National Evaluation of the SafeTrip-21 Initiative: California Connected Traveler Test Bed Final Evaluation Report: Networked Traveler-Foresighted Driving

Contract Number: DTFH61-06-D-00005 Task Order T-09-008

Submitted to:
United States Department of Transportation
ITS Joint Program Office,
Research and Innovative Technology Administration
RITA Report Number FHWA-JPO-11-012

Submitted by:
Science Applications International Corporation
January 19, 2011

U.S. Department of Transportation
Federal Highway Administration

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TECHNICAL REPORT DOCUMENTATION PAGE

<table>
<tr><td colspan="2">1. Report No.
FHWA-JPO-11-012</td><td colspan="2">2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="4" rowspan="2">4. Title And Subtitle:
National Evaluation of the SafeTrip-21 Initiative: Final Report Networked Traveler-Foresighted Driving</td><td colspan="2">5. Report Date
November 24, 2010</td></tr>
<tr><td colspan="2">6. Performing Organization Code</td></tr>
<tr><td colspan="4">7. Authors:
Keith Jasper (Delcan) Gary Golembiewski (SAIC) Chris Armstrong (SAIC) Sheryl Miller (SAIC)</td><td colspan="2">8. Performing Organization Report No.</td></tr>
<tr><td colspan="4" rowspan="2">9. Performing Organization Name and Address:

Science Applications International Corporation (SAIC)
8301 Greensboro Drive, Mailstop E-12-3 McLean, VA 22102

Delcan Corporation
8618 Westwood Center Drive, Suite 450, Vienna, VA 22182</td><td colspan="2">10. Work Unit No. (TRAIS)</td></tr>
<tr><td colspan="2">11. Contract Or Grant No.
DTFH61-06-D-00005, Task No. T-09-008</td></tr>
<tr><td colspan="4" rowspan="2">12. Sponsoring Agency Name and Address

United States Department of Transportation
ITS Joint Program Office
Research and Innovative Technology Administration (RITA)
1200 New Jersey Avenue, SE
Washington, DC 20590</td><td colspan="2">13. Type Of Report And Period Covered</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code
HOIT-1</td></tr>
<tr><td colspan="6">15. Supplementary Notes
Mr. James Pol, COTM</td></tr>
<tr><td colspan="6">16. Abstract
Through the U.S. Department of Transportation's (USDOT) SafeTrip-21 initiative, the USDOT is testing a variety of technologies in a number of locations in California as well as along the I-95 corridor on the east coast. This document presents the evaluation findings, resulting primarily from in-person interviews the Evaluation Team conducted with institutional partners.</td></tr>
<tr><td colspan="4">17. Key Words
traffic-monitoring, travel information, safety alerts
San Francisco, Bay Area, California, CA, Safetrip-21, evaluation,
final report, deployment</td><td colspan="2">18. Distribution Statement
No Restrictions.</td></tr>
<tr><td>19. Security Classif. (of This Report)
Unclassified</td><td colspan="3">20. Security Classif. (of This Page)
Unclassified</td><td>21.No of Pages
32</td><td>22. Price
N/A</td></tr>
</table>

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized.

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Cover image credits (clockwise from top left, ending in center): PATH, UC Berkeley; Sudhir Murthy, TrafInfo Communications, Inc.; PATH, UC Berkeley; CCIT, UC Berkeley; PATH, UC Berkeley.

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ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ADAS	Advanced Driver Assistance System
AHS	Automated Highway System
CACT	California Connected Traveler
Caltrans	California Department of Transportation
DOT	Department of Transportation
DRI	Caltrans Division of Research and Innovation
GPS	Global Positioning System
HOV	High Occupancy Vehicle
I-95	Interstate 95
ITS	Intelligent Transportation Systems
MOEs	Measures of Effectiveness
MTC	Metropolitan Transportation Commission
NAHSC	National Automated Highway System Consortium
NT-FD	Networked Traveler-Foresighted Driving
NTOC	National Transportation Operations Coalition
PATH	Partners for Advanced Transit and Highways
SAFETRIP-21	Safe and Efficient Travel through Innovation and Partnerships in the 21^{st} Century
UC	University of California
USDOT	U.S. Department of Transportation

EXECUTIVE SUMMARY

Under the guidance of the Volpe Center, the California Department of Transportation (Caltrans) was one of two organizations selected to conduct a test bed in support of the United States Department of Transportation's (USDOT) SafeTrip-21 Initiative. The Caltrans' test bed is located in the San Francisco Bay Area and is referred to as the California Connected Traveler (CACT) Test Bed. The second test bed is along the I-95 Corridor. Under the direction and funding of the RITA ITS Joint Program Office, SAIC was selected to conduct an independent national evaluation of the technologies being deployed as part of the two test beds. This document presents the findings of the national evaluation of one of the three applications that comprise CACT Test Bed, the Networked Traveler-Foresighted Driving (NT-FD) application.

PROJECT BACKGROUND

The NT-FD test was developed by the California Partners for Advanced Transit and Highways (PATH) and the University of California (UC) at Berkeley. PATH is administered by the UC Berkeley Institute of Transportation Studies, with a mission to develop solutions to the problems of California's surface transportation systems through cutting edge research.

This NT-FD test was focused on studying the effects of an Advanced Driver Assistance System that provided safety alerts regarding "Slow Traffic Ahead" when driving on a freeway. The test used four instrumented vehicles to provide data needed to generate in-vehicle auditory alerts and to record drivers' reactions. These alerts either interrupted the current radio channel or, in the event that the radio was not switched on, were transmitted through an auxiliary speaker system.

PATH recruited 24 drivers to participate in the test. One criterion for choosing the participants was that their daily commutes took place on the highways in the Bay area that were equipped with the sensors. (Alerts can only be generated for these highways.) Each driver was pre-screened for driving history and given a personal briefing about the test (including an explanation of how the alert system worked), and what to expect. The test occurred during the period from mid-July 2010 until early November 2010.

EVALUATION APPROACH

The evaluation approach was driven by a series of objectives that align with the USDOT's goals for the SafeTrip-21 initiative. Each objective was supported by corresponding hypotheses and measures of effectiveness, which in turn were used to identify specific data sources for the key activities for the evaluation. These data sources provide a detailed bank of knowledge relevant to the application, and a comprehensive look at lessons learned and the success of the NT-FD test. To achieve the evaluation objectives, the evaluation team implemented the following key activities:

- Analyzed ratings of the timeliness, accuracy, usefulness, acceptance, etc. of the safety alerts provided by the recruited drivers – discussed in **Section 2**;
- Documented user perceived benefits of the system by interviewing the recruited drivers – discussed in **Section 2**; and
- Conducted interviews with deployment and operational partners – discussed in **Section 3**.

SUMMARY OF FINDINGS

The NT-FD test involved the deployment of an experimental in-vehicle alert system in a real-world situation using 24 volunteers driving one of four specially instrumented vehicles, each following their normal daily routines. (In designing the experiment, PATH had determined that 24 drivers would provide sufficient data to confirm whether driving behavior had been changed by the in-vehicle alert system – PATH will report its experimental findings separately from the Evaluation Team.) The alert system was operational on freeways across the San Francisco Bay Area on a 24/7 basis for the duration of the test. Each driver had unlimited use of one of four instrumented vehicles for a two week period. The first week represented a baseline period, when driver behavior was monitored during alert situations but with no alerts issued. The second week represented the test period, when driver behavior was monitored in response to alerts. The number of alerts received by each driver varied according to their travel habits, and their speed relative to nearby traffic.

The Bay Area's network of above-ground speed sensors was the sole source of data for determining traffic speed ahead of each instrumented vehicle. Traffic speeds were averaged across all lanes, including HOV lanes, by direction at each sensor location. While the traffic speed information from this sensor network is critical to the NT-FD test, the sensors are neither operated nor maintained by PATH. Any inaccuracies or gaps in the traffic speed information during the NT-FD test were not identified.

The NT-FD test successfully generated in-vehicle alerts and captured information from sensors and cameras installed in the instrumented vehicles for the duration of the test. Through an online survey, drivers provided daily feedback on the alerts they received. When they returned their respective vehicles after two weeks, each driver participated in a face to face interview with the Evaluation Team regarding their overall perceptions of the in-vehicle alert system. The Evaluation Team also interviewed key members of the PATH development team.

Overall, test participants had favorable perceptions about the NT-FD in-vehicle alert system. They did not find the system to be distracting, and indeed most considered it was reassuring, and found it to be a positive aid to the driving task as it helped them maintain (or regain) focus on traffic. This was especially true when driving on less familiar routes, or at times of day when traffic was generally free flowing. During regular commute periods, drivers generally could anticipate upcoming slow downs and found the system to be less useful. Test participants were not concerned by any privacy issues related to the test, other than some initial awareness regarding the cameras installed in the vehicle. After a few days most drivers ceased to be concerned about being monitored by the cameras.

Many test participants encountered occasions when an alert was given that did not appear justified by downstream traffic conditions. (There were fewer occasions when drivers encountered traffic conditions that appeared to justify an alert when none was given.) The specific reasons for such "false alerts" could not be immediately identified by the Evaluation Team. However, the most plausible explanations for these false alerts were that 1) test participants exited the freeway after receiving an alert but before reaching the location associated with the alert, 2) the conditions that caused the alert to be generated were resolved by the time the test participant arrived at the sensor location, 3) there were inaccuracies in the traffic speed information provided by the external speed sensor network, or 4) anomalies occurred that were related to the traffic speed averaging technique, i.e. the test participant may have been driving in a lane at a speed that was considerably faster than the traffic speed averaged across all lanes.

One frequently encountered situation was how the alert system functioned under stop-start driving conditions. These conditions are typically encountered during recurrent congestion, when it is possible for traffic speeds to increase for short distances before coming to a standstill again. If the traffic speed at the sensor location is slower than that at the vehicle location, albeit temporarily, such conditions will correctly generate an alert. Indeed it is possible for multiple alerts to be generated if the congested conditions extend past several adjacent sensor locations. Some participants were able to figure out that this was occurring and modified their speed in an attempt to reduce the number of alerts they were receiving, anecdotally providing evidence of a positive change in driver behavior that would not only reduce the risk of an end-of-queue collision, but which would also help to smooth traffic flow.

The NT-FD test highlighted some future challenges that need to be addressed by transportation agencies and businesses before similar systems become more commonplace. Most participants liked the system, and some indicated they would be prepared to pay if it were commercially available as a standalone system or as an add-on to another in-vehicle system such as a navigation system. The test also highlighted the need for a comprehensive network of accurate and reliable traffic speed sensors as a pre-requisite for an alert system, and for the information from such a network to be available on a real time basis and updated frequently. While most state DOTs have traffic speed sensors, it is unknown how many agencies are currently able to provide real time speed data that could be used for an NT-FD type of system. The respective roles of the public and private sectors in the development, operation, and maintenance of a more widely available system would need to be defined. Regardless, the NT-FD test has much to contribute to the ongoing evolution of the traffic information services sector.

CONCLUSIONS

The NT-FD test successfully provided real time in-vehicle alerts that prepared drivers for upcoming slow-moving traffic that could potentially lead to end-of-queue collisions resulting in death/injury and property damage for those involved. In addition, responding agencies may incur emergency response and incident management costs, while travelers may experience congestion delays. The Evaluation Team has made no estimates of the possible impacts or cost savings of a system such as NT-FD test.

The 24 test participants provided valuable feedback on the in-vehicle alert system, including suggestions on how the system could be enhanced for possible future deployment. Such enhancements include an indication as to how far ahead the slow moving traffic is, e.g. in 30 seconds, and improvements in the delivery of the auditory alert, perhaps by using a chime to alert the driver to an impending message. PATH's own analysis (to be published separately from this evaluation report) of the data collected by the instrumented vehicles will investigate whether driving behavior changed as a result of the alerts. However the information collected by the Evaluation Team provides anecdotal evidence that drivers did modify their behavior during congested conditions to reduce the number of alerts they were receiving.

The NT-FD test demonstrated the potential for utilizing the vast amounts of traffic data collected by existing sensors to enhance safety by providing targeted and personalized traffic information to drivers. The test also highlighted the potential for personalized traffic information to provide greater control and reassurance to drivers.

In addition to the technical lessons learned, the NT-FD test indicated the importance of an effective public-private-academic partnership if the safety alert system is to become more widely available.

PART I: INTRODUCTION

In February of 2008, the Volpe Center established two test bed locations across the country to conduct a variety of field tests in support of the United States Department of Transportation's (USDOT) SafeTrip-21 Initiative. The overall goals of the initiative are to:

- Expand and accelerate the U.S. DOT's research in vehicle connectivity with wireless communications.
- Build upon Intelligent Transportation Systems (ITS) research in advanced-technology applications.
- Explore and validate the benefits of deployment-ready applications that provide travelers, drivers, and transit and commercial motor vehicle operators with enhanced safety, real-time information, and navigation assistance.

The Volpe Center solicited proposals from potential partners with real-time ITS information, navigation, communication, and electronic payment systems currently installed (or with the potential to be installed) in an integrated operational setting. The Test Bed sites were to test and evaluate integrated, intermodal ITS applications, particularly those that do not entail extensive public sector infrastructure requirements but achieve immediate benefits and demonstrate the potential for sustainable ongoing deployment.

