing with false alarms is sufficient to indicate that the hypothesis that "drivers trust EODS" should be rejected. Too many of the drivers learned to distrust or ignore the EODS signals even after the problem with false signals caused by rain was reduced. It is also important to point out however, that some drivers do consider the EODS useful under certain circumstances.

Hypothesis: Drivers prefer to use the system.

This hypothesis is rejected. The selected survey results presented in the Figure 5-17 suggest that most drivers place little overall value on the EODS in its current form. In both the Internet survey results portrayed in the chart and in individual interviews cited throughout this report, drivers are close to neutral on the question of whether they are better off with or without EODS.

Typically in the in-person interviews they said it made no difference to them whether they drove with it or without it. The mean scores of zero at the initial survey and –5 on the item "I feel I would be better off driving my bus without the object detection system," at the final survey confirm this view. For the hypothesis to be accepted, drivers would have had to soundly reject this statement.

Moreover, at the time of the initial survey, drivers gave a mean score of 15 to the idea that all buses in the Port Authority fleet should be equipped with EODS. However, by the time of the final survey that had slipped to -10. As drivers explained in the interviews, this deterioration had to do with the rate of false alarms and other reasons for which many drivers were disappointed in the performance of the system.

Hypothesis: EODS increases job satisfaction of drivers.

The hypothesis that EODS increases job satisfaction of drivers is rejected. Although one driver sought to work with an EODS-equipped bus (apparently for the novelty of it and interest in the test) most regarded driving with or without EODS in a neutral manner, and some actively avoided driving the EODS equipped buses. This is not to say that in the long-run a fully functional EODS system would not increase job satisfaction, but at the present state of development it does not.

5.6 Objective 5: Determine Drivers' and Mechanics' Perceptions of System Quality and Recommendations for System Improvement

This objective focuses on obtaining perceptions of quality and recommendations for system improvement from the participating drivers and mechanics. The recommendations can address system performance and functionality, training, ease of use, false alarms, and system reliability. Four hypotheses are associated with this objective:

Hypothesis: Drivers have recommendations for changes that might improve the performance or functionality of the EODS. (Examples include location, brightness, flashing rate, and size of lights; and duration, type, uniqueness, and loudness of chimes).

Hypothesis: Drivers have recommendations for changes that might make it easier to use or learn how to use the EODS.

Hypothesis: Drivers have recommendations that might reduce false alarm rates.

Hypothesis: Mechanics have recommendations for improving the reliability of components.

As indicated by the quotes provided throughout this report, the drivers and mechanics offered many recommendations for improvement of the EODS. The suggestions are by no means unanimous. In some cases they are the suggestion of only one driver, and should be regarded as such. However, the fact that they had thought about these recommendations is an indication of their optimism about the potential of this technology. The suggestions offered by the drivers covered many topics including the functionality of the driver-vehicle interface (types, levels, and frequency of alarms), the functionality of the sensors, system reliability, and driver training. Specific suggestions made by the drivers include:

- Reduce the double chime to a single chime.
- Drop the three-level system for the lights and replace it with a two-level system, including only flashing and steady-on.

- Just as the lights differentiate between events on the right and the left of the bus, create a dual system for the chimes also so that the driver can identify which side of the bus the chime is indicating.

- Develop a faster warning system to cope with highway speed situations in which a bus has been passed from behind at high relative speed, and to cope with other situations in which a bus is being passed by a vehicle moving at high relative rate of speed.

- Increase the reliability of the system by reducing its response to environmental factors such as rain and wind.

- Provide an ambient light sensor for the warning lights such that it can dim them at night to reduce the strobe-light effect that some drivers report.

- As the EODS system is being further developed, inform the drivers during training that the system is likely to provide some false warnings, and warnings that drivers would find irrelevant in order to reduce or avoid the initial post-training distrust of the system.

Maintenance personnel made two primary suggestions, one involving diagnostics, the other a suggestion involving training that echoed what the drivers had recommended.

- Realism in training is of interest to maintenance because it would perhaps reduce the number of occasions on which drivers reported what seemed to be a malfunction, but was in fact a normal operation.

- They suggested developing a method to determine which, if any, sensors were malfunctioning. The suggestion was to enable a laptop connection such that the sensors could be individually tested while on a test run. At the moment, the respondent said, the only way to test each sensor was to identify it through a process of elimination by physically blocking each sensor individually using a sheet of cardboard, and operating the bus briefly with the one sensor blocked – hardly an efficient method.

I would think that as far as the diagnosing of the system, the software that they provide for us, I think it's important for us to, as mechanics, to make a diagnosis, be able to look at what the sensor's seeing. We don't have that ability right now. In other words if there is a sensor that's acting up or whatever, we need to be able to do that while driving down the road with the laptop, have somebody driving and be able to address that particular sensor so that we can just see what it's looking at. Not that we need to change anything or want to change anything, but to have the ability to see what it's seeing.

Q: *Okay, so now all you can do-- Let's see if I understand this. Now if a driver comes to you and says this thing was beeping when it should not have been when he was out on Route 28 because there was nothing there for it to respond to, you just have to take the driver's word for it and try to figure it out from there, or you have to figure out some way to isolate each sensor to see if one is malfunctioning. Whereas what you would like to do is take a driver and somebody else, go out Route 28 with the laptop and watch what the sensor is seeing?*

A: *Right. They made a software change on the bus originally to turn off the two front sensors to try to eliminate some of false signals. We were still getting some false signals, but it would have been nice to be able to tune in to each one of those sensors while you're driving down the road, seeing if it's actually giving something back, a reading, when it shouldn't. So if it's still giving a signal back, then we know there's a problem over a certain mile per hour, say at 45 mph it shouldn't be giving a signal back, but it is, then we know we need to look there. We can't do that right now. All we can do is we get outside and basically tape a piece of cardboard over the sensor, but you have to pull off to the side of the road--*

Q: *So you'd like to be able to turn off the sensors even?*

A: *Not so much to turn them off, but just to see what they're doing, just to view it as a view only, nothing to change but it would be a lot easier than getting out of the bus, putting a piece of cardboard in front of it, especially when you're on the highway. It's a lot easier just to dial that in on the computer and do it. I guess they (the system designers) really didn't understand what help that would be for us, but as far as diagnosing something, just actually being able to see what it does would be helpful. Right now what we can do with the system is we can look at one individual sensor but we have to unplug the string to do it. When we do that we disable the system so you can't do that going down the road, because then the system's not working.*

Q: *So you want to look at all sensors really, not just one.*

A: *Yeah, basically be able to have the ability to plug in and then while the system's working and view a particular sensor, you know each one has an address on it, we can type in that address and look at that particular sensor if we suspect it's working or not working. We can actually check it.*

Q: *You can isolate the sensor that's giving you the trouble. And now the only way you can do that is to tape cardboard over it.*

5.7 Objective 6: Determine if Driver Acceptance is Affected by Maintenance Requirements

This objective focuses on the relationship between maintenance issues and drivers' acceptance of the EODS. For example, when perceived maintenance issues were reported by drivers, how well did they understand the true problem? And how did they feel about the severity and frequency of failures? Three hypotheses were concerned with this objective:

Hypothesis: Drivers perceive that the failure rate of the EODS is too high.

Hypothesis: System failures degrade the drivers' confidence in the system.

Hypothesis: System failures occur under certain conditions.

These hypotheses are all accepted with qualifications. The qualification regarding these hypotheses has to do with equipment performance that the drivers considered to be a malfunction, but that was often only be a misunderstanding of the system's capabilities. Of the 137 daily questionnaires turned in by the drivers, three had comments that indicated system shutdowns, but even those situations may not have been associated with actionable maintenance items. The reason is that there was a problem discovered during the FOT that involved the brake purge system, which was known to be causing some system failures when blasts of air from the brake purge system took the system off-line. The frequency of the air blast was so close to the sensors' operating frequency that the buses were causing their own EODS to shut down due to the interference, particularly when the sound from the air blast reflected off a nearby vertical surface (like another bus). Thus, the system may have been shut down temporarily by an organic stimulus without its actually having any malfunctions, although that distinction was not recognized by the drivers initially.

Of the 67 Object Detection System Maintenance Evaluation Forms submitted, only a small number were reported by Harmar's FOT mechanics to have described bona fide maintenance problems that they could fix. Many of the maintenance items reported by the drivers were not occurrences on which the Harmar maintenance group could take action, because they would require software changes that only Clever Devices could make. Rather, the Harmar maintenance group could only address issues in which the system was not operational (i.e., the blue light was not on). During the course of the FOT, Harmar mechanics replaced a few sensors and performed some rewiring. They had some trouble with their diagnostic equipment picking up all 20 sensors on a bus, but they commented favorably on the system's durability. There were only four maintenance events reported in which the operating system actually needed repair. The other reported malfunctions were either caused by special circumstances (like the brake purge system blasts) or alternatively, the drivers just did not understand the system design, capabilities, and limitations.

For example, many drivers submitted maintenance reports that identified a system delay in detecting a stationary object. In this scenario, a stationary object like a car may not have been detected until the bus had nearly passed it. Then the light or chime would finally sound when the object was at the bus' back corner. Given this scenario, many drivers felt that the system should have detected the object. Consequently, they thought the system was either malfunctioning or had a design flaw, and they turned in a maintenance report or wrote the circumstances in on a daily questionnaire.

What they did not understand (at least initially) was the physics and design limits of a system that was designed to give peak performance against objects with a relatively slow closing rate of approximately seven mph. The EODS was not intended to be a "car counter." If the bus was going relatively fast, the pulsing of sensor groups in their cycle times meant that an object could miss being detected as it passed down the side of the bus as a result of relative speed, location of the object, and the polling of the sensors. The drivers were virtually unanimous that the Urban Slow mode was the most useful, followed by Urban Fast, and then Highway Mode. One reason that helps explain their observation is that this phenomenon of missed detections was reduced at speeds.

During the training sessions, drivers were not informed about this situation because it was not recognized it as a problem. Later, Clever Devices worked with the Port Authority to explain what was happening. Although this represents a shortfall in the training program, the instructors themselves were not aware of the limitations of this design feature until the perceived "missed detection" phenomenon began to occur. This was the only shortfall encountered in the Port Authority's training program, but in retrospect it is understandable why the phenomenon may not have been recognized until the buses were operational. However, the maintenance staff stated that they needed to have more training in the basics of the system in order to perform more efficient diagnostics and maintenance.

5.8 Objective 7: Identify Institutional Barriers and Benefits Related to Driver Acceptance

Hypothesis: Drivers perceive that the EODS invades their privacy.

This hypothesis is rejected. Data collection instruments like the interviews, Internet surveys, and Quality Circle forum gave drivers a free and open opportunity to speak. The drivers never gave any indication that either the EODS or the data collection tools invaded their privacy. They did not appear to be inhibited in saying what they felt about the system.

Hypothesis: EODS will improve driver training.

This hypothesis is accepted. Previous technology implementations in Port Authority buses appear to have left some drivers with initial concerns about utilizing a system as advanced as the EODS, or with skepticism as to its effectiveness. However, the majority of drivers view the EODS in a positive light. The successful communications and organization that went into the driver training program helped make that acceptance possible and will serve as a useful guide for improving the process in other types of driver training.

Hypothesis: EODS will make it easier to test and deploy other new technologies.

This hypothesis is accepted. The training conducted at the Harmar Division was effective and useful. Further, it appears that the Port Authority, including its drivers, management, and maintenance staff, learned from the overall experience. These lessons included the areas of training, driving experience, maintenance experience, and management experience in how to field new technologies. There are also institutional lessons accrued from the stakeholders having worked together successfully. Thus, the lessons learned from generating and implementing the overall program for the high-technology EODS can be assumed to have collateral benefits for the abilities of a transit authority to test and deploy other new technologies.

Hypothesis: Testing of this technology will improve communications between drivers and management.