The Volpe Center made two awards, one being the California Connected Traveler (CACT) Test Bed, which involved an integrated Test Bed in the San Francisco Bay Area and two independent applications[1] that would be deployed in California. The other award was the I-95 Corridor Test Bed, which involved a Test Bed along the I-95 Corridor from North Carolina to New Jersey as well as an independent application[2] that would be deployed in North Carolina.

The CACT Test Bed includes the following three field test applications:

- Mobile Millennium: This application is a real time traffic information system for highways and arterials in the San Francisco Bay Area. The major source of traffic information was participants' GPS-enabled smart phones, which generated traffic data as their owners drove around the Bay Area, essentially serving as a large-scale deployment of vehicle probes. Traffic information, in the form of speed estimates displayed on a traffic map, was delivered to the participants' smart phones. Analysis of this application involved understanding consumer and stakeholder experience with the mobile application and assessing the highway and arterial models developed using smart phone data.
- Networked Traveler-Foresighted Driving: This application involves providing alerts of upcoming slow traffic to drivers of specially instrumented vehicles.
- Networked Traveler-Transit/Smart Parking: This application involves creating a multi-modal trip planning tool for travelers in the US-101 corridor in the Bay Area. The information is available to all travelers through a website and to registered users through a mobile website.

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[1] The independent applications were proposed by vendors. One was related to work zone safety and the other to intersection delay at traffic signals. Volpe directed Caltrans to allow these independent applications to be tested on the California Connected Traveler Test Bed.

[2] The independent application to be tested on the I-95 Test Bed was related to work zone safety.

Under the direction and funding of the RITA ITS Joint Program Office, SAIC was selected to conduct an independent national evaluation of the technologies being deployed as part of the two test beds, which are being managed by the Volpe Center. This document presents the findings of the national evaluation of Networked Traveler-Foresighted Driving, one of the three applications that comprise the CACT Test Bed. The remainder of this document is organized as follows:

Part I: Introduction. The current section provides information on the CACT Field Operational test deployed under the SafeTrip-21 Initiative.

Part II: Findings.

- **Section 1 – Background.** Provides background information on the timeline for development of Networked Traveler-Foresighted Driving (NT-FD), and describes the application. This section also summarizes the evaluation approach, hypotheses, and measures of effectiveness developed previously and detailed in the Evaluation Plan.
- **Section 2 – User Experience.** Summarizes the perceptions of participants, and presents the results from the online daily alert surveys.
- **Section 3 – Deployment Experience Assessment.** Details the design, deployment, and operational phases of the deployment by identifying successes, shortfalls, and significant lessons learned.

Part III: Summary and Conclusions. Summarizes the major findings of the evaluation and states the major conclusions drawn from the results.

Part IV: Appendices

PART II: FINDINGS

Part II of this evaluation report addresses the findings of the NT-FD test.

1. BACKGROUND

1.1 NETWORKED TRAVELER-FORESIGHTED DRIVING

This NT-FD test was focused on studying the effects of an Advanced Driver Assistance System (ADAS) that provided safety alerts regarding “Slow Traffic Ahead” when driving on a freeway. Generically speaking, the term ADAS is used to refer to any number of systems that might be conceived to support the driver in the task of driving. The range of ADAS systems encompasses backup cameras and alerts to collision avoidance systems that might automatically apply the vehicle’s brakes in a crash-imminent situation. While there has been much research done in the field of ITS that is related to various ADAS systems, there has been very little research published on the effectiveness of an ADAS system that provides safety alerts, such as the “Slow Traffic Ahead” ADAS that is being studied in this test.

The NT-FD test was developed by the California Partners for Advanced Transit and Highways (PATH) and the University of California (UC) at Berkeley. PATH is administered by the UC Berkeley Institute of Transportation Studies, with a mission to develop solutions to the problems of California's surface transportation systems through cutting edge research.

This test was re-scoped towards the end of 2009 to reflect USDOT’s concerns on distracted driving. Previously, PATH had planned to make alerts available to drivers through their dash-mounted smart phones. The GPS function on the smart phone would have provided location and trajectory information on the vehicle that would have been used to determine whether and when alerts would be triggered. After receiving an alert, drivers would have sent immediate feedback to PATH on the value of the alert by responding to simple questions on their smart phones. In so doing the application would “learn” how drivers use the alerts (i.e., their preferences), enabling the option to filter which alerts were sent to a specific driver. By entering their destination via their smart phone before starting their trip, drivers could receive alerts and other incident information based on their likely route (as calculated by the application) to their final destination. Since this option was not realized, the algorithms could not be refined enough to help minimize the false alarms.

The re-scoping of the test sought to retain the concept of providing targeted in-vehicle safety alerts while minimizing driver distraction. Instead of using drivers’ personal smart phones to track their location, deliver alerts, and transmit feedback, the test used four instrumented vehicles to provide data needed to generate alerts and to record drivers’ reactions. The alerts were auditory – no visual alerts were provided to the driver. In this way, the level of distraction to the driver was likely reduced (compared to the original concept using smart phones) save for the auditory alerts that were transmitted to the vehicle. These alerts either interrupted the current radio channel or, in the event that the radio was not switched on, were transmitted through an auxiliary speaker system.

PATH recruited 24 drivers to participate in the test. PATH sought to recruit an equal number of males and females, to satisfy experimental design criteria. The major criterion for selecting the participants was that their daily commutes took place on the highways in the Bay area that were equipped with the sensors. (Alerts can only be generated for these highways.) Recruitment used a variety of approaches, including advertisements on the local Craig’s List publication, involvement in previous PATH research, university contacts, and word of mouth by the recruited participants. No specific age limits were set, other than recruits had to be older than 18 years (to satisfy insurance requirements) and drive to work. Prior to recruitment, each driver was pre-screened for driving history. Demographics of the recruited test participants are provided in Section 2.2.1.

Instrumented vehicles were picked up and returned to PATH's Richmond Field Station facility. Vehicle pickups and returns were scheduled on alternate Saturday mornings for the duration of the test. Prior to receiving the instrumented vehicle, each participant was given a personal briefing about the test and what to expect. Participants also completed official paperwork.

Use of the instrumented vehicle was free of charge for the duration of each driver's two week participation, and fuel costs incurred for the instrumented vehicle were covered by PATH. Participants received an incentive payment (paid by PATH) of $100, as thanks for participating in the research. Participation included completion of an online daily survey, in which each driver provided ratings for the alerts he/she had received on each day during the second week. This rating information was used by the Evaluation Team. The incentive payment was made when each driver returned their vehicle at the end of their two week stint, and after they had participated in a face-to-face debrief interview with the Evaluation Team. Typically, the evaluation team reviewed the ratings provided in the online daily survey by each driver prior to their debrief interview.

Currently, traffic information in the Bay Area is available pre-trip (internet, television, etc.) or en-route (radio broadcasts, 511 etc.) However, this information may focus on major incidents rather than recurring congestion, and is generally not customized for individual drivers. In the NT-FD test, the ADAS safety alerts being studied actually targeted specific drivers, in specific circumstances, with information that was specifically relevant to them. Thus, instead of just telling the driver that there may be congestion on some part of the freeway network, the application only alerted those drivers who were rapidly approaching slow traffic in the next 60 seconds (e.g., the driver's speed was more than 15 mph greater than the speed of traffic ahead).

The test methodology utilized a naturalistic field test design in conjunction with the instrumented vehicle. In this design, cars were equipped with ADAS technology, and participants drove the cars for two weeks. The ADAS installed in the vehicles provided the driver with an auditory "Slow Traffic Ahead – xx MPH" alert; the alert states the speed of the traffic ahead. The volume level for the alert was preset, and the alert was generally provided 60 seconds before the system estimated the vehicle would encounter the slow traffic.

Traffic speeds were determined by a pre-existing network of traffic sensors on freeways in the Bay Area, operated and maintained on behalf of the Metropolitan Transportation Commission, the Bay Area's Metropolitan Planning Organization, as part of the region's 511 traffic information system.

Four vehicles were instrumented for the test – two Nissan Altimas, and two Audis (see Figure 1.) During the test, each driver had full use of an instrumented vehicle for two weeks. During the first week, all instruments were functioning but alerts were not given to the driver. The instrumented vehicles gathered baseline driving behavior; the driver simply drove as normal and did not receive any alerts. Drivers were not restricted to a specific section of highway or period of time, but were free to travel wherever and whenever they chose, i.e. to go about their normal daily business.

Figure 1. Audi Vehicle Used in the Test
Courtesy: PATH

During the second week, the alerts were activated, enabling a comparison of driving behavior both with and without the alerts. The number of alerts received per day depended on how frequently they encountered the transition between free flow and congested traffic conditions on freeways in the Bay Area. In practice, drivers could have received alerts at any time they drove, provided the application detected a speed differential of 15 mph or greater between an instrumented vehicle and traffic downstream from the instrumented vehicle.

NT-FD was launched on July 17, 2010 and continued through November 13, 2010, when the 24th driver returned their vehicle.

Test Conduct

The process for conducting the test was carefully designed to safely meet the experimental requirements of PATH and to address the evaluation objectives of the Evaluation Team. In addition, to protect the privacy of the 24 subject drivers both PATH and the Evaluation Team applied for and received formal approval from their respective review boards concerned with the protection of the test participants. To discharge its responsibilities with respect to protecting the identity of the test participants in the course of interacting with them, the Evaluation Team was cautious to maintain the anonymity of test participants at all times.

While PATH and the Evaluation Team conducted separate data gathering activities, these activities occurred in parallel and involved interaction with the test participants. As a result, test and evaluation activities needed to be highly coordinated.

PATH's experimental design, which is completely separate from the evaluation, seeks to test whether or not providing the test participants with safety alerts will influence driver behaviors, and has the potential to reduce the number of crashes or the probability of a crash at the end of queue or curve locations. In short, PATH will test this by comparing the driving behavior of test participants during a one week baseline period when they do not receive alerts to their corresponding driving behavior during the subsequent week when they do receive alerts. PATH's experiment relies predominantly on sensor and video data collected from the instrumented vehicles. This information is combined to form a composite video, as shown in Figure 2. At the time of writing this report, the combined sensor and video data is only available in a raw data format and has not been used by the Evaluation Team. PATH is expected to publish the findings of its research in early 2011.

Figure 2. Screenshot of Video and Vehicle Status

Courtesy: PATH
Note: the image shows a member of the PATH team, not one of the 24 test participants.

1.2 EVALUATION APPROACH

The evaluation approach was driven by a series of objectives that align with the USDOT's goals for the SafeTrip-21 initiative – see Table 1.

Table 1. Goals, Objectives, and Hypothesis Statements

SafeTrip-21 Goal	Evaluation Objectives	Hypothesis
Build on ITS research	Understand the technical, human-machine interface, and institutional issues associated with gathering specific vehicle location and speed data, and distributing safety information to drivers	Lessons learned through the development of the Networked Traveler project will build on current knowledge / understanding of providing in-vehicle safety alerts
Explore / validate benefits of real-time traveler information gathered from traffic probes	Analyze the perceived timeliness, accuracy, and usefulness of safety alerts	Safety alerts will be accurate and useful, particularly when compared to other sources of traffic information
	Explore the user-perceived benefits of the safety alerts	Safety alerts will be perceived to be beneficial

Each objective was supported by corresponding hypotheses and measures of effectiveness, which in turn were used to identify specific data sources for the key activities for the evaluation. These data sources provide a detailed bank of knowledge relevant to the application and a comprehensive look at lessons learned and the success of NT-FD. To achieve the objectives above, the evaluation team implemented the following key activities:

- Analyzed ratings of the attributes (timeliness, accuracy, usefulness, acceptance, etc.) of the safety alerts provided by the recruited drivers – discussed in Section 2;
- Documented user perceived benefits of the system by interviewing the recruited drivers – discussed in Section 2; and
- Conducted interviews with deployment and operational partners – discussed in Section 3.

Constraint

One aspect of the NT-FD test that is beyond the control of PATH is the accuracy of the speed measurement of traffic downstream of the subject drivers in the instrumented vehicles. Speed measurement is dependent on real time speed information provided by a network of traffic sensors deployed at some 600 locations across the Bay Area. These sensors monitor vehicle speeds across multiple lanes, including high occupancy vehicle (HOV) lanes, to generate an average speed at each sensor location for a given direction. In practice, individual lane speeds will likely vary from the average speed across all lanes, especially for the HOV lane. Individual drivers' perceptions of specific alerts will therefore be somewhat dependent on lane choice and the accuracy of the sensors. These sensors are provided by SpeedInfo and funded by the

Metropolitan Transportation Commission (MTC) as part of the region's 511 travel information system;[3] therefore, PATH has no specific knowledge of their accuracy or reliability and did not validate the accuracy of the speed information provided by sensors during the test. However MTC has provided an evaluation of the sensors, undertaken in 2006, to the Evaluation Team. The MTC evaluation compared sensor speeds with ground truth data collected from a single probe vehicle driven in mixed flow lanes during the morning, evening, and inter-peak commute periods on a single day in both directions of I-80 at a single sensor location near Richmond. The principal finding with regard to accuracy was: "It is evident…that the SpeedInfo data was closer to the ground truth when the speeds were closer to free flow. At lower speeds, there was a variance."

Indeed, for ground truth speeds greater than 55 mph, MTC's evaluation shows that corresponding SpeedInfo speeds were within 23 percent of the ground truth speed, and typically within 13 percent. However for ground truth speeds less than 45 mph, corresponding SpeedInfo speeds were at best within 24 percent of the ground truth speed, but occasionally greater than 95%, i.e. the SpeedInfo speed was nearly double the ground truth speed.

[3] Metropolitan Transportation Commission, "511 SF Bay Area" web site, Traffic and Driving Times Map. **http://traffic.511.org/default.asp?refresh=5**

2. USER EXPERIENCE

This section will summarize the participants' perceptions of the alerts. Their views of the alerts, overall impressions, and ratings on various scales were collected through online daily surveys and debrief interviews.

2.1 SURVEY APPROACH

Participant perception data were collected from two sources; the online daily survey and the debrief interview.

Online Daily Survey

The online daily survey was the source of information for user ratings during the second week of the test. This survey was developed to collect the participants' views for each alert received. In order to access the survey (a screen shot is presented in Appendix A), PATH helped each participant create a user ID and password which connected them to the survey developed by PATH. The participants were encouraged to access the site each evening and complete the items for each alert they received that day. To remind participants of the alerts they had received, the time and location of each alert was presented on their screen as they completed the survey. Each participant completed online surveys for most, if not all, of the alerts they received.

Debrief Interview

The debrief interview was the source of information for overall user perceptions of the safety alert system. With the exception of the 24th test participant, the interview was conducted face-to-face when the participant returned the test vehicle to the PATH facility on the Saturday following the second week of driving. (The interview with the 24th participant was conducted via telephone, a few days after completing the test. This was because this participant's vehicle had experienced technical issues associated with the database, which required the baseline week to be repeated. This participant's vehicle was collected from them, rather than being returned the PATH facility.)

For the other 23 test participants, after having been "checked in" by PATH staff, the participants were greeted by a member of the evaluation team who escorted the participant to an office at the PATH facility to conduct the interview (a copy of the interview protocol is contained in Appendix B). The debrief interviews typically lasted thirty minutes and focused on the participant's overall impressions of the alert system. In addition to asking the participants to rate the alerts on a number of different dimensions, the evaluation team members also encouraged the participants to offer their views and impressions on their experiences using the alerts during their daily commutes. After the interview was completed, the participants were thanked for their contribution to the project and they completed their "check out" process with PATH staff.

2.2 FINDINGS

Findings from the debrief interviews and the online daily surveys are presented below, beginning with the debrief interview responses from the 24 test participants. The remaining findings are combined from both information sources, to facilitate interpretation of responses to questions with overlapping topics.

2.2.1 Test Participants

A total of 24 participants were recruited by the PATH staff for inclusion in the study. As shown in Figure 3 most participants were in the 41 to 50 year old age group. Furthermore, 54 percent of the participants were male and 46 percent were female. (PATH had targeted an equal split of males and females.)

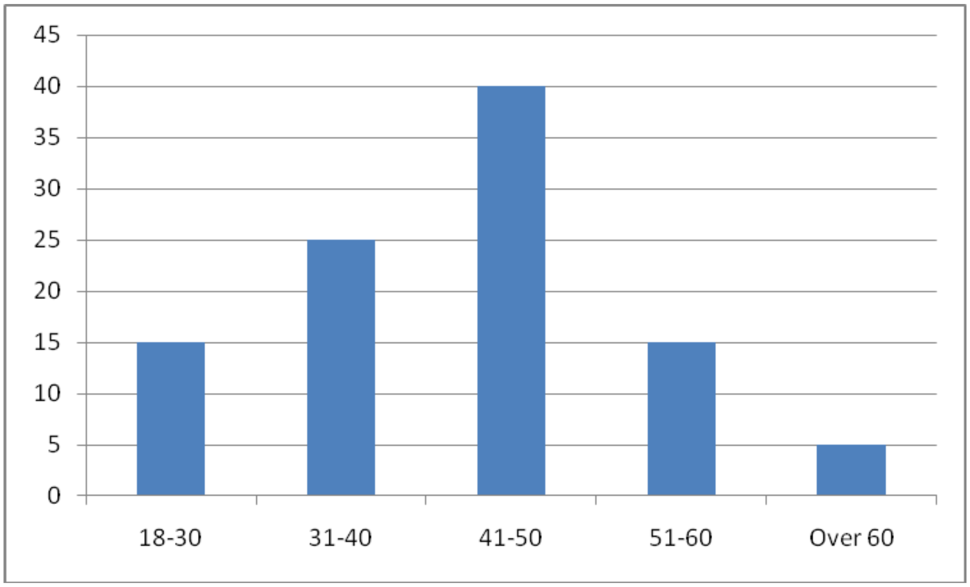

Figure 3. Participants by Age Group

The debrief interview began with a number of questions related to each participant's daily driving patterns and commuting behavior. As discussed in the Introduction, one criterion for choosing the participants was that their daily commutes took place on the highways in the Bay area that were equipped with the sensors. For the second week of the experiment, while the alerts were activated, the instrumented vehicles were equipped to receive the alerts for that entire week. Essentially all alerts were received while they were commuting to or from work, though a few participants did report they received an alert while running errands or on a drive that was not part of their usual commute.

Participants were asked a number of questions regarding their daily commuting patterns as shown in Figures 4 through 7. As presented, the majority of participants left home for their morning commute between the hours of 6:30 am and 9:30 am and most of their morning commutes took between 31 and 60 minutes.

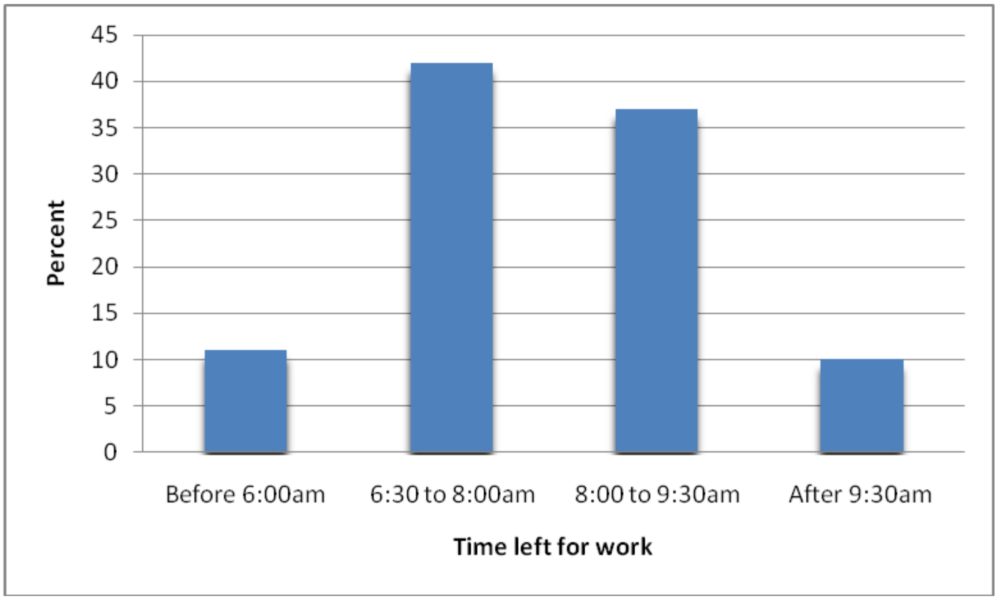

Figure 4. Participants' Morning Commute Start Time

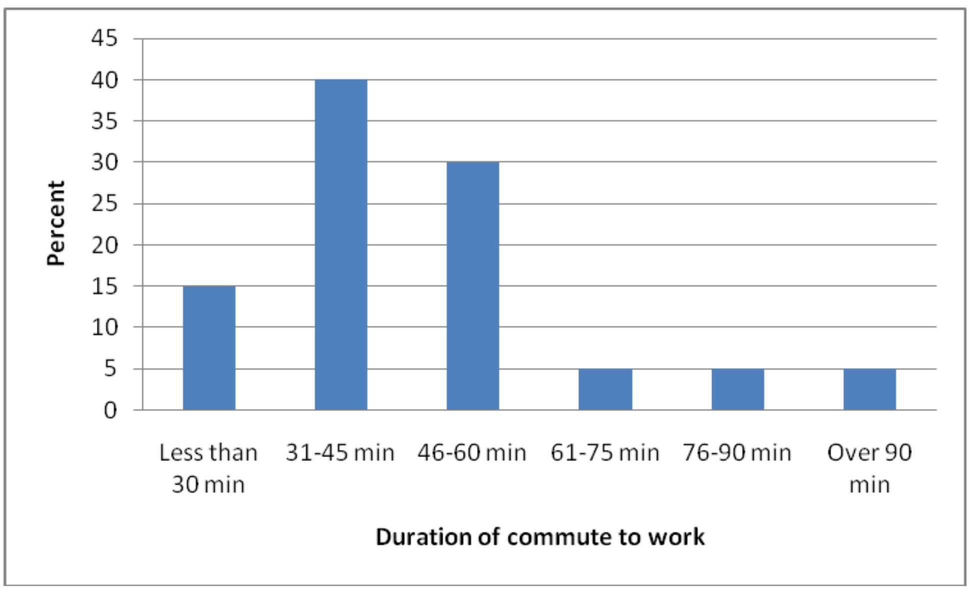

Figure 5. Participants' Morning Commute Time

Evening driving patterns also showed similar consistency for participants. As shown, most participants left work for home between 5:00 pm and 7:00 pm and their usual commuting time in the evening was similar to their morning commute time, between 31 and 60 minutes.

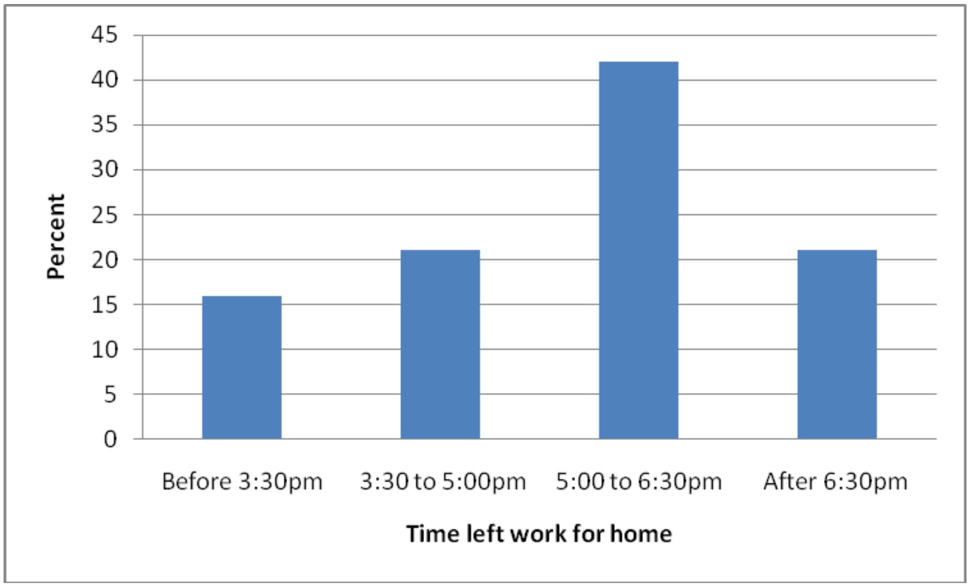

Figure 6. Participants' Evening Commute Start Time

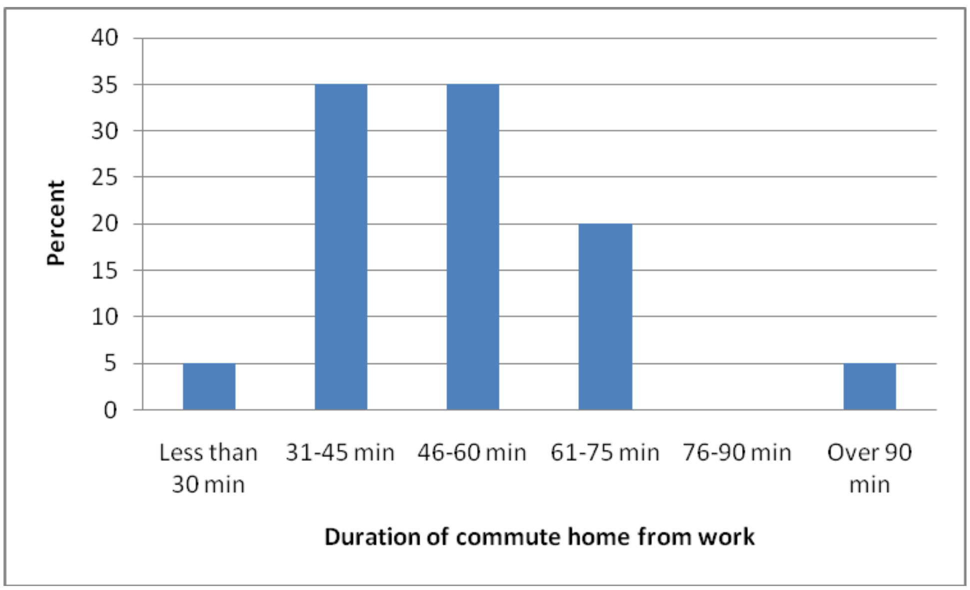

Figure 7. Participants' Evening Commute Time

No participants reported they regularly drove during the day on business and only one reported using the HOV lanes on a regular basis.