This hypotheses is accepted. The focus that the project brought to the Harmar Division and to the transit-riding public had positive results. The Port Authority did an excellent job involving all stakeholders. As the key FOT controlling organization, they understood the importance of clear, well-defined communications among all participants and moved to ensure that it was attained. Chains of communication appeared to function in a uniformly excellent manner. All stakeholders knew who the decision makers were and what they were doing. The Port Authority maintained strong communications with the funding organizations, FTA and PennDOT, as well as their own operations management, instructors, drivers, and mechanics. They also maintained a close relationship with Carnegie-Mellon University, who is involved with the side collision warning part of the Integrated Collision Warning System (ICWS). The Quality Circle meetings were routinely attended by a representative of the ICWS.

Every significant step in the FOT process was thoroughly documented. For example, at a December 2002 meeting prior to the FOT, the Harmar Division Director of Service Delivery published a Project Overview Report with a description of the Pre-Test Phase Organization/ Implementation Efforts. This very useful document included names and titles of team members, minutes of meetings held to date, photos of system hardware, maps of routes that were selected for the FOT, tracking forms, description of bus types and numbers, bus manuals, system functional specifications, and FOT objectives and timelines. The Port Authority included representatives of the Amalgamated Transit Union, Local 85 squarely in all of their planning and execution steps. One of the union representatives trained on the EODS system as a driver.

The training was similarly comprehensive. Drivers received information by several different methods including video, classroom, and hands-on. Clever Devices was present at many of the meetings and was teleconferenced in on others. They were thoroughly integrated into the FOT, so that their technical representatives were visible and familiar to all participants. Decision makers in the chain of command were known to all. They typically acted quickly on any problems or issues, deriving a strategy for solution if the issue could not be addressed right away. The Port Authority's commitment and enthusiasm for the FOT and its evaluation were strong.

In short, the Port Authority executed their role flawlessly, which could not have happened without the solid communications they put in place. That communications structure appeared to have brought drivers and management together in a close operating relationship, which serves as a good model for any future deployer of the EODS technologies.

Hypothesis: Drivers perceive that the EODS improves the public's perception of the Port Authority.

There is insufficient evidence with which to accept or reject this hypothesis. The only reference to the public's perception in the findings came from drivers' reports (in the Quality Circle meetings) that transit passengers asked more questions about the audible warning sound (chime) in the morning. One instructor reported that no customers asked questions about the chimes during a mid-day follow-up session that she conducted. The reason for this trend is not known. Passengers gave no direct responses related to their perception of the Port Authority. However, the EODS-equipped bus that was demonstrated at the National IVI Meeting in Washington, D.C. in June 2003 received a great deal of media attention, both locally in Pittsburgh and nationally.

6.0 CONCLUSIONS

1. **<u>The test produced useful information for the system developer</u>.** The developer of the EODS, Clever Devices, was actively involved throughout the design, installation, and operational phases of the FOT. They were constantly assessing the functionality of the five retrofit bus systems based on their own observations and the comments received from drivers and mechanics. While this FOT was not specifically designed to make comparisons between the Gen1 system (as tested in 2001) to the current Gen2 system, Table 6-1 summarizes the observed results of selected enhancements tested on the EODS FOT as a result of the lessons learned from the 100 bus Gen1 FOT.

Table 6-1. ODS Evolution from Gen1 to Gen2 and Driver Reactions

System Characteristic	Gen1 Limitation	Gen2 Change	Driver Reaction to Gen2
Audible tone	Annoying	Changed tone and frequency	No complaints about Gen2 audible tone
Frequency of audible alerts	Too often	Many situations used only visual alerts	Drivers appeared to appreciate change
Alert algorithm	Large percentage of unwanted alerts – did not give driver useful or new info.	Differentiated alerts based on speed and distance of object from bus	A much smaller percentage of warnings appeared to be unwanted
Alert levels	Only one level	Three levels based on speed and distance of object from bus	Accepted by drivers but two levels recommended
Proximity to objects	No capability to differentiate	Three zones implemented	Drivers appeared to see as favorable
Enhance proximity detection at corners	No capability	Additional sensitivity added at corners	Drivers appeared satisfied with changes
Variation of alert mechanisms	None	Several based on flashing lights and audible alarms	Drivers liked having both lights and audible alarms. Prefer single chime.
Security of systems from vandalism	Poor	Enclosure durability improved	No apparent vandalism
Suitability for low speed operations	Not good	Additional sensors and granularity	System performed better at low relatives speeds
Effect of weather	Not identified – too many other issues	Sensors embedded in "beauty strip"	Wind and rain, including sensor water intrusion, degraded system performance

Just as the limitations of the Gen1 ODS were addressed by the Gen2/EODS design (as illustrated in Table 3), Clever Devices, the system developer, plans to continue to explore ways to improve on the limitations of the EODS for the next phase of this technology. Thus, lessons learned from this incremental improvement process will benefit both the evolving EODS-based technology as well as the ICWS developmental efforts.

2. **<u>Drivers used the EODS as a tool, not as a system designed to give warnings of imminent collisions</u>.** Initially, drivers tended to think – erroneously – that the EODS might be a collision warning or avoidance system. As the FOT progressed, drivers became more aware of the EODS' true design and grew more comfortable using it as a driver assistive aid.

3. **<u>Drivers found the system easy to learn but needed a better understanding of system limitations</u>.** For example, many drivers initially believed EODS should detect all objects around them, including stationary objects such as lampposts. Consequently, when a bus passed such an object at a relatively fast speed and no detection registered, they concluded that the EODS was not working correctly. That initial misperception about the EODS' design limits proved difficult to reverse.

4. **<u>The majority of the drivers perceive the benefits of the EODS technology (once it is fully developed)</u>.** EODS did not reduce the drivers' workload (many drivers found that the technology presented them with additional demands in an already hectic environment). But drivers valued it and saw its great potential for safety improvements, particularly if the rate of false alarms and the adverse effects of weather were reduced. Two of the drivers felt that EODS had helped them avert accidents, including one potentially serious collision.

5. **<u>The EODS FOT was pioneering work that produced much useful information, particularly about the DVI</u>.** That information will benefit development of the ICWS. It will advance transit community knowledge on how to successfully implement applied research, train transit operators in the use of high-tech systems, and facilitate the collaboration between transit agency and research team.

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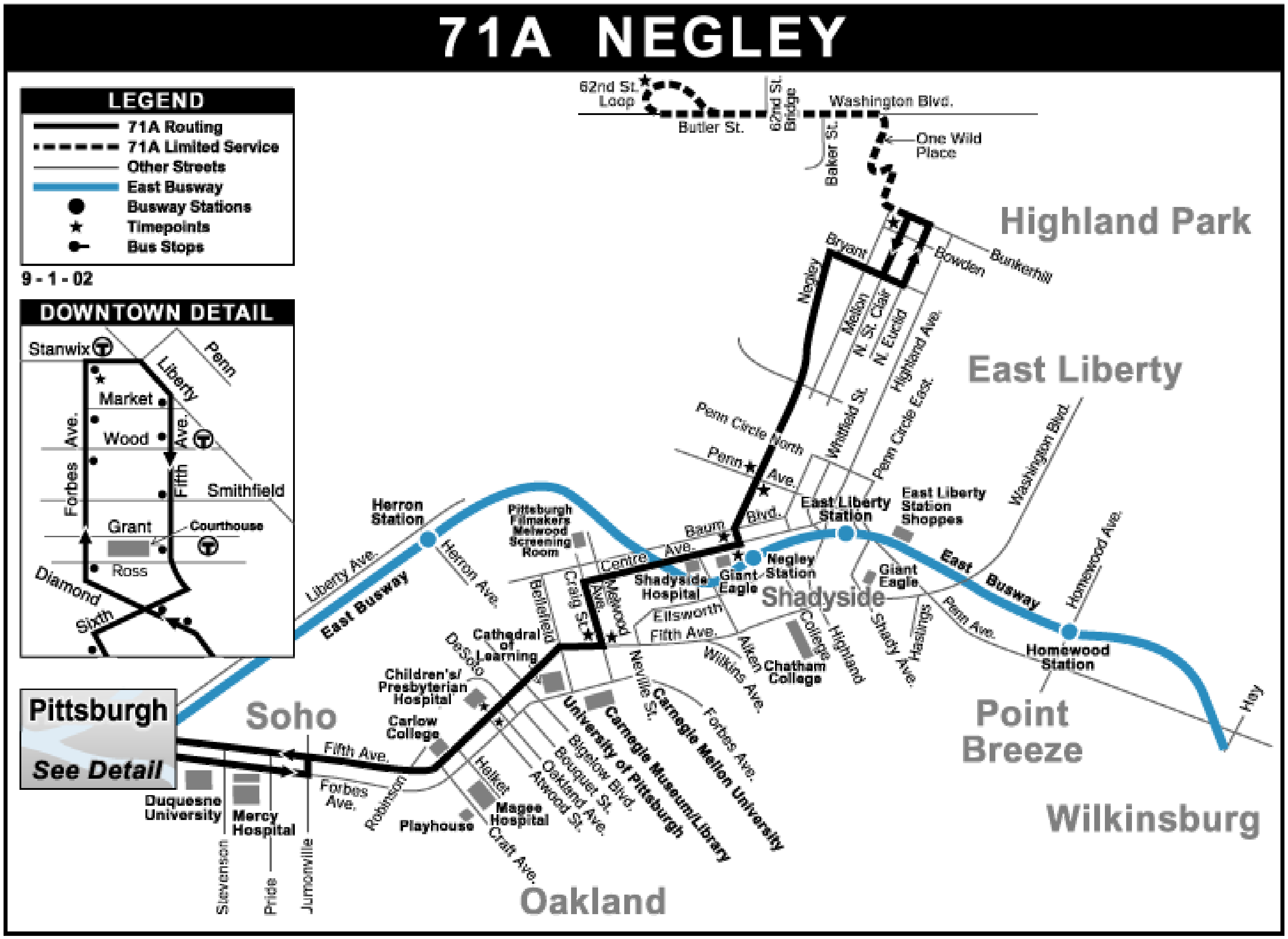
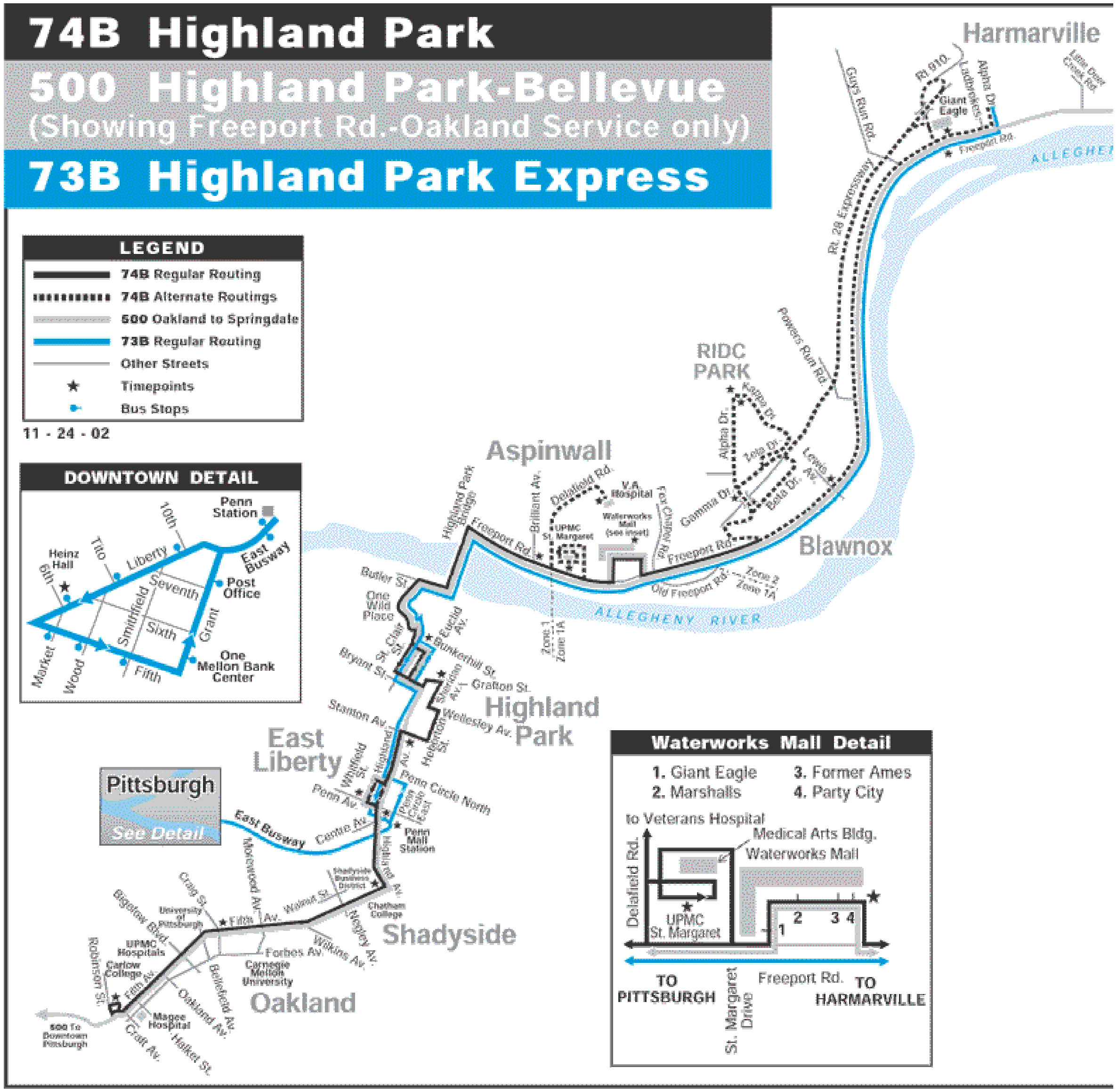
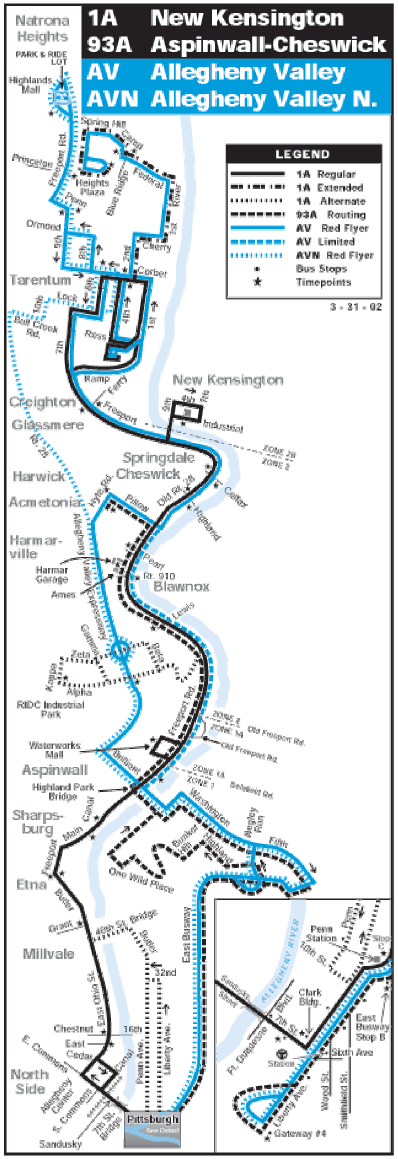
Evaluation Plan for the Clever Devices Enhanced Object Detection System (EODS) Field Operational Test, Battelle Memorial Institute for the Federal Transit Administration, February 7th, 2003.