2.2.2 User Perceptions and Ratings

The results presented below reflect the two information sources used to assess participants' perceptions – the online daily survey and the debrief interview. It must be noted here that while each technique was used to measure perceptions, these sources reflect slightly different types of results and must be interpreted in that light. The debrief interview data focused on the participants' overall perceptions of having driven the instrumented vehicle for two weeks and receiving alerts for the second of these two weeks. Ratings of the system's attributes were collected as were general comments and observations that participants had during the test period. Therefore, the results presented here using the debrief interview data primarily reflect participants' overall experience. The online daily survey focused on participants rating each individual alert on the day it was received. Many of the attributes rated by participants were similar on both surveys, however, when reviewing the results of the online daily survey, it is important to note that these represent aggregates of individual ratings of each alert; rather than an overall impression or composite, as was gathered in the debrief interview.

On average, test participants received 26 alerts during the second week of their driving experience, with a range of 11 to 70 (one participant drove during the day for his job, therefore, had many more alerts than average). On a typical commuting day, each driver received approximately three alerts during their morning commute and three during their evening commute. Participants were asked about specific attributes of the alerts, including the loudness, timing, and various aspects of the message.

Loudness

When considering the loudness of the alerts, the overwhelming majority of participants indicated the sound level was "just right" as shown in Figure 8. Interestingly, many said they missed the first alert (after having driven the car for a week without the alerts) or they were a bit startled when they received the first alert. However, they quickly became accustomed to receiving them. A few participants said that while they learned to expect the alerts when the radio or CD player was interrupted, it would possibly have been more effective to have a beep or a tone precede the alert, which may have made them more aware that an alert was forthcoming.

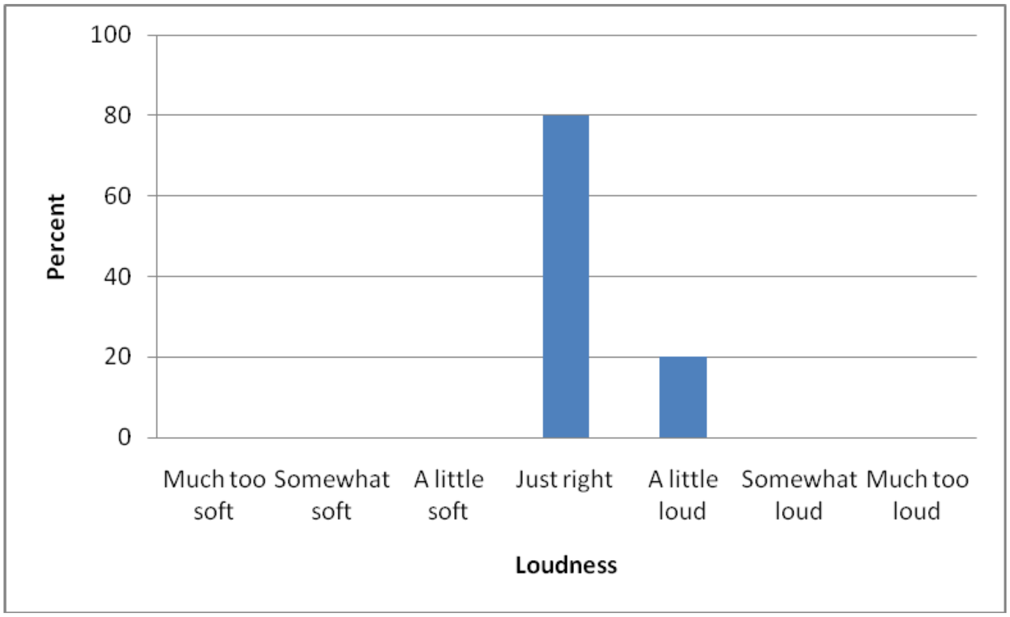

Figure 8. Participants' Ratings of Alert Loudness

Timing of the Alert

As shown in Figure 9, during the debrief interview virtually none of the participants thought the alerts were late; most thought the timing was "just right," though many also felt they were "slightly early" or "a little early." Ratings collected during the debrief interview were consistent with the results of the online daily survey, as shown in Figure 10. Comments made by participants during the debrief interview indicated that the alerts were a bit early since they may have received the alerts but could not immediately see the slower traffic. In addition, a few participants reported that some of the alerts overlapped, especially when they were in heavy congestion and were driving in conditions where they would be driving very slowly then speed up. Those who expressed this understood that it was due to the way the system was programmed, but felt that the additional alerts may have been unnecessary. Those who reported that the alerts were a little late would have liked to have heard them earlier so they could have had more time to decide to change their routes. (As noted earlier, the alerts were triggered approximately sixty seconds before the driver would have encountered slow traffic.) For those drivers who did report this, the lateness of the alert typically occurred as they were approaching decision points such as highway interchanges or exits. They would have liked to have had more than sixty seconds to assess the conditions and determine if a route change would have been beneficial.

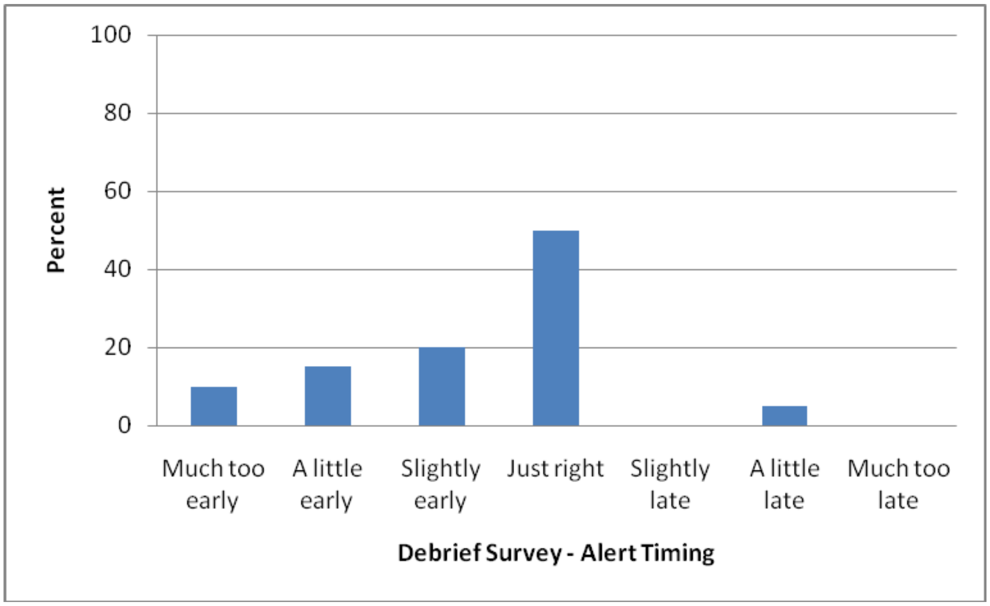

Figure 9. Participants' Rating of Alert Timing – Debrief Survey

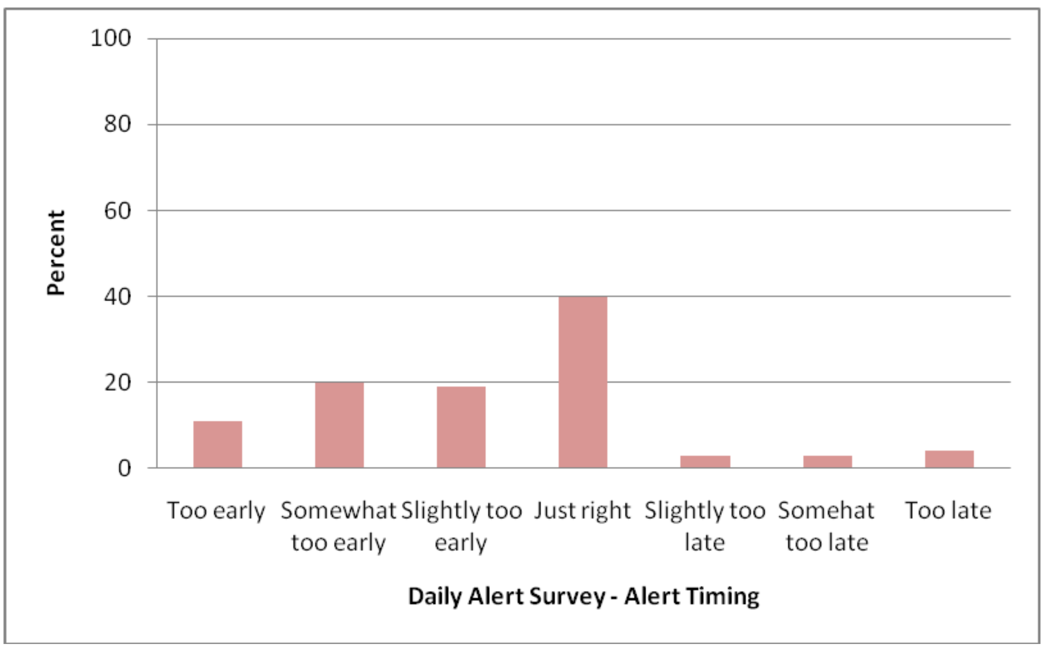

Figure 10. Participants' Rating of Alert Timing – Daily Alert Survey

Quality of the Alert

When asked if the alerts were annoying, over half reported they were not annoying, as shown in Figure 11. Approximately one-third reported they were "a little" or "slightly annoying." Comments from participants such as, "the alerts cut off the radio" and "they always seemed to come on when I was hearing a quote on the news so I missed it" indicates a very low level of annoyance, but the majority of participants reported they, “got used to the alerts and they weren’t a big deal.”

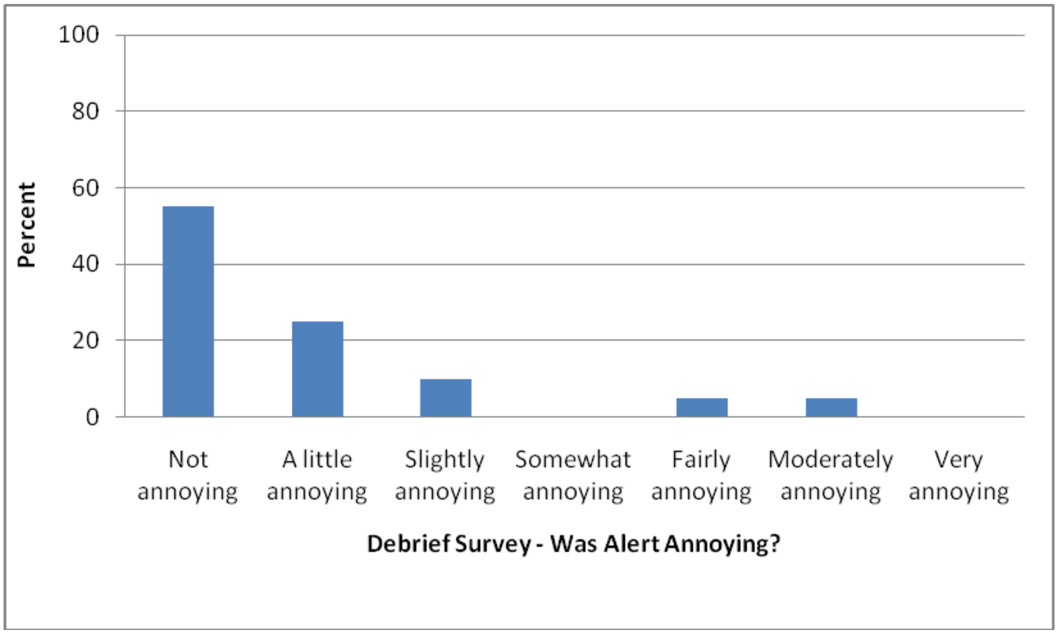

Figure 11. Participants’ Rating of Alert Quality

Distraction

Test participants were asked whether or not they found the alerts distracting to the driving task. As noted by Regan, et. al., distracted driving can be defined as, "the diversion of attention away from activities critical for safe driving toward a competing activity."[4] As shown in Figure 12, almost two-thirds reported the alerts were not distracting, fifteen percent thought they were "a little distracting, " and one-fourth reported, "slightly distracting." None of the respondents reported that the alerts caused them to take their eyes off the road or interfered with the driving task. When queried further, a few participants replied that the alert came on while they were completing a maneuver, such as changing lanes or exiting, and they remembered the alert since they were a bit startled. These comments reinforce the fact that these were not distracting to the driving task and their responses to the alerts were not competing activities. In fact, many reported that when they received the alerts, it made them more aware of their surroundings and caused them to scan the road for traffic. This was especially true if they were listening to music or involved in conversation and may have been driving "on autopilot" – the alerts brought them back to the driving situation. Therefore, participants reported that the alerts served the function of providing an audio signal that there was slow traffic ahead and helped them increase their situational awareness and become more focused on traffic without being distracted.

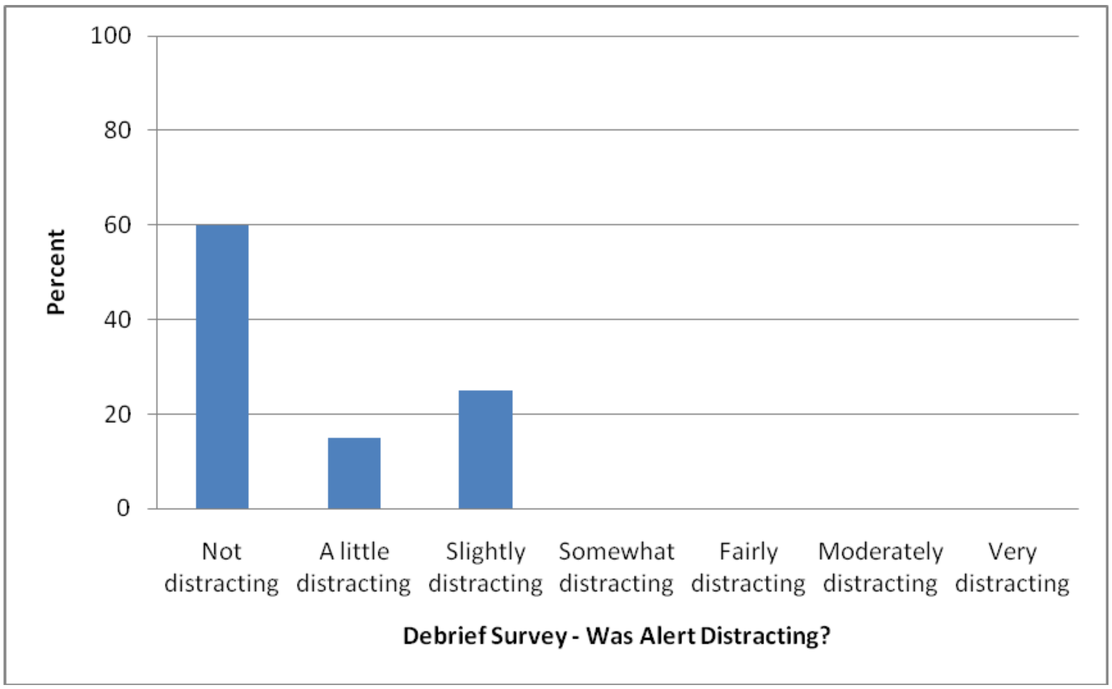

Figure 12. Participants' Rating of Distraction by the Alert

Accuracy/Correctness

As shown in Figure 13, during the debrief interviews none of the participants rated the alerts as "very accurate" or "very inaccurate." Overall responses did hover on the positive side with almost three-fourth rating them as "slightly accurate" or "somewhat accurate." One-fourth of the respondents rated them as "somewhat" or "slightly inaccurate." A similar question asked on the

[4] Regan, M.A., Lee, J.D., and Young, K.L. (eds.) (2009). *Driver Distraction: Theory, Effects, and Mitigation*. CRC Press

online daily survey, as shown in Figure 14, asked for ratings of “correctness” of the individual alerts. This showed a different pattern of results to those from debrief interviews, with ratings dispersed across all categories (including the extremes.) For example, twenty percent of the alerts received a “strongly agree” rating for correctness and ten percent received a “strongly disagree” rating. Overall, less than one-third of the alerts were rated negatively and over one-half were rated positively for their perceived correctness. This is similar to overall ratings from the debrief interviews.

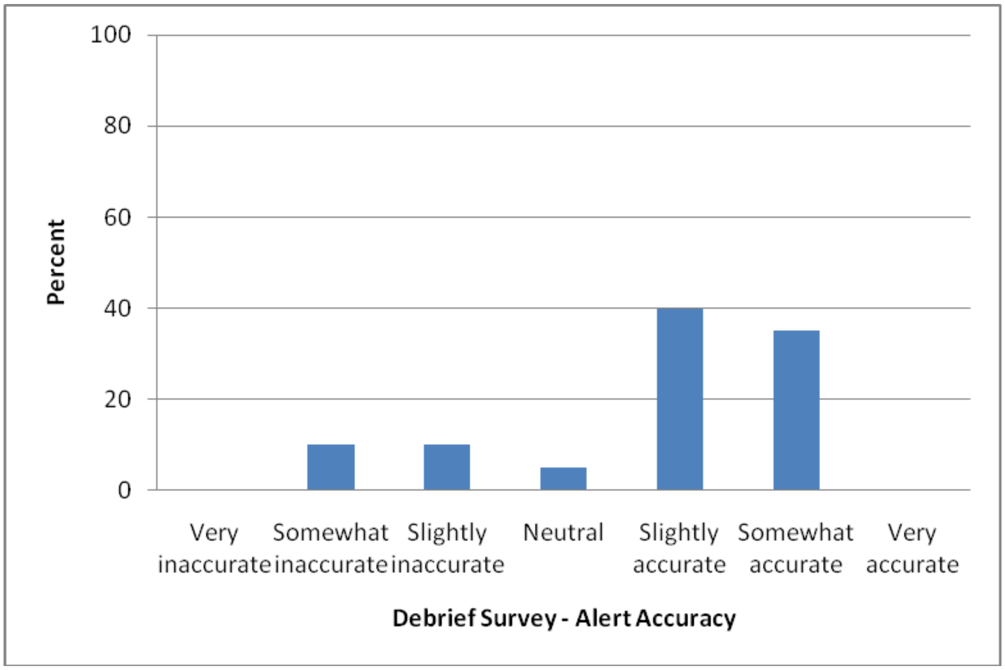

Figure 13. Participants’ Ratings of Alert Accuracy

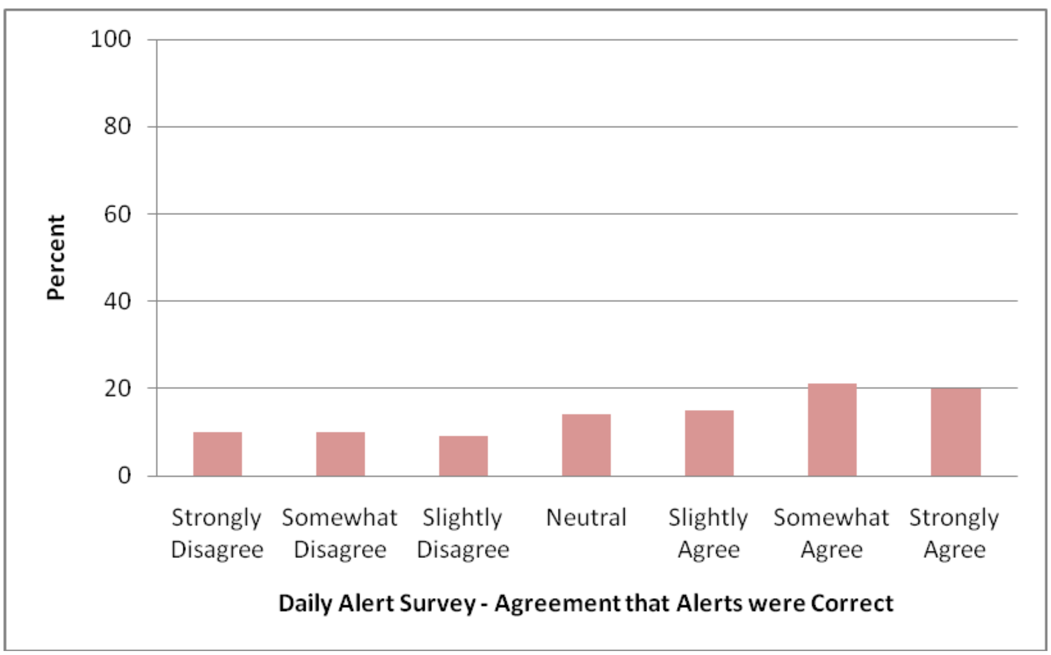

Figure 14. Participants’ Rating of Alert Correctness

Discussions with the participants indicated their perceptions of the alerts' accuracy or correctness depended on a number of factors. Some participants felt that if they didn't see the congestion ahead of them immediately, then the traffic speed sensors or the safety alert system must not have been working correctly; some reported it took 20 seconds to get to the slowdown or that when they reached what was supposed to be congestion, none was there. In addition, there were some instances where drivers could see congestion but no alert came on, also leading to a perception that the alerts weren't working as intended. In addition, they also reported that they saw congestion in the opposite direction but not on the side they were driving on, congestion being gone by the time they got there, congestion on the other highway (freeway interchanges), and getting an alert while traffic in other lanes was slow but "not in my lane." However, while participants did recount there were a number of times when the system seemed inaccurate, they rated the system rather positively, as most reported the alerts were accurate 60 to 70 percent of the time.

Usefulness

Participants who completed the daily alert survey were also asked to rate the overall usefulness of the alerts. As shown in Figure 15, the ratings were distributed across all response categories. Just over one-half reported they "slightly, somewhat, or strongly agreed" the alerts were useful. Fewer, approximately four in ten, said they "strongly, somewhat, or slightly disagreed" that the alerts were useful. This finding is somewhat surprising since participants' ratings on the other attributes, reflected in the online daily survey, were not as negative. However, comments made by the participants showed that while they found the alerts made them more aware of traffic when they came on, the participants also reported that their daily commuting routes and times were "pretty routine" and that they were "pretty aware" when and where slow traffic and congestion would occur. The alerts, for some, provided only redundant information about slow traffic on their regular commutes. Some participants did comment that the alerts were particularly useful when they were driving on non-commute routes, or at times other than their regular commutes. The alerts warned them of slow traffic they couldn't see, such as around curves.

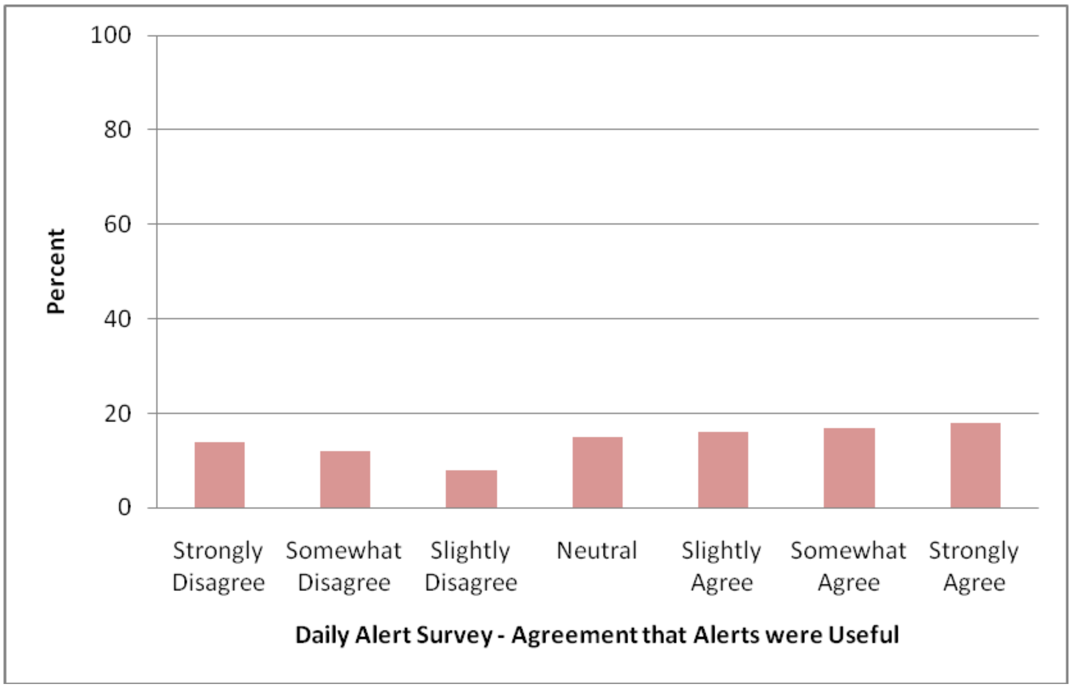

Figure 15. Participants' Rating of Alert Usefulness – Daily Alert Survey

Sense of Feeling Safer

While their ratings of alert usefulness may have been distributed across all categories, participants' ratings of the alerts' effect on safety showed they felt the alerts made them feel safer. As shown in Figure 16, three-fourths of participants said the alerts made them feel "slightly, somewhat, or more safe." This feeling seemed to reflect participants' experiences that when driving and receiving the alerts, they would begin to scan traffic patterns and look for congestion – causing them to increase their situational awareness. In addition, participants also reported that they felt if they did "get lost in their thoughts" or "were listening to music or conversation" they appreciated the alerts to "bring them back to the traffic conditions."