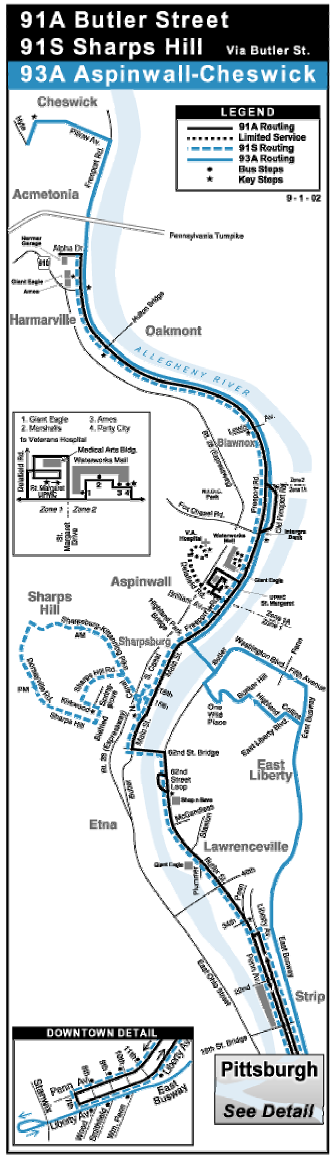
Appendix A:

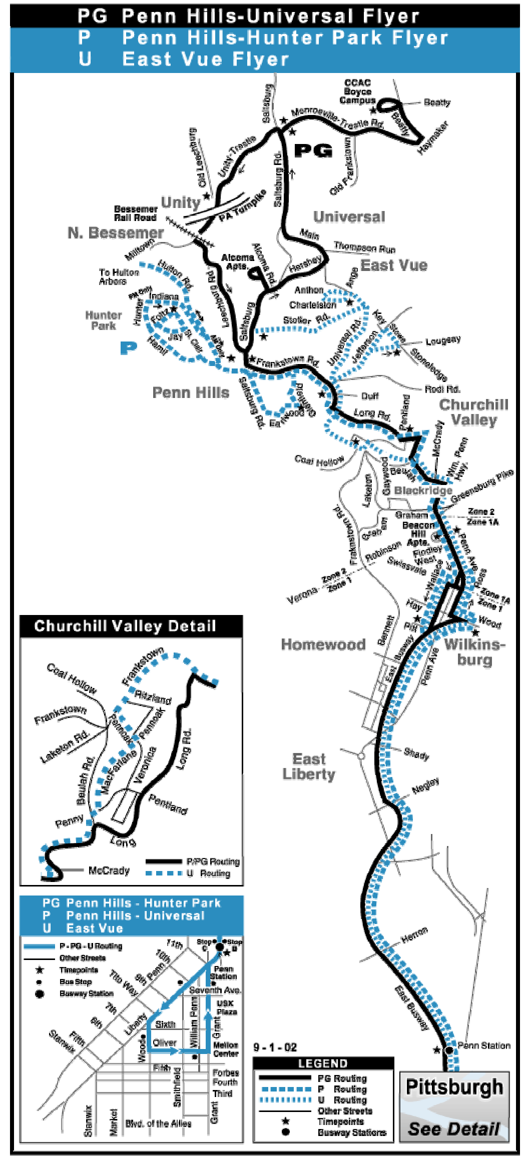
Maps of the FOT Bus Routes

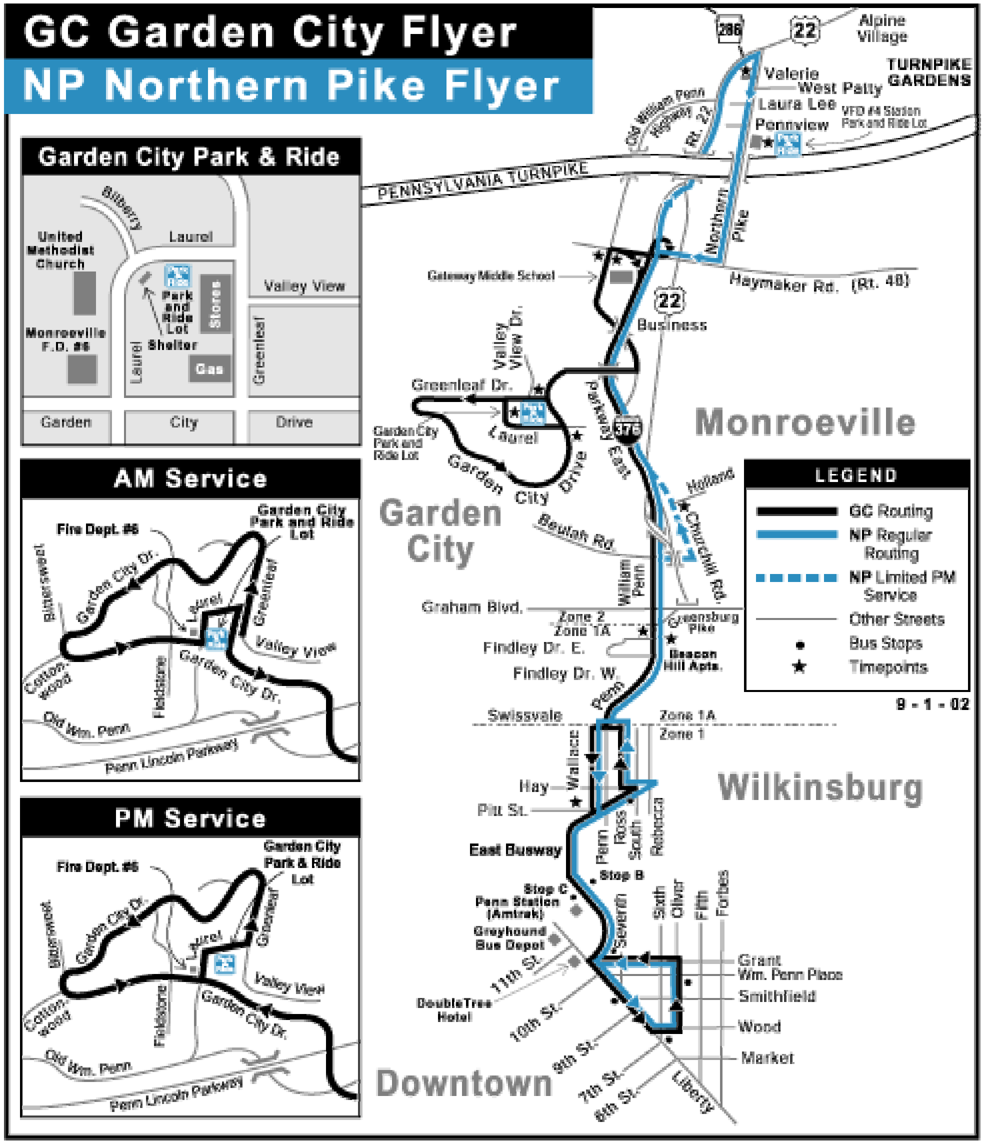

71A NEGLEY
LEGEND
71A Routing
71A Limited Service
Other Streets
East Busway
Busway Stations
Timepoints
Bus Stops
9 - 1 - 02
DOWNTOWN DETAIL
Stanwix
Penn
Liberty
Market
Wood
Forbes Ave.
Fifth Ave.
Smithfield
Grant
Courthouse
Ross
Diamond
Sixth
Pittsburgh
See Detail
Highland Park
East Liberty
Shadyside
Point Breeze
Wilkinsburg
Soho
Oakland
62nd St. Loop
Butler St.
62nd St. Bridge
Washington Blvd.
Baker St.
One Wild Place
Bryant
Bowden
Bunkerhill
Negley
Mellon
N. St. Clair
N. Euclid
Highland Ave.
Whitfield St.
Penn Circle North
Penn Circle East
Penn Ave.
Baum Blvd.
East Liberty Station
East Liberty Station Shoppes
Washington Blvd.
Herron Station
Liberty Ave.
East Busway
Herron Ave.
Pittsburgh Filmakers Melwood Screening Room
Centre Ave.
Shadyside Hospital
Giant Eagle
Negley Station
Bellefield
Craig St.
Melwood Ave.
Ellsworth
Fifth Ave.
Wilkins Ave.
Aiken
Chatham College
College
Highland
Shady Ave.
Hastings
Giant Eagle
Penn Ave.
Homewood Ave.
Homewood Station
Hay
Cathedral of Learning
DeSoto
Children's/ Presbyterian Hospital
Carlow College
Neville St.
Carnegie Museum/Library
Carnegie Mellon University
Forbes Ave.
University of Pittsburgh
Bigelow Blvd.
Bouquet St.
Oakland Ave.
Atwood St.
Halket
Magee Hospital
Craft Ave.
Playhouse
Robinson
Fifth Ave.
Forbes Ave.
Duquesne University
Mercy Hospital
Stevenson
Pride
Jumonville