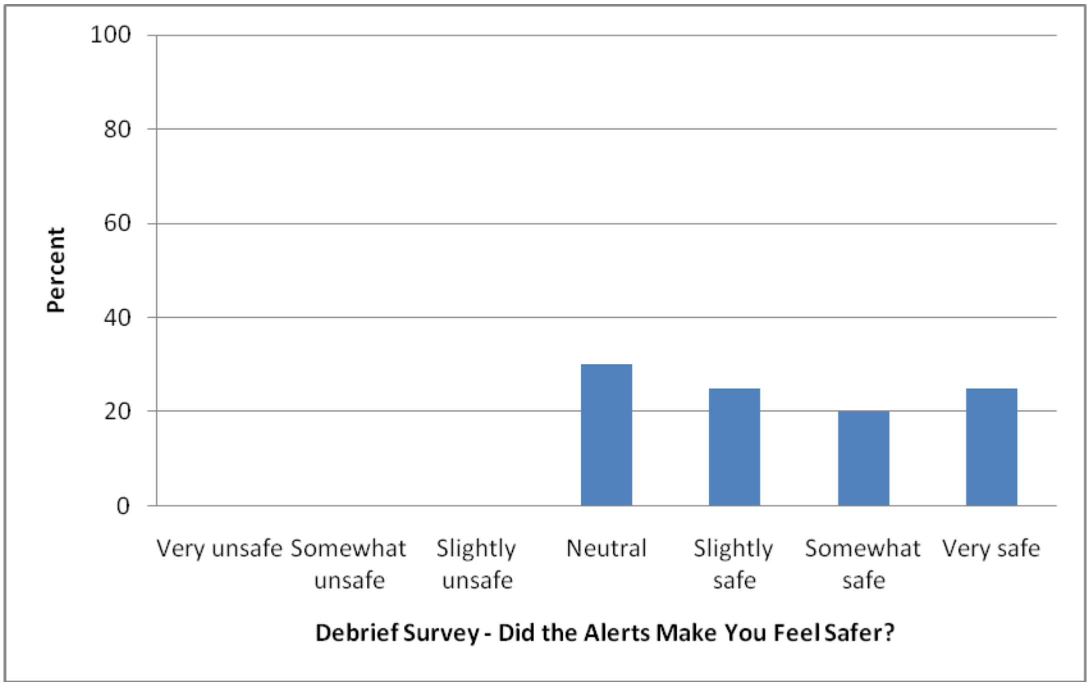

Figure 16. Participants' Rating of Feeling Safer

Behavior Changes

Further insight as to why test participants perceived an increased sense of safety is provided by the behavior changes they made in response to the alerts. As shown in Figure 17, respondents reported the alerts made them more aware of the traffic conditions (57 percent) and that they reduced their speed (40 percent). On the other hand, few participants made route changes or changed lanes as a result of the alerts, which is not surprising because participants typically received the alerts 60 seconds prior to the slow traffic, and no guidance was possible regarding which lanes were affected.

It should be noted that the results for the category "Changed Mode" may be misleading. In debrief interviews, participants talked about slight changes to the way they drove (i.e., their driving mode) – none of the participants reported using transit for their commutes and none reported specific mode shifts based on the congestion alerts.

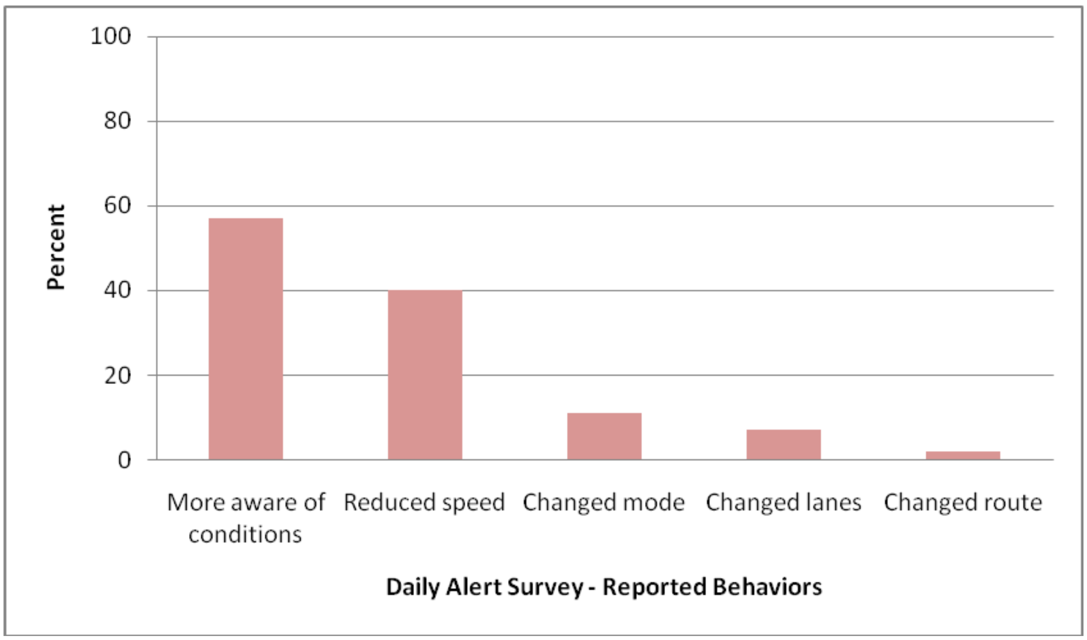

Figure 17. Participants' Reported Behavior Changes

Overall Rating

Overall, the responses from the debrief interviews and the online daily survey (as shown in Figures 18 and 19 respectively) indicated that participants' reactions to the alerts were relatively positive. Approximately 25 percent of respondents rated the alerts as "slightly or very ineffective" at the debrief interview and a similar proportion rated them "bad" through the online daily survey (the latter allowed three response categories – Good, Neutral, and Bad). A higher proportion of positive ratings were obtained in the debrief interview (60 percent) than in the online daily survey (43 percent).

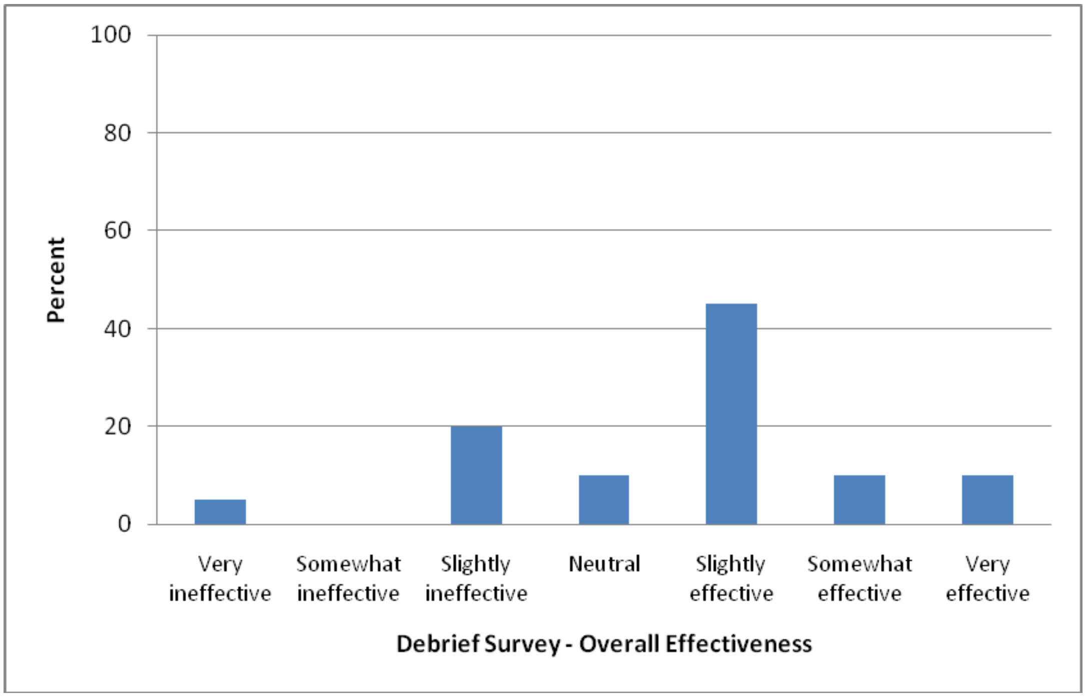

Figure 18. Participants' Ratings of Overall Effectiveness

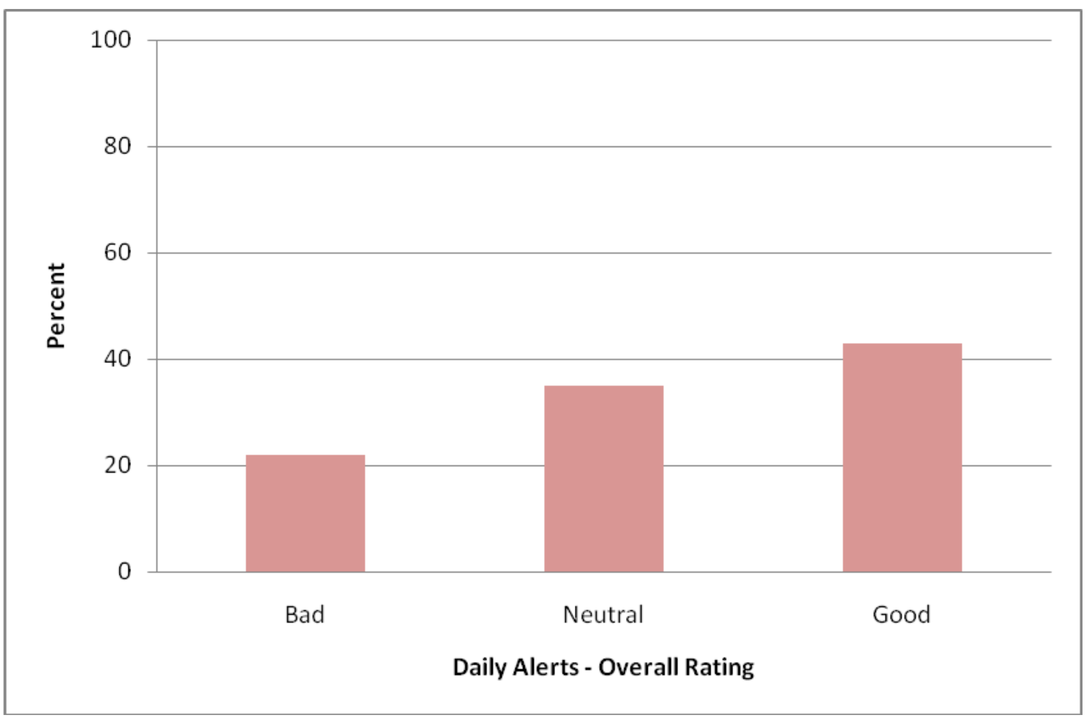

Figure 19. Participants' Overall Rating

Willingness to Pay

Test participants indicated a willingness to pay for a safety alert system in their personal cars. When asked if they would like a system like the one used in the NT-FD test, initially about half said they would consider buying a system similar to the alert system and would be willing to pay "about $10 to $15 dollars a month" for it.

After further discussion, approximately half of those who indicated a willingness to pay modified their responses. Some indicated that an alert system would be much more helpful for trips where they did not know the traffic as well as their daily commutes, some reduced the amount they were willing to pay to $5 a month, and some thought the public sector should supply the information for free on the basis that it enhanced travel safety.

Many participants thought the alert system could be linked to a car's GPS or navigation system, rather than be an additional standalone system.

Suggested Improvements

When asked what could be improved about the system, many participants responded that while the alerts were useful and helpful, it would have been even more helpful if the alert message provided more specific information. While the message was easy to comprehend, if it had also included information on the specific location of the congestion or how long the congestion lasted, it would have been even more valuable.

Privacy

Finally, test participants were asked if they had any privacy concerns while they were taking part in the test. None said they were concerned about having the onboard system record their driving routes and destinations; for the most part, they said they had not really thought about that fact. One participant did mention that she was a bit concerned but knew that all the data would be destroyed after the data collection was completed, so she felt assured her information would not be made public.

Most participants mentioned that the only privacy concern they felt was the fact that there was a camera mounted in the car to record their facial expressions during the experiment. This made them feel somewhat self-conscious, especially at the beginning of their driving experiences, but they also reported they soon learned (for the most part) to ignore the camera.

2.3 SUMMARY

Overall, the results of the experiment showed that the participants did consider the alert system as a valuable device to have in their car to warn them of slow traffic ahead. Participants reported that the system did help them to become more aware of traffic conditions when the alert was triggered and that it helped especially for those instances when congestion did not occur at the "normal" times or locations during their daily commutes. In addition to being more aware, they also reported that the alerts did cause some behavioral changes including reducing their speeds in response to the alerts. They also thought the alert message was delivered at the right loudness level, was very clear and was understandable. However, they also reported that the information may have been more valuable if specific congestion information (e.g., miles upstream and duration) would have been available. This response was also related to their perceived willingness to pay for the system; while some participants said that they would subscribe to this type of system for $10-15 per month, many felt that integrating the alerts with a GPS navigation and traffic information would be the most valuable option.