74B Highland Park
500 Highland Park-Bellevue
(Showing Freeport Rd.-Oakland Service only)
73B Highland Park Express
LEGEND
74B Regular Routing
74B Alternate Routings
500 Oakland to Springdale
73B Regular Routing
Other Streets
Timepoints
Bus Stops
11 - 24 - 02
DOWNTOWN DETAIL
Penn Station
Heinz Hall
Post Office
One Mellon Bank Center
Harmarville
RIDC PARK
Aspinwall
Blawnox
ALLEGHENY RIVER
Highland Park
East Liberty
Pittsburgh
See Detail
Shadyside
Oakland
Waterworks Mall Detail
1. Giant Eagle
2. Marshalls
3. Former Ames
4. Party City
to Veterans Hospital
Medical Arts Bldg.
Waterworks Mall
UPMC St. Margaret
TO PITTSBURGH
Freeport Rd.
TO HARMARVILLE


1A New Kensington
93A Aspinwall-Cheswick
AV Allegheny Valley
AVN Allegheny Valley N.
LEGEND
1A Regular
1A Extended
1A Alternate
93A Routing
AV Red Flyer
AV Limited
AVN Red Flyer
Bus Stops
Timepoints
3 - 31 - 02
Natrona Heights
Tarentum
New Kensington
Creighton
Glassmere
Springdale
Cheswick
Harwick
Acmetonia
Harmarville
Blawnox
Aspinwall
Sharpsburg
Etna
Millvale
North Side
Pittsburgh


91A Butler Street
91S Sharps Hill Via Butler St.
93A Aspinwall-Cheswick
LEGEND
91A Routing
Limited Service
91S Routing
93A Routing
Bus Stops
Key Stops
9 - 1 - 02
Cheswick
Acmetonia
Harmarville
Oakmont
ALLEGHENY RIVER
Blawnox
Aspinwall
Sharps Hill
Sharpsburg
Etna
East Liberty
Lawrenceville
Strip
DOWNTOWN DETAIL
Pittsburgh
See Detail


PG Penn Hills-Universal Flyer
P Penn Hills-Hunter Park Flyer
U East Vue Flyer
PG
Unity
N. Bessemer
Universal
East Vue
Hunter Park
P
Penn Hills
Churchill Valley
Blackridge
Homewood
Wilkinsburg
East Liberty
Churchill Valley Detail
P/PG Routing
U Routing
PG Penn Hills - Hunter Park
P Penn Hills - Universal
U East Vue
9 - 1 - 02
LEGEND
PG Routing
P Routing
U Routing
Other Streets
Timepoints
Busway Stations
Pittsburgh
See Detail


GC Garden City Flyer
NP Northern Pike Flyer
Garden City Park & Ride
AM Service
PM Service
Monroeville
Garden City
Wilkinsburg
Downtown
PENNSYLVANIA TURNPIKE
LEGEND
GC Routing
NP Regular Routing
NP Limited PM Service
Other Streets
Bus Stops
Timepoints
9 - 1 - 02

Appendix B:

Evaluation Workshop Goals and Results

Evaluation Goals (focusing on Operator reaction Feedback Session)

- Is the system compatible with the application?
- Are the displays in the right location? Is the sound appropriate?
- Do displays communicate properly? Can it be determined appropriately?
- Cost Effectiveness?
- How fast do Operators adjust to it?
- Is training appropriate?
- Do sensors provide effective warnings?
- Is system performance consistent with every bus? Consistent on every route?

What do we want to learn?

- Does it reduce collisions and maintenance?
- Reliability
- Adequacy of operator reaction time?
- Diagnostic capability
- Is operator response consistent?
- Did operator's performance change?
- Is the operation intuitive or do you have to train?
- Are ranges set appropriately?
- Do we get central office calls from public?
- What type of media coverage will the system get?
- Will it reduce complaints of people getting cut off by bus?
- How to make it better
- Are there institutional barriers to making this happen?
- What is the level of unwanted alarms? False alarms?
- Is the sound less annoying? Is the type and level of sound appropriate?

Driver Performance Categories

(This is a broad set of categories to which issues identified by the team will be assigned)

- Usability or understanding? Was it useful? How long did it take to understand?
- Impact on Operator workload or stress
- Impact on Operator behavior
- Operator's perception of quality? How much is it valued?
- How can it be improved? What is Operators perception of technology maturity?
- Maintenance/Cost
- Public Perception
- Institutional Barriers

Anticipated Results Of Object Detection System Evaluation Feedback Session

(Developed at January 9, 2003 Object Detection Team Meeting at Harmar Garage)

- Blind Spot/Turn Detection
- Annoying to Divers
- Reinforce New Driver Training
- Accident Reduction
- Operator Awareness
- Allow Driver to Focus on Front
- Enhance Experienced Driver's Abilities
- Reduce Accident Severity
- Engage Interest of Customers
- Break Bad Habits
- Create Additional Maintenance
- Assess Desirability of Feature Set
- Effectiveness of Driver/Vehicle Interface
- Stimulate Industry Awareness
- LEDs Reinforce Use of Mirrors
- Increase MBRF by Reducing Accidents
- Could be a Distraction
- Other Applications of the Technology
- Improve Port Authority's Image and Ridership
- Positive Effects on Attention and Awareness
- Distractions from Passengers Asking Questions
- New Drivers May Over-rely on Object Detection System
- Complaints
- Stepping Stone to Next Technology
- Encourage Additional Technology Applications
- May Place Extra Stress on Operators
- Increase credibility of Port Authority Training
- Change (+or -) of Mental Workload of Driving a Bus
- May Not Maintain Technology Adequately
- Operators Will "Creatively Adapt" to System
- Demonstrate Value of Cooperation Between Union and Management
- Less Maintenance – Less Dings and Nicks
- Improve Morale
- Improved Operator/Instructor Dialog
- Will Cost Money
- Will Encourage Operator Feedback

Appendix C:

Baseline Interview Guide

Discussion Outline for Port Authority Bus Operators Baseline Interviews

Part I: Introduction

1. Ground rules

(1) Absolutely confidential
(2) No right or wrong answers
(3) Schedule to keep
(4) Audio-taping, but names will be deleted and tape will not be shared with management. [NOTE: I prefer to tape. However, the respondent is not just given permission, but is encouraged to say when he or she wants to turn recorder off. Also, if it is considered intrusive, taping is not essential. However, without the tape, note taking is obviously required.]
(5) Purpose of the interview is to discuss your expectations about safety technologies, including the new on-board system for side-collision warning
  (a) What are drivers calling this system when talking together?
  (b) We're looking for objective feedback, both pros and cons of the technologies
(6) Introductions
  (a) Explain role/function of the evaluation
  (b) This is an informal discussion, the first in a series of data collections
  (c) First name only
  (d) How many years driving a bus?
  (e) How long with Pittsburgh Area Transit?

2. Use and Comfort with information-oriented and other high tech technological innovation

(1) Do you use a computer at home or at work?
  (a) If so, how long have you been using a computer?
  (b) Level of expertise? (Hands on? Skill level?)
  (c) Do others come to you or do you ask others?
  (d) Overall, how comfortable would you say you feel with high tech things?

3. Initial reaction to new control systems

(1) Are there any other automated systems on the Port Authority buses?
(2) When your employers have introduced high-tech systems, have others come to you for advice on how to use them, or have you gone to others to ask questions about using them?
(3) What do the other drivers think about the prospects of this new safety system?

4. Perception of the problem of side-collision

(1) The device on which you were recently given an orientation relates to side-collision situations
  (a) Since I know nothing about driving a bus, tell me what situations or conditions could make it difficult to spot a potential side-impact without a system like this?

5. Expectations about the side warning systems – its functions and its functionality

(1) What is your understanding of the circumstances when side-collision warning system is supposed to give you a warning?
  (a) (open end)
  (b) Probes:
    (1) Under what situations is it supposed to warn you?
    (2) Are those the situations in which you actually need it?
    (3) Are there side-collision danger situations you have experienced the new system does not cover?
    (4) Are there particular driving conditions when this may be more helpful? (Probe: bad weather, night driving, etc.)

(2) What is your understanding of how the warnings are supposed to work?
  (a) Nature of the warning
    (1) Open end
    (2) Probe if needed: Sounds?
    (3) Probe if needed: Warning lights?
  (b) Effectiveness
    (1) Do you think they will be effective in getting your attention?
    (2) Do you think they will be effective in getting your attention fast enough that you can avoid an accident?
  (c) Are there any downsides to the warnings?
    (1) Open end
    (2) Probe if needed: Would there be any possibility of the warnings being a distraction?
    (3) Probe if needed: Would there be any possibility of the warnings being annoying?
    (4) Probe if needed: Any possibility of confusing the side-collision warnings with other system warnings in the bus? Alternatively ask: Are there any other systems on the bus that issue warnings (lights and/or sounds)?

(3) How it will work in practical application?
  (a) In what situation would the system be most useful to you on the route you generally drive?
  (b) Are you concerned about your becoming dependent on the system and having it fail to give a warning when it should have?
  (c) Are you concerned about getting warnings when you don't think you really need one?
  (d) I'm not an experienced bus driver, but like anything, it seems to me there could be two types of situations in which the system might not be too helpful– one is a warning that even if it is valid, you really did not need to know about it (or do you mean you don't need it because you have other ways of knowing about it?). The other is when it is not valid at all

(4) How will it affect your thoughts about the nature of your job?
  (a) Do you expect that this system will increase your confidence in your driving?
  (b) Are you concerned that this system is in some sense taking away or adversely affecting some of your responsibility for the safety of your passengers?
  (c) Are you concerned about any liability implications of having this technology on your bus?

6. Perceptions of advantage / disadvantage of these systems

(1) Every driver is different. People have different levels of experience and different styles of driving. In your case, do you expect this system to work for you personally as it is intended?
  (a) IF SO: In what way do you think it may help?
  (b) IF NOT: Why do you think it might not help you?

(2) Overall, how comfortable are you having these kinds of systems in your bus?
  (a) Probe: Do you expect it to provide greater safety of operation?
  (b) Probe: What is the main "payoff" for having this system? Is it avoiding major dangerous crashes that could hurt someone or is it avoiding little dents that cause a lot of paperwork and lost schedule?

(3) What is the most important advantage of having side collision warning on your bus?
  (a) What do you expect will be the most important helpful thing about having this system on your bus?
  (b) Do you expect there will be disadvantages? [If so what are they?]
  (c) Is there anything about this system that is not really helpful, but really not a disadvantage either -- just unnecessary?
  (d) Considering what is helpful and what is not helpful altogether, what is your net conclusion? Do you think this system will help you drive more safely and avoid side-collisions, or that it will not be worthwhile to you?
  (e) Do you think these systems will in any way change your job?
  (f) When you are trying to make up time on your schedule because you have been delayed by traffic or some other problem, would a system like this help you in changing lanes or turning tight corners a little faster than you would otherwise, or would it make no difference?
  (g) Do you think these systems will in any way change the way you drive your bus? (Probe: Might you become less attentive, relying on the system? Might you become more attentive, being more sensitized to driving risks?)

7. Wrap up

(1) Anything else you would like to say about these matters?

Appendix D:

Daily Questionnaire and Tabulation of Responses

Object Detection System Daily Questionnaire

Date_____/_____/________ Route No._________ Bus No._________ P/R No._________

1. As far as you know, was your bus' Object Detection System working properly during your run? (If no, complete an Object Detection System Maintenance Evaluation Survey Form.)	Yes ☐ No ☐
2. Approximately how many times during your run today did you get an alert from the solid light with chime?	*Indicate number of times:* _______ *[If "0" times, skip to #5]*
3. When did this occur most often? When your bus was:	Stopped? ☐ Traveling less than 15 mph? ☐ Traveling 15 to 50 mph? ☐ Traveling 50 mph or more? ☐
4. Did either the solid light with chime or the flashing light alert help you avoid a possible collision or other dangerous situation during your run?	Yes ☐ No ☐
5. Think about the most significant safety-related driving event that occurred during your run. For this event, did you get either the solid light with chime or the flashing light alert?	Yes ☐ No ☐ No event occurred *[skip to #6]* ☐
5a. What was your bus doing during that event: *[check all responses that apply]*	Turning a corner? ☐ Changing lanes? ☐ Pulling away from a curb? ☐ Close Maneuvering? ☐ Stopped? ☐ Other?______________________
5b. In your opinion, what caused the alert – did the bus come close to: *[check one response]*	A stationary object such as parked car, signpost, etc) ☐ (what was object?______________ A moving vehicle ☐ Unknown ☐
5c. How was the solid light with chime or flashing light alert helpful to you in handling this situation? *[check all responses that apply]*	It alerted me to the situation ☐ It made me more aware that I had to take corrective action ☐ It was not helpful at all ☐
6. Did you encounter a situation today in which you thought you **should** have gotten the solid light with chime or flashing light alert **but did not**?	Yes ☐ No ☐ If yes, briefly describe the situation below under "Comments".
7. Did it rain during any part of your run today? If so, for approximately how long?	No rain ☐ 1-2 hours ☐ 3-5 hours ☐ 6-8 hours ☐

Comments:

	Question	CODE	Response	Frequency	Valid Total Total	%	Cumulative %	Valid %	Cumulative Valid %
Q1	1. As far as you know, was your bus' Object Detection System working properly during your run?	0	Stopped	55		40.4%	40.4%	42.0%	42.0%
		1	Traveling less than 15 MPH	76		55.9%	96.3%	58.0%	100.0%
		999	Blank	5		3.7%	100.0%		
Q2	2. Approximately how many times during your run today did you get an alert from the solid light with chime?	0	0	3		2.2%	2.2%	2.7%	2.7%
		2	2	4		2.9%	5.1%	3.5%	6.2%
		3	3	1		0.7%	5.9%	0.9%	7.1%
		4	4	5		3.7%	9.6%	4.4%	11.5%
		5	5	8		5.9%	15.4%	7.1%	18.6%
		6	6	10		7.4%	22.8%	8.8%	27.4%
		7	7	3		2.2%	25.0%	2.7%	30.1%
		8	8	13		9.6%	34.6%	11.5%	41.6%
		9	9	5		3.7%	38.2%	4.4%	46.0%
		10	10	18		13.2%	51.5%	15.9%	61.9%
		11	11	3		2.2%	53.7%	2.7%	64.6%
		12	12	1		0.7%	54.4%	0.9%	65.5%
		13	13	1		0.7%	55.1%	0.9%	66.4%
		15	15	10		7.4%	62.5%	8.8%	75.2%
		18	18	2		1.5%	64.0%	1.8%	77.0%
		20	20	12		8.8%	72.8%	10.6%	87.6%
		25	25	1		0.7%	73.5%	0.9%	88.5%
		30	30	9		6.6%	80.1%	8.0%	96.5%
		35	35	1		0.7%	80.9%	0.9%	97.3%
		40	40	1		0.7%	81.6%	0.9%	98.2%
		50	50	2	113	1.5%	83.1%	1.8%	100.0%
		999	Blank	23	136	16.9%	100.0%		
Q3	3. When did the alerts occur most often? When your bus was:	0	A stationary object (parked car, sign post, etc)	2		2.0%	2.0%	2.3%	2.3%

		1	A moving vehicle	86	88	87.8%	89.8%	97.7%	100.0%
		999	Blank	10	98	10.2%	100.0%		
Q4	4. Did either the solid light with chime or the flashing light alert help you avoid a possible dangerous situation during your run?	0	No	120		88.9%	88.9%	98.4%	98.4%
		1	Yes	2	122	1.5%	90.4%	1.6%	100.0%
		999	Blank	13	135	9.6%	100.0%		
Q5	5. Think about the most significant safety-related driving event that occurred during your run. For this event, did you get either the solid light with chime or the flashing light alert?	0	No	27		19.9%	19.9%	22.9%	22.9%
		1	Yes	17		12.5%	32.4%	14.4%	37.3%
		3	No Event Occurred	74	118	54.4%	86.8%	62.7%	100.0%
		999	Blank	18	136	13.2%	100.0%		
Q5a	5a. What was your bus doing during that event (check all that apply):	1	Turning a corner	5		8.8%	8.8%	31.3%	31.3%
		2	Changing lanes	3		5.3%	14.0%	18.8%	50.0%
		3	Pulling away from a curb	5		8.8%	22.8%	31.3%	81.3%
		4	Close maneuvering	2		3.5%	26.3%	12.5%	93.8%
		5	Stopped	1	16	1.8%	28.1%	6.3%	100.0%
		0	Blank	41	57	71.9%	100.0%		
Q5b	5b. In your opinion, what caused this alert – did the bus come close to (Check one response):	0	A stationary object (parked car, sign post, etc)	11		8.1%	8.1%	61.1%	61.1%
		1	A moving vehicle	7	18	5.1%	13.2%	38.9%	100.0%
		999	Blank	118	136	86.8%	100.0%		
Q5b1	If stationary object, what was object?	1	a moving vehicle	2		4.0%	4.0%	50.0%	50.0%
		2	Parked auto	1		2.0%	6.0%	25.0%	75.0%
		3	parked cars	1	4	2.0%	8.0%	25.0%	100.0%
		0	Blank	46	50	92.0%	100.0%		
Q5c	5c. How was the solid light with chime or flashing light alert helpful to you in handling this situation (check all that apply):	1	Alerted me to situation	10		17.2%	17.2%	58.8%	58.8%
		2	Alert made me more aware of needed corrective action	2		3.4%	20.7%	11.8%	70.6%

		3	Alert was not helpful at all	5	17	8.6%	29.3%	29.4%	100.0%
		0	Blank	41	58	70.7%	100.0%		
Q6	6. Did you encounter a situation today in which you thought you should have gotten the solid light with chime or flashing light alert but did not?	0	No	96		71.1%	71.1%	80.0%	80.0%
		1	Yes	24	120	17.8%	88.9%	20.0%	100.0%
		999	Blank	15	135	11.1%	100.0%		
Q7	Is Question #7 present on the form?	0	No	56		41.2%	41.2%	41.2%	41.2%
		1	Yes	80	136	58.8%	100.0%		
Q7a	7. Did it rain during any part of your run today? If so, for approximately how long?	0	No rain	68		74.7%	74.7%	78.2%	78.2%
		1	1-2 hours	11		12.1%	86.8%	12.6%	90.8%
		2	3-5 hours	8	87	8.8%	95.6%	9.2%	100.0%
		999	Blank	4	91	4.4%	100.0%		
Q10	Device Problem:	1	Detection Delayed	2		1.8%	1.8%	2.8%	2.8%
		2	False Alarm	23		21.1%	22.9%	31.9%	34.7%
		3	Malfunction	45		41.3%	64.2%	62.5%	97.2%
		4	Outside Zone	2	72	1.8%	66.1%	2.8%	100.0%
		0	Blank	37	109	33.9%	100.0%		

Question		Response
5a. Other (Describe):		No Answers Provided
6a. Any additional comments to describe situation that are not in comments below:		No Answers Provided
Comments	1	Changing lanes at Penn and Nealey. Vehicle on my left had its left turn signal on, I received a light warning but no chime. Slight winds.
	2	A car pulled out of a driveway toward the right side of the bus. No lights came on.
	3	Left side giving false alerts, and chimes going off too often.
	4	Left side giving false alert causing chimes to of off just about every time the turn signal is used.
	5	Left side giving false alerts causing chimes to go off. System shut down later.
	6	System shut down after one trip.
	7	Left turn close to vehicle no chime with turn signal on.
	8	Rain affects system too much-Chimes come on without any flashing alerts both sides-Audible comes on when the bus has stopped with turn signals on.
	9	Left side audible goes off without any lights or without any visible objects on that side.
	10	Left side warning comes on for no reason. The right side works ok.
	11	Right side wouldn't light when it should have. Left side chime went off, nothing around and lights when nothing around.
	12	Every time you put on left turn signal, it chimes away. Nothing around moving of stopped it chimed.
	13	Left side blinking and chimes - nothing there.

	14	Left side, false lights and chimes. Right side doesn't seem to work at all.
	15	As I was pulling to a stop at Center and Negley, a car ran a stop sign on Roup Ave coming from my right. At first glance, there was nothing coming and then the chimes went off. The system prevented an accident. The guy in the car never saw me and if I
	16	Very close to parked vehicles. Going off with nothing beside the bus. Chimes going off too far from objects; lights are very bright at night.
	17	System is delayed (lights start flashing half-way pass the bus). Weather conditions, rainy to no rain.
	18	The left side still picks up objects that are not there. Chimes are going off for more than one cycle. The system picks up objects too far away. Cloudy and light rain
	19	Left side: Chimes, no lights (lights go off with nothing there).
	20	Left side constantly alerts visual and audio alarm false readings very annoying. Almost don't want to use turns signals.
	21	A few false readings on the left side, the system seemed to work well. Slight winds.
	22	I had many flashing lights, fast, slow and solid lights on the left side of the bus at highway speed. The left and right sensors seemed to work well at the urban slow speeds.
	23	Chimes sound almost every time turn signal is used.
	24	False alerts, and chimes go off often.
	25	Rain does effect the sensors
	26	The system is greatly affected by the weather - It gives too many false warnings.
	27	Left side warning comes on for no reason.
	28	Left side goes off more often when objects are far than when they are close and sometimes not at all. ODS went back for about 15 minutes. After you start the bus, the system stays on about 15 seconds then the system goes black
	29	Both sides constantly flashed while raining-Audible goes off with no lights on also while stopped
	30	Lights and chime with nothing around the bus (false alarm - left side): right side - lights and does not chime when it should.

	31	The system works better today than before. It picked up objects on both sides.
	32	Tones Constant when turn signal on even when no object lights flash. No object.
	33	Seemed to work ok.
	34	Right side false lights and chimes. Left doesn't do much of anything.
	35	Right side false chimes and lights constantly. Left barely works. Never chimes.
	36	System worked efficiently, I felt comfortable knowing that it was working.
	37	Both sides chime without solid light. Some of it I think was a high curb, while making a turn.
	38	Both sides chimes going off-nothing there with and without lights. Also lights going off all the time-both sides.
	39	Driver's side sensor was giving flashing lights and chimes constantly with every turn even when nothing was within range. Door side sensor did not give accurate reads either - a lot of times it gave no lights or chimes.
	40	Same as 6-24-2003 a lot of false reads
	41	False readings on both sides while raining. After the rain stopped, the system worked fine.
	42	Left side continuous false readings audio alarm sounds three or four times for no reason. Turn signal on no lights no object in zone audio sounds.
	43	Did not receive warning lights or chimes making left hand turn on Liberty Ave. (Bus way entrance) There were vehicles on the left and right side; left turn signal was used. Very windy.
	44	Lots of flashing lights while in urban fast and highway mode. No objects on either side at the time. Heavy rain could have been why the lights were flashing.
	45	Chime is coming on too often.
	46	False alerts and none where there should have been.
	47	Same situation of car in blind spot changing lanes no chime.