Participants' overall positive perceptions were surprising in that they conflicted with the relatively low ratings on the overall usefulness of the system, though this may have to do with how the system was designed and the participants' daily commute patterns. For the most part, participants had driven their daily routes "for years" and were aware of where and when traffic congestion occurred. While the alerts did help them maintain awareness, they also felt that in many cases it didn't supply any new information. In fact, when asked, many reported that they saw no congestion after getting the alert. While participants understood that the congestion may have cleared by the time they reached the apparently congested location, these types of performance issues perhaps contributed to a decrease in overall ratings of accuracy. However, they did appreciate that the system helped them be more aware of congestion ahead. They reported that the alerts helped them to have more situational awareness and more focus on traffic. This was especially helpful for non-routine routes (while running errands) and for situations (such as around curves) where they could not actually see the traffic ahead. And, while participants were frank in their opinions on the system, they also saw its value as a safety device and many commented that it would be worthwhile to have this type of alert integrated into a navigation system.

3. DEPLOYMENT EXPERIENCE ASSESSMENT

This section focuses on the deployment experience of the NT-FD test, including operational experiences and lessons learned during development and deployment. The information in this section is mostly based on interviews conducted with representatives of PATH. The purpose of the interviews was to identify obstacles and difficulties that the project partners encountered as well as best practices and successes while implementing this application.

3.1 FINDINGS

The NT-FD test focused on how 24 volunteer drivers reacted to the information provided by the in-vehicle alert system. The test did not provide a management or operational tool, and did not attempt to assess the accuracy of the speed alerts, in large part because these were based on an external source, i.e. the Bay Area's traffic speed sensor network. While the safety alert system was a "beta" system, i.e. a pre-mass market application, with a small number of screened volunteer participants, it nonetheless had to be managed in a real world situation (as opposed to in a simulator.)

3.1.1 Background

Since its inception in 1986, PATH has been a leader in ITS research. PATH was one of the ten core participants in the National Automated Highway System Consortium (NAHSC), which began a seven-year effort to conduct the System Definition Phase of the Automated Highway System (AHS) program in October 1994. PATH researchers were active in most of the tasks of the NAHSC work plan, leading the development of AHS modeling and analysis tools, and making significant contributions to evaluation and development of enabling technologies for AHS, development of the 1997 AHS demonstration in San Diego, evaluation and selection of AHS operating concepts, and design and development of a prototype AHS.

Prior to the SafeTrip-21 initiative, PATH had already developed a Vehicle-Infrastructure Integration (VII) test bed to explore the concept of information exchange between vehicles, from the roadside-to-vehicle or from the vehicle-to-roadside. VII was a prime enabler for emerging safety and mobility applications. PATH demonstrated VII technologies at the 2005 ITS World Congress, held in San Francisco. Ongoing research by U.S. DOT into vehicle-to-infrastructure communications led to the creation of the SafeTrip-21 field operational test, to explore how currently available technology could be applied. PATH demonstrated examples of the Networked Traveler concepts, focused on leveraging increasingly ubiquitous smart phone technologies, at the 2008 World Congress, held in New York City. One of those concepts eventually evolved into the NT-FD test.

3.1.2 PATH Goal

PATH had one goal for the NT-FD test, namely to test driver behavior in response to audible situational awareness alerts. The test hypothesized that alerts would influence positive behavior in drivers that may in turn lead to safer driving. To investigate driver behavior, PATH collected deceleration profiles and video data from the instrumented vehicles to determine whether participants braked earlier and more slowly when they were provided with safety alerts, compared to no alerts. As noted previously, PATH will report the findings of its research separately from this evaluation report. The Evaluation Team is therefore unable to report on PATH's findings, other than to confirm that PATH successfully recruited 24 test participants, all of whom completed the requirement to drive an instrumented vehicle for two weeks.

3.1.3 Implementation Challenges and How they Were Overcome

The overriding implementation challenges were related to re-scoping of the NT-FD test to minimize the likelihood of test participants being distracted while driving. This meant that instead of drivers using their smart phones to receive safety alerts, each instrumented vehicle required the capability to:

- Accurately record the vehicle's location, direction, and speed in real time and transmit this information to the NT-FD server.
- Broadcast audible safety alerts to the driver when directed by the NT-FD server, taking account of whether the in-vehicle radio system was in use.
- Capture and store driver behavior through a series of in-vehicle sensors and cameras, in addition to capturing video of traffic conditions ahead of, and behind, the vehicle.
- Do all the above with minimal distraction to the driver.

While PATH had use of four vehicles (two Nissans and two Audis) for the test, none of these vehicles were equipped with the instrumentation required to conduct the test. Indeed, because the original intent of the test had been to use registered users' smart phones as the means to track the users, transmit alerts, and obtain driver feedback, extensive design and development work was needed to specify the hardware and software required for the test. This design and development activity was compounded by the fact that two different makes of vehicle were involved. (Data stored on each vehicles' on-board computer were required as part of PATH's proposed analysis.) To complicate matters further, access to data from the Audis' on board computers was subject to more restrictive terms and conditions than that from the Nissans. This necessitated interaction with research engineers at VW/Audi who were based in Germany, introducing language and time zone issues. While VW/Audi was helpful, the company was not a test partner, and addressing PATH's questions was not a priority. This introduced delays that resulted in the Audis taking longer to get into service than the Nissans, and considerably longer than anticipated. These delays resulted in unanticipated costs and associated budget issues.

While PATH is highly capable of developing such systems, it acknowledges it was less well equipped to estimate the levels of effort associated with meeting the considerable time constraints in specifying, procuring, installing, testing, and debugging the vehicle subsystems for the NT-FD test.

3.1.4 Methodologies for Determining User Needs

No formal process was followed with regard to determining user needs. In part the test was motivated by Caltrans' concerns that end-of-queue collisions were a significant cause of freeway crashes, and the NT-FD concept offered the potential to address this issue. Also of interest to Caltrans was the extent to which the existing cellular communications system could be leveraged in lieu of a dedicated communications system.

Following the re-scoping of the test to minimize distracted driver concerns, the importance of determining user needs was somewhat diminished as the experimental design dictated there would be a maximum of 24 drivers; consequently, a comprehensive user requirements analysis was not conducted. Further development of the safety alert system was mostly influenced by the need to address hardware, software, power, and communications issues, and to integrate subsystems related to in-vehicle instrumentation, the database/server, external traffic speed data, and the generation of safety alerts. These issues were addressed through regular coordination between team members responsible for these respective areas. During the course of this coordination, human factors considerations influenced the design of the interface with users, which essentially consisted of synthesized voice messages announcing the alert.

3.1.5 Institutional Challenges

Given that the development, deployment, and operation of the NT-FD test primarily involved the PATH development team and the 24 recruited participants, institutional challenges were limited to two areas – internal resources and the administrative arrangements between PATH, UC Berkeley, and Caltrans.

These technical issues were compounded by internal administrative issues with Caltrans and UC Berkeley, specifically related to availability of funding to purchase equipment in a timely manner. PATH considers that this was a major impediment to the timely execution of the experiment.

3.1.6 Approaches for Managing Anonymity and Privacy

PATH took stringent steps to protect the privacy of the test participants, and was transparent about what information was collected and why. That said, test participants had to provide sufficient information for PATH to be able to conduct a background check on their driving history. Given that the test involved the capture of video images of the driver while driving, test participants were given a range of options for allowing their image to be used for future research opportunities using that footage.

Based on the surveys conducted, there were no participant concerns about privacy, even though they were tracked whenever they were driving. Some test participants were initially apprehensive about the in-vehicle camera recording their driving behavior. However, this was a short-lived concern for the first few days of the two-week test period.

The extent to which any future deployment of the NT-FD concept leads to related privacy concerns depends on several factors, including the respective roles of the public and private sectors. While a commercialized system for providing alerts would retain the need to accurately track the vehicle’s location, direction, and speed, the in-vehicle cameras will not be required. Whether the system was provided as a standalone product or as an add-on service to another device, it would be essential to make the user aware that it will be used for the purposes of providing location-based alerts while driving. Obviously if privacy was a concern, the user would either not purchase the system (if provided commercially) or would at least have the option to disable the service.

It also appears unlikely, based on the test participants’ responses, that any future deployment would lead to concerns about the inherent need of the system to track users. Indeed the test participants expressed positive views that the system provided early warning about potentially dangerous driving conditions resulting from unexpected slow moving traffic. In effect the participants traded off any negative feelings of intrusiveness against the positive sense of having greater control and the reassurance that the system made them feel safer.

PART III: SUMMARY AND CONCLUSIONS

3.2 SUMMARY

The NT-FD test involved the deployment of an experimental in-vehicle alert system in a real-world situation using 24 volunteers driving one of four specially instrumented vehicles, each following their normal daily routines. (In designing the experiment, PATH had determined that 24 drivers would provide sufficient data to confirm whether driving behavior had been changed by the in-vehicle alert system – PATH will report its experimental findings separately from the Evaluation Team.) The alert system was operational on freeways across the San Francisco Bay Area on a 24/7 basis for the duration of the test. Each driver had unlimited use of one of four instrumented vehicles for a two week period. The first week represented a baseline period, when driver behavior was monitored during alert situations but with no alerts issued. The second week represented the test period, when driver behavior was monitored in response to alerts. The number of alerts received by each driver varied according to their travel habits and their speed relative to nearby traffic.

The Bay Area's network of above-ground speed sensors was the sole source of data for determining traffic speed ahead of each instrumented vehicle. Traffic speeds were averaged across all lanes, including HOV lanes, by direction at each sensor location. While the traffic speed information from this sensor network is critical to the NT-FD test, the sensors are neither operated nor maintained by PATH. Any inaccuracies or gaps in the traffic speed information during the NT-FD test were not identified.

The NT-FD test successfully generated in-vehicle alerts, and captured information from sensors and cameras installed in the instrumented vehicles for the duration of the test. Through an online survey, drivers provided daily feedback on the alerts they received. When they returned their respective vehicles after two weeks, each driver participated in a face to face interview with the Evaluation Team regarding their overall perceptions of the in-vehicle alert system. The Evaluation Team also interviewed key members of the PATH development team.

Overall, test participants had favorable perceptions about the NT-FD in-vehicle alert system. They did not find the system to be distracting, and indeed most considered it was reassuring, and found it to be a positive aid to the driving task as it helped them maintain (or regain) focus on traffic. This was especially true when driving on less familiar routes, or at times of day when traffic was generally free flowing. During regular commute periods, drivers generally could usually anticipate upcoming slow downs, and found the system to be less useful. Test participants were not concerned by any privacy issues related to the test, other than some initial awareness regarding the cameras installed in the vehicle. After a few days most drivers ceased to be concerned about being monitored by the cameras.

Many test participants encountered occasions when an alert was given that did not appear justified by downstream traffic conditions. (There were fewer occasions when drivers encountered traffic conditions that appeared to justify an alert when none was given.) The specific reasons for such 'false alerts' could not be immediately identified by the Evaluation Team. However, the most plausible explanations for these false alerts were that 1) test participants exited the freeway after receiving an alert but before reaching the location associated with the alert, 2) the conditions that caused the alert to be generated were resolved by the time the test participant arrived at the sensor location, 3) there were inaccuracies in the traffic speed information provided by the external speed sensor network, or 4) anomalies occurred that were related to the traffic speed averaging technique, i.e. the test participant may have been driving in a lane at a speed that was considerably faster than the traffic speed averaged across all lanes.

One frequently encountered situation was how the alert system functioned under stop-start driving conditions. These conditions are typically encountered during recurrent congestion, when it is possible for traffic speeds to increase for short distances before coming to a standstill again. If the traffic speed at the sensor location is slower than that at the vehicle location, albeit temporarily, such conditions will correctly generate an alert. Indeed it is possible for multiple alerts to be generated if the congested conditions extend past several adjacent sensor locations. Some participants were able to figure out that this was occurring and modified their speed in an attempt to reduce the number of alerts they were receiving, anecdotally providing evidence of a positive change in driver behavior that would not only reduce the risk of an end-of-queue collision, but which would also help to smooth traffic flow.

The NT-FD test highlighted some future challenges that need to be addressed by transportation agencies and businesses before similar systems become more commonplace. Most participants liked the system, and some indicated they would be prepared to pay if it were commercially available as a standalone system or as an add-on to another in-vehicle system such as a navigation system. The test also highlighted the need for a comprehensive network of accurate and reliable traffic speed sensors as a pre-requisite for an alert system, and for the information from such a network to be available on a real time basis and updated frequently. While most state DOTs have traffic speed sensors, it is unknown how many agencies are currently able to provide real time speed data that could be used for an NT-FD type of system. The respective roles of the public and private sectors in the development, operation, and maintenance of a more widely available system would need to be defined. Regardless, the NT-FD test has much to contribute to the ongoing evolution of the traffic information services sector.

3.3 CONCLUSIONS

The conclusions that follow are grouped according to the evaluation objectives for the NT-FD test.