	48	The left side picks up beyond 8 feet (12-15 feet).
	49	Right side chime didn't work. Lights were ok.
	50	Left side false lights. Nothing was near
	51	Right, no chime otherwise seemed to be working
	52	Left side lights and chimes, nothing there. Constant flashing lights nothing around, no chimes.
	53	Turning the corner at Craig and 5th, there was heavy construction equipment in the right lane; the lights flashed, but there were no chimes. It was a rainy morning; the left side seemed to flash more than it should have. (There was nothing on its side an
	54	Chimes a lot at a complete stop. Lights both sides (especially the left side) when there's nothing there. Delayed reaction ½ pass the bus. There was rain during the run.
	55	A few times got lights and no chimes! A lot of false reads also lights flashing and nothing in close range of the bus!
	56	System was not working properly. After the first trip, I ignored the system.
	57	Audio sounded when no visual. Many false signals.
	58	System works well.
	59	Making a left turn onto Highland Ave, with cars passing close on the left, no objects at that time.
	60	System involuntary shutdown. Restarted the engine to reset the system.
	61	Felt the chime sounded more than it should have.
	62	Right turn close car (parked) twice.
	63	Every ODS bus I've had, the audible goes off without Flashing lights. This bus had fewer false warnings.
	64	Less false readings

	65	Worked well
	66	I felt it should have chimed but didn't. Worked on express way.
	67	Seemed to be working fairly well
	68	Seemed ok.
	69	No chimes when should left no lights.
	70	About three times when turning a corner I didn't get light or chimes till I was already through and on my straight away.
	71	Chimes both sides with no lights and nothing there.
	72	Right and left side's lights very little and also chimes with no lights.
	73	Lights not of much use. Anytime there was a chime, I was already aware of the object. Chime seemed delayed when passing objects.
	74	A few times got flashing lights but no chime.
	75	Several times I got no flashing lights or chimes when normally I could have.
	76	Chimes only went off twice lights flashed on several occasions but wasn't getting a chime!
	77	Several times had flashing lights but no chimes.
	78	System (left display) gave false reading
	79	A couple of times, cars were on the left side while stopped and there were no alerts.
	80	Monitor shuts down. Left side triggered by gusts of wind.
	81	ODS seemed to be working well.

	82	System seem to be working fairly well, but if I relied on it to warn me of a close car, I would have hit it before detection. There is a delayed reaction in the warning.
	83	In town when making my turn onto Ft. Duquense Blvd from 7th, there was a huge truck parked on the corner; no chimes went off. Tight fit.
	84	System worked intermittently. It also seemed to me only one side at a time worked. When I felt both sides should be lighting up only one or the other did. It didn't work at all at times and then it just started to work. It seemed the right side was ou
	85	The Chime sounded most often while I was making turns in urban slow mode. Nothing significant happened as far as warning me of any objects I was not already aware of: a few times I passed parked cars before turning with signal on and I didn't get a chime
	86	ODS gave false readings during heavy rain. When the rain stopped, the system worked fine.
	87	Traveling on 28 South at 55 mph - left side constantly gave a false signal. Very windy with light rain.
Weather Conditions	1	Heavy rain
	2	Rain
	3	Slightly windy
	4	The system is greatly affected by the weather - It gives too many false warnings.
	5	Windy
	6	Windy/light rain

Appendix E:

Final Internet Survey Questions and Tabulation of Responses

Final Driver Survey
Enhanced Object Detection System (EODS)

If you have registered a login password previously, continue on to the survey...

If you are new to this site, please provide a login password you would like for use at this site (5 to 14 characters in length). Be certain to record this login password, so you may enter the site later and review your responses.

(Note: if your requested password is assigned to another user already, you will return to this page so you may request an alternate login password)

password

confirm password

Register

This survey is being conducted by Battelle on behalf of the Federal Transit Administration as part of an independent evaluation of driver reactions to the Enhanced Object Detection System. Your participation in this study is completely voluntary. All of the information you provide in this survey will be kept strictly confidential and only aggregate statistics will be disclosed. Your name will not be associated with any of your responses.

Please answer these questions on your own, without first discussing them with others. We want your personal opinions, both pro and con, about these systems.

There are 9 main questions, some of which have sub-questions, and the survey should take about 10 minutes to complete. In order to follow-up with you later, we need to have your name and P/R number.

Final Driver Survey
Enhanced Object Detection System (EODS)

Please **read** the information **below**.
When you are finished, you may hit the "Continue" button to proceed to the survey.

This survey is being conducted by Battelle on behalf of the Federal Transit Administration as part of an independent evaluation of driver reactions to the Enhanced Object Detection System. Your participation in this study is completely voluntary. All of the information you provide in this survey will be kept strictly confidential and only aggregate statistics will be disclosed. Your name will not be associated with any of your responses.

Please answer these questions on your own, without first discussing them with others. We want your personal opinions, both pro and con, about these systems.

There are 9 main questions, some of which have sub-questions, and the survey should take about 10 minutes to complete. In order to follow-up with you later, we need to have your name and P/R number.

Continue

Enhanced Object Detection System
Final Driver Survey

P/R Number:

Type your name here:

1. How useful did you find this training in learning how to use the object detection system effectively?

	Choose one answer below				
1a. Your training experience	**Very Useful** ○	**Somewhat Useful** ○	**Uncertain (Neutral)** ○	**Not Very Useful** ○	**Not At All Useful** ○

1b. Is there any kind of training you didn't get that you would like to have had?

○ No
○ Yes *(Briefly Describe)*

2. Please compare your bus driving experiences over the period of Object Detection System Testing on buses with and without the Object Detection System. Consider how many times you had to take evasive maneuvers, such as braking hard, making sudden lane changes, or other actions to avoid a side collision. Did these situations occur:

- None of the time?
- Much more frequently without the Object Detection System?
- Somewhat more frequently without the Object Detection System?
- About the same with and without the Object Detection System?
- Somewhat more frequently with the Object Detection System?
- Much more frequently with the Object Detection System?

3. How useful are each of these to you in detecting an object to the side of your bus?

	Choose one answer in each row below				
3a. Lights flashing slowly	**Very Useful**	**Somewhat Useful**	**Uncertain (Neutral)**	**Not Very Useful**	**Not At All Useful**
3b. Lights flashing fast	**Very Useful**	**Somewhat Useful**	**Uncertain (Neutral)**	**Not Very Useful**	**Not At All Useful**
3c. Lights solid "on"	**Very Useful**	**Somewhat Useful**	**Uncertain (Neutral)**	**Not Very Useful**	**Not At All Useful**
3d. Audible warning (chime) when traveling _under_ 45 mph	**Very Useful**	**Somewhat Useful**	**Uncertain (Neutral)**	**Not Very Useful**	**Not At All Useful**
3e. Audible warning (chime) when traveling _over_ 45 mph	**Very Useful**	**Somewhat Useful**	**Uncertain (Neutral)**	**Not Very Useful**	**Not At All Useful**

4. We are interested in your attitudes and opinions about this bus safety system. Please indicate your level of agreement or disagreement with each of the statements below. When answering each part of Question 4, consider the entire object detection system, including amber warning lights, blue status lights, and chime. (Check one response in each row)

Question 4: Part 1 of 2

Statement	Please select one option for each statement				
4a. The object detection system interferes with my driving tasks.	**Strongly Disagree** ○	**Disagree** ○	**Neither Agree nor Disagree** ○	**Agree** ○	**Strongly Agree** ○
4b. It has been easy for me to *learn how* to use the object detection system.	**Strongly Disagree** ○	**Disagree** ○	**Neither Agree nor Disagree** ○	**Agree** ○	**Strongly Agree** ○
4c. My driving habits have **not** changed for the worse as a result of having the object detection system on my bus.	**Strongly Disagree** ○	**Disagree** ○	**Neither Agree nor Disagree** ○	**Agree** ○	**Strongly Agree** ○
4d. The object detection system increases the amount of effort and concentration it takes to drive my bus.	**Strongly Disagree** ○	**Disagree** ○	**Neither Agree nor Disagree** ○	**Agree** ○	**Strongly Agree** ○
4e. The object detection system reduces the stress and fatigue of driving my bus.	**Strongly Disagree** ○	**Disagree** ○	**Neither Agree nor Disagree** ○	**Agree** ○	**Strongly Agree** ○
4f. The object detection system helps to reduce the number of accidents or near-accident situations.	**Strongly Disagree** ○	**Disagree** ○	**Neither Agree nor Disagree** ○	**Agree** ○	**Strongly Agree** ○
4g. Most bus drivers will like having the object detection system on their bus.	**Strongly Disagree** ○	**Disagree** ○	**Neither Agree nor Disagree** ○	**Agree** ○	**Strongly Agree** ○
4h. The more experienced a bus driver is, the less need there is for an object detection system like this.	**Strongly Disagree** ○	**Disagree** ○	**Neither Agree nor Disagree** ○	**Agree** ○	**Strongly Agree** ○

Continuation of Question 4: Part 2 of 2

Statement	Please select one option for each statement				
4i. I feel I would be better off driving my bus without the object detection system.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
4j. I think every bus in our fleet ought to be equipped with the object detection system.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
4k. I am comfortable with high technology devices in general.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
4l. I am comfortable having high technology devices operating on my bus.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
4m. It is easy to use the object detection system.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
4n. The object detection system makes me a safer bus driver.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
4o. The object detection system is really only helpful in situations of careless or inattentive driving.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
4p. Weather, such as rain, affects the performance of the object detection system. *(If so, please describe briefly in comments at end.)*	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
4q. The object detection system helps me detect an object I otherwise might not have seen in my mirror.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○

5. This next set of questions focuses on the effectiveness of the *visual* aspects of the object detection warning system. As before, please indicate your level of agreement or disagreement with each of the statements below.
(Check one response in each row)

Statement	Please select one option for each statement				
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
5a. The amber lights are clearly visible when looking in the side mirrors or in the direction of the bumper corners.	○	○	○	○	○
5b. It is easy to distinguish between whether the amber warning lights are flashing slow or fast.	○	○	○	○	○
5c. It is easy to distinguish between whether the amber warning lights are flashing or are solid "on".	○	○	○	○	○
5d. The brightness of the amber warning lights is adequate during daylight hours.	○	○	○	○	○
5e. The brightness of the amber warning lights is distracting during night driving.	○	○	○	○	○
5f. It is difficult to interpret the meaning of the different object detection warning lights in real bus driving situations.	○	○	○	○	○
5g. The warning lights are distracting to my driving under normal daytime conditions.	○	○	○	○	○

5h. It is easy to distinguish the object detection warning lights from other operating lights and displays in my bus.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
5i. I would prefer to just have the warning lights without any audible chime.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○

6. This next set of questions focuses on the effectiveness of the *audible* aspects of the object detection warning system. As before, please indicate your level of agreement or disagreement with each of the statements below.
(Check one response in each row)

Statement	Please select one option for each statement				
6a. It would be helpful to have the audible chime occur sooner than it does.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
6b. It is distracting to have the chime make the double sound more than once for a single detection.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
6c. The fact that there is no audible chime provided when the bus is stopped is acceptable.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
6d. It is easy to distinguish the audible chime from other sounds in my bus.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
6e. The audible warning chime is distracting to my driving.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
6f. I would prefer to just have the audible chime warning without any warning lights.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
6g. Some passengers on my bus are annoyed by the audible chimes associated with the object detection system.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
6h. I would prefer a different type of warning sound than the chime. *(Please note your preference in the comment areas provided at the end in Question 9.)*	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○

7. "Mental workload" refers to the mental effort it takes for you to perform driving tasks. Think in terms of your level of concentration, amount of mental effort, or degree of mental focus.
Consider an increasing scale of mental workload that ranges from 1 to 10, where:

1 means very low mental workload, and
10 means very high mental workload.

Please check a number between 1 and 10 that reflects your estimate of the average level of mental workload required under each of the following situations:

Driving Situation	Very Low Mental Workload ---------------> Very High Mental Workload
7a. Normal **urban slow** driving conditions when you drive your own personal automobile?	1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 ○
7b. Normal **urban fast** driving conditions when you drive your own personal automobile?	1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 ○
7c. Normal **highway** driving conditions when you drive your own personal automobile?	1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 ○
7d. When driving your bus under **urban slow** conditions ***without*** the object detection system operating?	1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 ○
7e. When driving your bus under **urban slow** conditions ***with*** the object detection system operating?	1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 ○
7f. When driving your bus under **urban fast** conditions ***without*** the object detection system operating?	1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 ○

7g. When driving your bus under **urban fast** conditions ***with*** the object detection system operating?	1 2 3 4 5 6 7 8 9 10
7h. When driving your bus under **highway** conditions ***without*** the object detection system operating?	1 2 3 4 5 6 7 8 9 10
7i. When driving your bus under **highway** conditions ***with*** the object detection system operating?	1 2 3 4 5 6 7 8 9 10

8. *Please note here any* *general comments, pro or con, about your experience with the object detection system:*

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9. *Write any additional* *specific comments below. Please note the question numbers to which any specific comment(s) may apply:*

(If necessary, use your browser's "Back" button to reference earlier questions. Then use your browser's "Forward" button to return to this question.)