3.3.1 Understand the Technical, Human-Machine Interface, and Institutional Issues Associated with Gathering Specific Vehicle Location and Speed Data, and Distributing Safety Information to Drivers

The NT-FD test contributed significantly to transportation industry's collective understanding of distributing safety information to drivers. The test demonstrated the ability to integrate traffic speeds from existing traffic speed sensors systems with location, direction, and speed information from individual vehicles, in real time using the existing cellular communications system. The test highlighted the potential for distributing personalized in-vehicle speed alerts regarding upcoming slow moving traffic, giving greater situational awareness to the driver with comparable distraction to that caused by listening to the car radio.

There were many technical challenges associated with the test, most notably the instrumentation of the vehicles. While PATH has been involved in related research for more than a decade, this test was different in that volunteer drivers used the instrumented vehicles in place of their own vehicle while following their normal daily routines. In other words, the test was conducted under real world conditions and not in a driving simulator or on an off-road test facility. In addition to the technical challenges associated with fully instrumenting four vehicles from two different manufactures, PATH's experimental design required 24 test participants to drive for two weeks each in order to ensure a robust analysis as to whether the safety alerts resulted in a change in driver behavior resulting from the safety alerts. These technical challenges were compounded by, and contributed to, schedule, budget, and inter-partner contracting issues, highlighting the need for strong capabilities in both technical design and project management. While PATH has strong capabilities in both areas, the NT-FD test highlighted how the technical and programmatic areas interact in situations where there is limited fiscal and schedule flexibility to deal with unexpected circumstances, such as the technical challenges arising from the more restrictive agreement with Audi regarding accessing data from the vehicles' on-board computers.

In its current form, the NT-FD concept cannot be made available to the public at large without first addressing how the safety alert system could be productized. This may be possible as an add-on to an existing in-vehicle service that includes a GPS system. Also required is the ability to communicate with a central server, so that safety alerts can be issued when threshold criteria are met. Finally, to calculate when threshold criteria for safety alerts are met, real-time access to the traffic speed information from the Bay Area's network of traffic speed sensors is required, subject to any restrictions placed on that data by MTC. Expansion of the NT-FD concept will likely require a public-private partnership, given the respective roles of public agencies such as MTC with regard to traffic speed information, and private sector companies with regard to in-vehicle devices and services.

3.3.2 Analyze the Perceived Timeliness, Accuracy, and Usefulness of Safety Alerts

The overwhelming consensus among test participants was that the timing of alerts was about right, or slightly early. Those who reported that the alerts were a little late would have liked to have heard them earlier so they could have had more time to decide to change their routes. (As noted earlier, the alerts were triggered approximately sixty seconds before the driver would have encountered slow traffic.) For those drivers who did report this, the lateness of the alert typically occurred as they were approaching decision points such as highway interchanges or exits. They would have liked to have had more than sixty seconds to assess the conditions and determine if a route change would have been beneficial.

Overall, test participants considered the alerts were "slightly accurate" or "somewhat accurate." However, individual alerts were rated from one extreme to the other, rather than being clustered in a narrow range. Perceptions about the alerts' accuracy depended on a number of factors. Some participants felt that if they didn't see the congestion ahead of them immediately, then the traffic speed sensors or the safety alert system must not have been working correctly; some reported it took 20 seconds to get to the slowdown or that when they reached what was supposed to be congestion, none was there. In addition, there were some instances where drivers could see congestion but no alert came on, also leading to a perception that the alerts weren't working as intended. In addition, they also reported that they saw congestion in the opposite direction but not on the side they were driving on, congestion being gone by the time they got there, congestion on the other highway (freeway interchanges), and getting an alert while traffic in other lanes was slow but "not in my lane." However, while participants did recount there were a number of times when the system seemed inaccurate, they rated the system rather positively, as most reported the alerts were accurate 60 to 70 percent of the time.

As with perceptions of accuracy, the usefulness of individual alerts was rated from one extreme to the other, rather than being clustered in a narrow range. Just over one-half of participants reported they "slightly, somewhat, or strongly agreed" the alerts were useful. Fewer, approximately four in ten, said they "strongly, somewhat, or slightly disagreed" that the alerts were useful. Comments made by the participants showed that while they found the alerts made them more aware of traffic, the participants also reported that their daily commuting routes and times were ”pretty routine” and that they were “pretty aware” when and where slow traffic and congestion would occur. The alerts, for some, provided only redundant information about slow traffic on their regular commutes. Some participants did comment that the alerts were particularly useful when they were driving on non-commute routes, or at times other than their regular commutes. The alerts warned them of slow traffic they couldn’t see, such as around curves.

3.3.3 Explore the User-Perceived Benefits of the Safety Alerts

Overall, the results of the experiment showed that the participants did consider the alert system as a valuable device to have in their car to warn them of slow traffic ahead. Participants reported that the system did help them to become more aware of traffic conditions when the alert was triggered and that it helped especially for those instances when congestion did not occur at the “normal” times or locations during their daily commutes. In addition to being more aware, they also reported that the alerts did cause some behavioral changes including reducing their speeds in response to the alerts. They also thought the alert message was delivered at the right loudness level, was very clear and was understandable. However, they also reported that the information may have been more valuable if specific congestion information (e.g., miles upstream and duration) would have been available. This response was also related to their perceived willingness to pay for the system; while some participants said that they would subscribe to this type of system for $10-15 per month, many felt that integrating the alerts with a GPS navigation and traffic information would be the most valuable option.

3.4 ACKNOWLEDGEMENTS

Special thanks are offered to the following PATH and UC-Berkeley personnel for their assistance in interviews and document review in support of this project:

- Larry Orcutt, Caltrans Headquarters
- Greg Larson, Caltrans Headquarters
- Sean Nozzari, Caltrans District 4
- Jim Misener, formerly with PATH
- Christopher Nowakowski, PATH
- Raja Sengupta, UC Berkeley
- Christian Manasseh, UC Berkeley

PART V: APPENDICES

APPENDIX A: ONLINE DAILY SURVEY

networkedtraveler

1. Overall, how would you rate this alert? Good ◯ Neutral ◯ Bad ◯

2. This alert was correct. Strongly Agree 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ Strongly Disagree

3. This alert was useful. Strongly Agree 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ Strongly Disagree

4. How was the timing of this alert? Too Early 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ Too Late

5. Check all that apply:
   - ☐ I felt that I was more aware of upcoming traffic conditions because of the alert.
   - ☐ I reduced my speed because of this alert.
   - ☐ I changed lanes because of the alert.
   - ☐ I changed my route because of the alert.
   - ☐ I changed my mode of travel because of the alert.

6. Is there anything we should know about the traffic or road conditions when you received the alert?

7. Do you have any additional comments about this alert?

Cancel Submit

APPENDIX B: DEBRIEF INTERVIEW

Foresighted Driving Field Experiment – Debrief Protocol

ID: ____

Date: ____________ (Testing period: Week 1 ___________ Week 2 __________)

Vehicle: ____________________________

Travel Patterns

1. What is your home zip code?

2. What is your primary work zip code?

3. Approximately how long is your daily commute (*one way*)?

   Less than 10 miles

   10-19 miles

   20-29 miles

   30-39 miles

   40-49 miles

   50-59 miles

   60-69 miles

   70-79 miles

   80-89 miles

   90+ miles

4. What roadways do you typically use for your daily commute?

   - Do you typically drive in the HOV lanes? How often?

   4a. Every day
   3-4 days per week
   1-2 days per week

5. At what time do you typically *leave home* for work?

6. Approximately how long does it normally take to drive from *home to work*?

   30 minutes or less

   31 to 45 minutes

   46 to 60 minutes

   61 to 75 minutes

   76 to 90 minutes

   More than 90 minutes

   Varies

7. At what time do you typically *leave work* for home?

8. Approximately how long does it take to drive from *work to home*?

   30 minutes or less

   31 to 45 minutes

   46 to 60 minutes

   61 to 75 minutes

   76 to 90 minutes

   More than 90 minutes

   Varies

9. During a typical work week, how often do you drive during the day for business purposes (excluding your regular commute)?

   Rarely or never

   Once or twice a week

   3 to 4 days a week

   Every day

10. When you drive during the day for business purposes, approximately how much total time do you typically spend on the road (excluding your regular commute)?

    Less than 1 hour

    1 – 2 hours

    More than 2 hours

    N/A

11. What roadways do you typically use when you drive for business purposes?

Demographic Info

1. How old are you?

    18-30

    31-40

    40-50

    51-60

    Over 60

2. What is your gender?

    Male

    Female

3. What is your household income level?

    Less than $50,000
    $50,000 - $74,999
    $75,000 - $99,999
    $100,000 - $124,999
    $125,000 - $149,999
    Greater than $150,000

A. Travel Behavior While Participant

I'd first like to talk about your daily travel behavior in the past two weeks:

A-1. Please tell me, did your daily travel behavior over the past two weeks differ from normal?

A-2. If so, tell me in what ways it differed.

B. Alert Messages Received in the Past Week

Now, I'd like for us to talk about the Alert Messages you received this past week.

B-1. First, can you tell me about how many alerts you received per day?

- How many you received during peak periods (rush hour?)

B-2. Were there days you received more alerts than others or were the number of alerts pretty **consistent** across the five days?

B-3. In general, how did you feel about the **timing** of the alerts? That is, how did you feel about when you got the alerts in relation to when you encountered the slow traffic ahead?

Much too early	A little early	Slightly early	Just right	Slightly late	A little late	Much too late
1	**2**	**3**	**4**	**5**	**6**	**7**

B-4. Could the timing of the alerts be adjusted to make them more effective?

B-5. When thinking about the **accuracy** of the alerts, about what *percent* of the alerts, would you say, accurately conveyed the traffic conditions ahead?

B-6. If any of the alerts were inaccurate, can you tell me what was wrong with them (i.e., what made them inaccurate)?

B-7. Do you have any other comments regarding the **accuracy** of the alerts?

B-8. Overall, how would you rate the accuracy of the alerts?

Very inaccurate	**Somewhat inaccurate**	**Slightly inaccurate**	**Neither accurate nor inaccurate**	**Slightly accurate**	**Somewhat accurate**	**Very accurate**
1	**2**	**3**	**4**	**5**	**6**	**7**

B-8. Were the alerts loud enough?

Much too soft	Somewhat soft	A little soft	Just right	A little loud	Somewhat loud	Much too loud
1	2	3	4	5	6	7

B-9. How did you feel about the content of the message? Was it clear and understandable?

B-10. Can the alert messages be improved? If so, how?

C. Reactions to the Alert Messages

C-1. In general, do you think the alerts changed the way you drove in certain situations?

- If so, what changes did you make?

a) Did you react differently to the alerts at different locations? (e.g., when entering/merging on a freeway; on some freeways but not others; or slowing down to leave/exit a freeway? If so, how did you react in these different situations?

C-2. For about what *percentage* of the situations where you received alerts, were you able to **anticipate** the slow moving traffic on your own (without the alert)?

a) How were you able to anticipate the slow moving traffic without the alert?

[basically, if the driver takes the same route each day, s/he may already know where the "bottlenecks" are – so this may not be new information]

C-3. Did the alert messages **distract** you? (did you lose focus on your driving)

Not distracting at all	**A little distracting**	**Slightly distracting**	**Somewhat distracting**	**Fairly distracting**	**Moderately distracting**	**Very distracting**
1	**2**	**3**	**4**	**5**	**6**	**7**

C-4. Did you find the alerts **annoying**? If so, in what way?

Not annoying at all	A little annoying	Slightly annoying	Somewhat annoying	Fairly annoying	Moderately annoying	Very annoying
1	2	3	4	5	6	7

C-5. Did the alerts make you feel more aware of oncoming traffic conditions (especially when compared to driving without the alerts?)

C-6. How would you compare the alerts to other forms of traffic information you receive while driving

- What other types of information do you use (radio updates, subscription service, real time data, etc.)?

C-7. Overall, did this system make you feel more or less safe while driving? Or about the same? Please explain.

Very unsafe	Somewhat unsafe	Slightly unsafe	Neither safe nor unsafe	Slightly safe	Somewhat safe	Very safe
1	2	3	4	5	6	7

D. Experience with the System

D1. In your experience, were the alerts more effective or useful in certain situation over other situations? If so, which ones? Why?

a) In situations where the alerts were less effective or not effective at all, why was this?

D2. Were there situations when you encountered slow moving or stopped traffic but did not receive an alert? If so, about how many times did this occur?

a) If you can, please tell me about the situations, such as the day, time, route, direction, approximate location?

D3. Would you consider paying for a system like this? If so, how much (per month) would you be willing to pay? If not, why not?

D. Final Thoughts

D1. Did you have any privacy concerns about using this system? (Explain if asked). If so, what were your concerns?

a) If you did have concerns, were they outweighed by having the benefits of the system?

D2. Overall, how effective were the alerts in warning you upcoming slow traffic conditions?

Very ineffective	Somewhat ineffective	Slightly ineffective	Neither effective nor ineffective	Slightly effective	Somewhat effective	Very effective
1	2	3	4	5	6	7

D3. Do you have any other feedback or suggestions about the alert system that you would like to share?