9a. Question No.

9a. Comment:

Enhanced Object Detection System
Final Driver Survey

Thank you for your participation.

At this time, you may review your answers by clicking the "Review" button.

If, however, you are satisfied your responses best reflect your opinions and experience, simply click the "Submit" button. Please be aware that after you press the "Submit" button, you will no longer be able to view, modify, or add information (i.e. your survey will be closed).

Previous Review Submit

EODS Final Driver Survey

Your survey has been successfully submitted.

If you have specific questions regarding this survey, please contact Chris Cluett of Battelle at (206) 528-3333. Questions concerning the EODS or this evaluation project should be directed to your supervisor.

We will be conducting another similar survey about one month from now to obtain additional input from you concerning your driving experiences using this new safety system.

Thank you for your participation!

CONFIDENTIALITY: This information collection complies with the Federal Statistical Confidentiality Order. Therfore, by law, your responses may be used only for statistical purposes and may not be disclosed, or used, in identifiable form for any other purpose. Your survey instrument will be treated as confidential.

Question 1a	Survey	Not At All Useful	Not Very Useful	Uncertain	Somewhat Useful	Very Useful	Average Score	Difference [Final - Initial]	Uncertainty (+/-)
How useful did you find this training in learning how to use the object detection system effectively?	Initial	0	0	1	3	6	75		
	Final	0	0	0	4	6	80	5	±20

Question 1b	Survey	No	Yes	Average Score	Difference [Final - Initial]	Uncertainty (+/-)
Is there any kind of training you didn't get that you would like to have had?	Initial	10	0	-100		
	Final	10	0	-100	0	±0

Question 3 How useful are each of these to you in detecting an object to the side of your bus?

	Survey	Not At All Useful	Not Very Useful	Uncertain	Somewhat Useful	Very Useful	Average Score	Difference [Final - Initial]	Uncertainty (+/-)
3a: Lights flashing slowly	Initial	0	3	3	4	0	5		
	Final	0	3	2	5	0	10	5	±31
3b: Lights flashing fast	Initial	0	3	3	2	2	15		
	Final	0	3	1	5	1	20	5	±39
3c: Lights solid "on"	Initial	0	2	3	3	2	25		
	Final	0	1	2	5	2	40	15	±34
3d: Audible warning (chime) when traveling under 45 mph	Initial	0	1	1	4	4	55		
	Final	0	2	3	0	5	40	-15	±45
3e: Audible warning (chime) when traveling over 45 mph	Initial	0	1	2	4	3	45		
	Final	1	3	1	3	2	10	-35	±45

* Question numbers refer to final survey

Initial Survey

Question 4	Response	Frequency	%	Cumulative Valid %	Valid %
Please think about your bus driving experiences over the most recent 30 bus trips you took before the object detection system was installed. Estimate how many times you had to take evasive maneuvers, such as braking hard, making sudden lane changes, or other actions to avoid a side collision.	None that I can remember	3	17.6%	20.0%	20.0%
	1 time in 30 bus trips	0	0.0%	20.0%	0.0%
	2 – 3 times in 30 bus trips	2	11.8%	33.3%	13.3%
	4 – 10 times in 30 bus trips	4	23.5%	60.0%	26.7%
	11 – 20 times in 30 bus trips	5	29.4%	93.3%	33.3%
	21 – 30 times in 30 bus trips	1	5.9%	100.0%	6.7%
	More than 1 time per bus trip	0	0.0%	100.0%	0.0%
	Missing	2	11.8%		
	Total	17	100.0%		100.0%

Final Survey

Question 2	Response	Frequency	%	Cumulative Valid %	Valid %
Please compare your bus driving experiences over the period of Object Detection System Testing on buses with and without the Object Detection System. Consider how many times you had to take evasive maneuvers, such as braking hard, making sudden lane changes, or other actions to avoid a side collision. Did these situations occur:	None of the time?	2	16.7%	16.7%	16.7%
	Much more frequently without the Object Detection System?	0	0.0%	16.7%	0.0%
	Somewhat more frequently without the Object Detection System?	0	0.0%	16.7%	0.0%
	About the same with and without the Object Detection System?	10	83.3%	100.0%	83.3%
	Somewhat more frequently with the Object Detection System?	0	0.0%	100.0%	0.0%
	Much more frequently with the Object Detection System?	0	0.0%	100.0%	0.0%
	Missing	0	0.0%		
	Total	12	100.0%		100.00%

Question 4 We are interested in your attitudes and opinions about this bus safety system. Please indicate your level of agreement or disagreement with each of the statements below. When answering each part of Question 4, consider the entire object detection system, including amber warning lights, blue status lights, and chime.
(-) indicates a negative effect or recommended change
(+) indicates a beneficial quality
(0) indicates a neutral question

	Survey	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Average Score	Difference [Final - Initial]	Uncertainty (+/-)
4a. The object detection system interferes with my driving tasks.	Initial	1	4	4	1	0	-25		
	Final	0	3	3	4	0	5	30	±18
4b. It has been easy for me to learn how to use the object detection system.	Initial	0	0	1	7	2	55		
	Final	1	1	1	6	1	25	-30	±42
4c. My driving habits have not changed for the worse as a result of having the object detection system on my bus.	Initial	0	0	0	4	6	80		
	Final	0	0	1	5	4	65	-15	±34
4d. The object detection system increases the amount of effort and concentration it takes to drive my bus.	Initial	1	5	1	3	0	-20		
	Final	0	4	2	3	1	5	25	±39
4e. The object detection system reduces the stress and fatigue of driving my bus.	Initial	4	4	2	0	0	-60		
	Final	2	7	1	0	0	-55	5	±26

4f. The object detection system helps to reduce the number of accidents or near-accident situations.	Initial	1	2	5	2	0	-10		
	Final	1	5	2	2	0	-25	-15	±29
4g. Most bus drivers will like having the object detection system on their bus.	Initial	2	1	2	5	0	0		
	Final	2	2	3	3	0	-15	-15	±45
4h. The more experienced a bus driver is, the less need there is for an object detection system like this.	Initial	1	2	4	0	3	10		
	Final	1	2	1	5	1	15	5	±26
4i. I feel I would be better off driving my bus without the object detection system.	Initial	0	4	3	2	1	0		
	Final	0	4	3	3	0	-5	-5	±36
4j. I think every bus in our fleet ought to be equipped with the object detection system.	Initial	1	1	3	4	1	15		
	Final	1	3	3	3	0	-10	-25	±35
4k. I am comfortable with high technology devices in general.	Initial	0	0	1	7	2	55		
	Final	0	1	0	7	2	50	-5	±20
4l. I am comfortable having high technology devices operating on my bus.	Initial	0	0	1	9	0	45		
	Final	0	0	0	8	2	60	15	±17
4m. It is easy to use the object detection system.	Initial	0	1	1	7	1	40		
	Final	1	0	3	5	1	25	-15	±17

4n. The object detection system makes me a safer bus driver.	Initial	1	1	7	1	0	-10		
	Final	2	2	4	2	0	-20	-10	±23
4o. The object detection system is really only helpful in situations of careless or inattentive driving.	Initial	2	4	2	2	0	-30		
	Final	0	5	3	2	0	-15	15	±34
4p. Weather, such as rain, affects the performance of the object detection system. (If so, please describe briefly in comments at end.)	Initial	0	1	2	6	1	35		
	Final	0	1	2	5	2	40	5	±39
4q. The object detection system helps me detect an object I otherwise might not have seen in my mirror.	Initial	0	3	2	4	1	15		
	Final	0	2	3	4	1	20	5	±46

Question 5 This next set of questions focuses on the effectiveness of the visual aspects of the object detection warning system. As before, please indicate your level of agreement or disagreement with each of the statements below.

(-) indicates a negative effect or recommended change
(+) indicates a beneficial quality
(0) indicates a neutral question

	Survey	4	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Average Score	Difference [Final - Initial]	Uncertainty (+/-)
5a. The amber lights are clearly visible when looking in the	Initial	0	0	2	8	0	40		

when looking in the side mirrors or in the direction of the bumper corners.	Final	0	0	3	6	1	40	0	±17
5b. It is easy to distinguish between whether the amber warning lights are flashing slow or fast.	Initial	0	1	2	6	1	35		
	Final	0	2	2	6	0	20	-15	±24
5c. It is easy to distinguish between whether the amber warning lights are flashing or are solid "on".	Initial	0	1	1	7	1	40		
	Final	0	1	0	9	0	40	0	±17
5d. The brightness of the amber warning lights is adequate during daylight hours.	Initial	0	0	1	8	1	50		
	Final	0	0	1	8	1	50	0	±17
5e. The brightness of the amber warning lights is distracting during night driving.	Initial	0	4	5	1	0	-15		
	Final	0	4	4	2	0	-10	5	±31
5f. It is difficult to interpret the meaning of the different object detection warning lights in real bus driving situations.	Initial	0	1	4	5	0	20		
	Final	0	4	4	2	0	-10	-30	±30
5g. The warning lights are distracting to my driving under normal daytime conditions.	Initial	0	8	1	1	0	-35		
	Final	0	8	2	0	0	-40	-5	±20
5h. It is easy to distinguish the object detection warning	Initial	0	0	0	10	0	50		

detection warning lights from other operating lights and displays in my bus.	Final	0	1	0	8	1	45	-5	±26
5i. I would prefer to just have the warning lights without any audible chime.	Initial	2	3	4	1	0	-30		
	Final	0	6	2	1	1	-15	15	±51

Question 6 This next set of questions focuses on the effectiveness of the audible aspects of the object detection warning system. As before, please indicate your level of agreement or disagreement with each of the statements below.
(-) indicates a negative effect or recommended change
(+) indicates a beneficial quality
(0) indicates a neutral question

	Survey	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Average Score	Difference [Final - Initial]	Uncertainty (+/-)
6a. It would be helpful to have the audible chime occur sooner than it does.	Initial	1	2	2	5	0	5		
	Final	0	1	2	4	3	45	40	±47
6b. It is distracting to have the chime make the double sound more than once for a single detection.	Initial	0	1	3	6	0	25		
	Final	0	2	2	5	1	25	0	±41
6c. The fact that there is no audible chime provided when the bus is stopped is acceptable.	Initial	0	2	1	7	0	25		
	Final	0	2	1	4	3	40	15	±38
6d. It is easy to distinguish the	Initial	0	0	0	7	3	65		

audible chime from other sounds in my bus.	Final	0	0	0	6	4	70	5	±20
6e. The audible warning chime is distracting to my driving.	Initial	1	5	4	0	0	-35		
	Final	0	6	2	2	0	-20	15	±41
6f. I would prefer to just have the audible chime warning without any warning lights.	Initial	1	5	4	0	0	-35		
	Final	1	5	2	2	0	-25	10	±28
6g. Some passengers on my bus are annoyed by the audible chimes associated with the object detection system.	Initial	0	3	6	1	0	-10		
	Final	0	4	4	2	0	-10	0	±29
6h. I would prefer a different type of warning sound than the chime.	Initial	1	4	5	0	0	-30		
	Final	0	5	5	0	0	-25	5	±31

Question 7 "Mental workload" refers to the mental effort it takes for you to perform driving tasks. Think in terms of your level of concentration, amount of mental effort, or degree of mental focus. Consider an increasing scale of mental workload that ranges from 1 to 10, where:

1 means very low mental workload, and
10 means very high mental workload.

Please check a number between 1 and 10 that reflects your estimate of the average level of mental workload required under each of the following situations:

	Survey	1	2	3	4	5	6	7	8	9	10	Average Score	Difference [Final - Initial]	Uncertainty (+/-)
7a. Normal urban slow driving	Initial	3	1	3	1	1	0	1	0	0	0	3		

conditions when you drive your own personal automobile?	Final	3	0	1	0	2	3	1	0	0	0	4.1	1.1	±1.41
7b. Normal urban fast driving conditions when you drive your own personal automobile?	Initial	1	1	2	0	1	3	2	0	0	0	4.6		
	Final	2	0	2	0	0	3	2	1	0	0	4.8	0.2	±1.38
7c. Normal highway driving conditions when you drive your own personal automobile?	Initial	1	0	2	1	1	2	2	1	0	0	5		
	Final	1	1	1	0	1	3	2	1	0	0	5.1	0.1	±1.09
7d. When driving your bus under urban slow conditions without the object detection system operating?	Initial	2	0	1	0	2	1	1	1	0	2	5.6		
	Final	0	1	0	1	4	0	0	2	1	1	6.1	0.5	±1.49
7e. When driving your bus under urban slow conditions with the object detection system operating?	Initial	1	0	0	1	2	1	2	1	0	2	6.3		
	Final	0	0	0	2	3	1	0	2	1	1	6.4	0.1	±1.14
7f. When driving your bus under urban fast conditions without the object detection system operating?	Initial	1	0	0	1	1	0	2	3	0	2	6.8		
	Final	0	1	0	1	1	1	0	4	1	1	6.8	0	±1.43
7g. When driving your bus under urban fast conditions with the object detection system operating?	Initial	0	0	0	0	2	0	3	3	0	2	7.5		
	Final	0	0	0	2	1	0	1	4	1	1	7.1	-0.4	±0.98
7h. When driving your bus under highway conditions without the object detection system operating?	Initial	1	0	0	0	4	0	1	3	0	1	6.2		
	Final	0	0	1	0	2	2	0	4	0	1	6.7	0.5	±1.33

7i. When driving your bus under highway conditions with the object detection system operating?	Initial	0	0	0	0	3	1	2	3	0	1	6.9		
	Final	0	0	0	0	3	1	1	4	0	1	7	0.1	±0.79

Question 7 "Mental workload" refers to the mental effort it takes for you to perform driving tasks. Think in terms of your level of concentration, amount of mental effort, or degree of mental focus. Consider an increasing scale of mental workload that ranges from 1 to 10, where:

1 means very low mental workload, and
10 means very high mental workload.

Please check a number between 1 and 10 that reflects your estimate of the average level of mental workload required under each of the following situations:

	Survey	1	2	3	4	5	6	7	8	9	10	Average Score	Difference [Final - Initial]	Uncertainty (+/-)
7a. Normal urban slow driving conditions when you drive your own personal automobile?	Initial	3	1	3	1	1	0	1	0	0	0	3		
	Final	3	0	1	0	2	3	1	0	0	0	4.1	1.1	±1.41
7b. Normal urban fast driving conditions when you drive your own personal automobile?	Initial	1	1	2	0	1	3	2	0	0	0	4.6		
	Final	2	0	2	0	0	3	2	1	0	0	4.8	0.2	±1.38
7c. Normal highway driving conditions when you drive your own personal automobile?	Initial	1	0	2	1	1	2	2	1	0	0	5		
	Final	1	1	1	0	1	3	2	1	0	0	5.1	0.1	±1.09
7d. When driving your bus under urban slow conditions without the object detection system operating?	Initial	2	0	1	0	2	1	1	1	0	2	5.6		
	Final	0	1	0	1	4	0	0	2	1	1	6.1	0.5	±1.49

7e. When driving your bus under urban slow conditions with the object detection system operating?	Initial	1	0	0	1	2	1	2	1	0	2	6.3		
	Final	0	0	0	2	3	1	0	2	1	1	6.4	0.1	±1.14
7f. When driving your bus under urban fast conditions without the object detection system operating?	Initial	1	0	0	1	1	0	2	3	0	2	6.8		
	Final	0	1	0	1	1	1	0	4	1	1	6.8	0	±1.43
7g. When driving your bus under urban fast conditions with the object detection system operating?	Initial	0	0	0	0	2	0	3	3	0	2	7.5		
	Final	0	0	0	2	1	0	1	4	1	1	7.1	-0.4	±0.98
7h. When driving your bus under highway conditions without the object detection system operating?	Initial	1	0	0	0	4	0	1	3	0	1	6.2		
	Final	0	0	1	0	2	2	0	4	0	1	6.7	0.5	±1.33
7i. When driving your bus under highway conditions with the object detection system operating?	Initial	0	0	0	0	3	1	2	3	0	1	6.9		
	Final	0	0	0	0	3	1	1	4	0	1	7	0.1	±0.79

Appendix F:

Final Interview Guide

Discussion Outline for End-of-Test Harmar Division Bus Operator Interviews

Part I: Introduction

8. **Ground rules**
   (1) Absolutely confidential
   (2) No right or wrong answers
   (3) Schedule to keep
   (4) Audio-taping, but as previously names will be deleted and tape will <u>not</u> be shared with management
   (5) Purpose of the interview is to discuss your experiences with the on-board system for side-collision warning

9. **Training**
   (1) Prior to your going out with an equipped bus, you had training that told you what to expect. Now that you have experienced the system, remembering back to the training, did the training adequately prepare you for how the system really would work?

   (2) How much time, in days or weeks or months, does it realistically take after training to get used to this system so that it is useful to the driver?

   (3) How difficult or easy was it to learn to use the system to your advantage?

10. **Expectations about the side warning systems – its functions and its functionality**
    (1) What was your initial reaction to the system in the first week or two you were using a bus equipped with it? (Probe if necessary: Did it initially seem helpful or did it seem to be more distracting than helpful?)
    (2) Did your views of the system change over the course of the test? (If so, why?)

11. **System design**
    (1) Did the ODS rarely, sometimes, or often provide a warning when you felt there was no real cause for it?
        (a) [IF SOMETIMES OR OFTEN] What kinds of objects did it respond to that you thought it ought to ignore?
        (b) [IF SOMETIMES OR OFTEN] I know you feel the alarms were not necessary. But were they consistent with the way the ODS is supposed to work?
        (c) What was your understanding of the way the system was supposed to work?

    (2) Did the ODS rarely, sometimes, or often fail to provide warnings when you felt there was legitimate need for one?
        (a) [IF SOMETIMES OR OFTEN] What kinds of situations were those?

(3) Did the speed and situation make a difference in terms of when you could trust or not trust that the **lights** were warning of a real danger?

(a) At a stop, did you trust that the lights were giving effective warnings of a real danger? Yes No

(b) At urban slow speed? Yes No

(c) Urban fast? Yes No

(d) Highway? Yes No

(4) Did the lights get your attention?

(a) During daylight hours? Yes No

(b) At night? Yes No

(5) How easy or difficult was it to interpret the signals the lights were giving in real driving conditions?

(1) Very easy (2) Easy (3) Difficult (4) Very difficult

(a) [IF DIFFICULT, WHAT MADE IT DIFFICULT?]

(6) The same questions now with regard to the chimes. Not including the stop, when the chime would not be operating, did the speed and situation make a difference in terms of when you could trust that the chimes were warning of a real danger?

(a) First, did you trust the chime at urban slow speed? Yes No

(b) Did you trust the chime at urban fast? Yes No

(c) did you trust the chime at highway speed? Yes No

(7) And could you always hear the chime adequately…

(a) In normal traffic? Yes No

(b) In heavy traffic or other relatively noisy conditions? Yes No

(8) In terms of how fast the system warned you of a potential danger, did you find that:

(a) The lights warned you quickly enough for you to take action?

(b) The chimes warned you quickly enough for you to take action?

(9) In what mode were the lights?

(a) Most helpful?

(b) Least helpful?

(10) In what mode were the chimes…

(a) …Most helpful?

(b) …Least helpful?

(11) Would you prefer to have…

(a) Only lights and no chimes or only chimes and no lights

(b) Why?

(12) Did you find that at some point you began to ignore the system some or all of the time?
- (a) If so, did you begin simply to ignore it all the time, or did you begin to ignore it only some of the time?
- (b) If you ignored it some of the time, under what circumstances did you ignore it?

(13) Did your passengers notice the warnings?
- (a) If so, did they ask about them?
- (b) What did they think they were?

12. Comparisons ODS/NON-ODS EQUIPPED VEHICLES

(1) Mental effort [IN EACH OF THE FOLLOWING, IF THE ANSWER IS THAT IT TOOK MORE MENTAL EFFORT, ASK WHY]
- (a) Did you find it took more mental effort or less mental effort to operate a bus with the ODS than one without it in slow urban traffic?
- (b) Did you find it took more mental effort or less mental effort to operate a bus with the ODS than one without it in fast urban traffic?
- (c) Did you find it took more mental effort or less mental effort to operate a bus with the ODS than one without it at highway speeds?

(2) When you were driving a bus not equipped with ODS, did you find yourself wishing you had it or glad you did not have it, or did it make no difference to you?
- (a) [IF WISHING THEY HAD IT, UNDER WHAT CONDITIONS?]
- (b) [IF GLAD THEY DID NOT HAVE IT, WHY?]

13. Variations in system performance with varied conditions

(1) How did weather affect the operation of the system?
- (a) Did rain affect it? If so, in what way?
- (b) Wind?
- (c) Anything else?

(2) What differences were there in the usefulness of the system in various traffic situations – say in …
- (a) Close maneuvering in the city?
- (b) Light traffic or heavy traffic?
- (c) Low speed or high speed?
- (d) Curved or straight roads?
- (e) When changing lanes?
- (f) When merging into traffic from a passenger stop?
- (g) Making a left or right turn?

(3) Were there any conditions under which the system just turned itself off while you were driving?
- (a) What were the conditions?
- (b) Do you know why it turned off?

(c) Did it come back on, or did you just leave it off, or what did you do?
(d) Did that experience affect your feelings about the system in any way?

14. Several changes were made in the systems as the test went on. I'd like to know if you saw any difference in performance as the changes were made. First…

(1) Initially, there was an air blast resulting from the brakes that sometimes caused the system to shut itself down. A special type of muffler was installed around May 12 to prevent that. Did you notice any change in that shut-down problem after that?

(2) The rain, especially heavy rain, seemed to produce false alarms.
(a) Did you notice that effect?
(b) Also around May 12, Clever Devices programmed the two front corner sensors on the bumper to stop detecting when the bus was above 45 mph. Did you notice any change in response to rain after that?

15. Bottom lines: Perceptions of advantage / disadvantage of these systems

(1) Every driver is different. People have different levels of experience and different styles of driving. In your case,
(a) In what way did the system help you most?
(b) In what was the system a problem for you?

(2) Avoiding accidents
(a) Did the ODS help you avoid an accident? Yes No

(b) [IF NO] If you used it for a year or so, do you believe that the ODS would or would not help you avoid an accident? Would Would not

(3) Do you feel that the ODS helped you reduce the number of times you had to make evasive maneuvers to avoid an accident? Yes No
(a) [IF YES] Can you roughly estimate how much of a reduction that was? For example, for every ten times you had to take evasive action without the ODS, you would have to take evasive action how many times with the ODS? #____

(4) Overall,
(a) Did the system provide greater safety of operation for you?
(b) At the beginning of the project, we asked if the warnings would be more of a distraction than a help or more help than distraction. What is your bottom line conclusion now about that?
(c) Did you personally have any problem with seeing the lights during the day or being too bright at night?

16. Wrap up

(1) If you could make one improvement in the system, what would you do?
(2) If you could make two improvements, what would the other one be (if any)?
(3) Any others?

Appendix G:

Object Detection System Maintenance Evaluation Survey Form

Object Detection System Maintenance Evaluation Survey

Bus___________ Payroll____________ Date____________

What was the initial complaint?_______________________________________

Where was the problem: (check all that apply)

Left Display________ Left Sensor________ Command Module_______

Right Display_______ Right Sensor________

What was fixed?____

How long was the system down?____

What parts were needed for the repair?____________________________________

What parts were ordered?____

Supervisor___________________________________ Date______________