

National Evaluation of the **SafeTrip-21** Initiative Combined Final Report



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16. Abstract Through the U.S. Department of Transportation's (U.S. DOT) SafeTrip-21 Initiative, the U.S. DOT tested 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 findings of the independent national evaluation of eight ITS applications. Part I of the report provides an overview of the initiative and the evaluation activities. Part II summarizes each application that was tested and the related evaluation findings. Part III synthesizes the evaluation findings across four topics relevant to the ITS community – collecting and using traffic conditions data, providing real-time traffic information to drivers, providing multi-modal travel information to travelers, and providing safety information to drivers.			
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TABLE OF CONTENTS

EXECUTIVE SUMMARY	XI
PART I: INTRODUCTION	1
1 OVERVIEW OF THE SAFETRIP-21 INITIATIVE AND THE NATIONAL EVALUATION	2
1.1 The SafeTrip-21 Initiative	2
1.2 The SafeTrip-21 Applications	3
1.2.1 <i>California Connected Traveler Test Bed (CACT) Applications</i>	4
1.2.2 <i>The I-95 Corridor Test Bed Applications</i>	6
1.2.3 <i>Independent Applications</i>	8
1.3 Evaluation Activities	9
1.3.1 <i>Data Collection and Analysis</i>	9
1.3.2 <i>Reporting</i>	9
2 GUIDE TO REPORT ORGANIZATION AND SEARCH INDEX	11
PART II: SAFETRIP-21 APPLICATIONS	13
3 MOBILE MILLENNIUM	14
3.1 Overview	14
3.2 Evaluation Objectives	15
3.3 Evaluation Activities	15
3.3.1 <i>Usage Statistics</i>	15
3.3.2 <i>Ground Truth Analysis</i>	16
3.3.3 <i>Interviews with Deployment and Operational Partners</i>	16
3.3.4 <i>User Survey</i>	16
3.4 Evaluation Findings	16
3.4.1 <i>Consumer Response</i>	16
3.4.2 <i>Ground Truth Analysis</i>	18
3.4.3 <i>Implementation Challenges and How They Were Overcome</i>	19
3.4.4 <i>Methodologies for Determining User Needs</i>	19
3.4.5 <i>Institutional challenges</i>	20
3.4.6 <i>Approaches for Managing Anonymity and Privacy</i>	20
3.5 Conclusions.....	22
4 NETWORKED TRAVELER – FORESIGHTED DRIVING	24
4.1 Overview	24

4.2	Evaluation Objectives	24
4.3	Evaluation Activities	25
4.4	Evaluation Findings	25
4.4.1	<i>User Perceptions</i>	25
4.4.2	<i>Implementation Issues</i>	26
4.5	Conclusions.....	27
5	NETWORKED TRAVELER – TRANSIT / SMART PARKING	30
5.1	Overview	30
5.1.1	<i>PATH2Go Web Based Traveler Information</i>	31
5.1.2	<i>PATH2Go Smart Phone Application</i>	32
5.2	Evaluation Objectives	34
5.3	Evaluation Activities	34
5.3.1	<i>Geofencing Test</i>	34
5.3.2	<i>Usage Statistics</i>	35
5.3.3	<i>User Perceptions</i>	35
5.4	Evaluation Findings	36
5.4.1	<i>Geofencing</i>	36
5.4.2	<i>Usage Statistics</i>	37
5.4.3	<i>User Perceptions</i>	38
5.5	Conclusions.....	38
6	DEPLOYMENT OF REAL-TIME INTERSECTION DELAY MONITORING	41
6.1	Overview	41
6.1.1	<i>How RTID Works</i>	42
6.2	Evaluation Objectives.....	42
6.3	Evaluation Activities	43
6.3.1	<i>The RTID Test</i>	43
6.4	Evaluation Findings	44
6.4.1	<i>Technical Issues</i>	46
6.4.2	<i>Institutional Issues</i>	46
6.4.3	<i>Ease of Downloading</i>	46
6.4.4	<i>Usefulness</i>	47
6.5	Conclusions.....	48
6.5.1	<i>More Frequent Review of Traffic Signal Timing</i>	48
6.5.2	<i>Targeted Use of Resources</i>	49

6.5.3	<i>Reduced Delay to Travelers</i>	49
7	PROVIDING MULTI-MODAL TRAVEL INFORMATION TO AIRPORT USERS	50
7.1	Overview	50
7.2	Evaluation Objectives.....	50
7.3	Evaluation Activities	50
7.4	Evaluation Findings	52
8	DISPLAYING TRAVEL TIMES IN PUBLIC AREAS	54
8.1	Overview	54
8.2	Evaluation Objectives.....	56
8.3	Evaluation Activities	56
8.3.1	<i>Virginia Welcome Centers</i>	56
8.3.2	<i>Tysons Corner Center</i>	57
8.4	Evaluation Findings	57
8.4.1	<i>Virginia Welcome Centers</i>	57
8.4.2	<i>Tysons Corner Center</i>	58
9	LONG DISTANCE TRIP PLANNING USING REAL-TIME TRAVEL TIME DATA	60
9.1	Overview	60
9.2	Evaluation Objectives.....	60
9.3	Evaluation Activities	60
9.4	Evaluation Findings	61
10	DEPLOYMENT OF PORTABLE TRAFFIC MONITORING DEVICES	64
10.1	Overview	64
10.2	Evaluation Objectives.....	64
10.3	Test Sites	64
10.3.1	<i>NCDOT Test Sites</i>	65
10.3.2	<i>Caltrans Test Sites</i>	66
10.4	Evaluation Findings	68
	PART III: EVALUATION FINDING SYNTHESIS	69
11	ALTERNATIVE APPROACHES FOR MONITORING AND USING TRAFFIC CONDITIONS DATA . 70	
11.1	Design and Development	71

11.2	Deployment	72
11.3	Marketing.....	73
11.4	User Experience.....	73
11.5	Institutional Issues.....	74
11.6	Privacy.....	74
11.7	Conclusions.....	74
12	PROVIDING USEFUL AND USABLE REAL-TIME TRAFFIC INFORMATION	76
12.1	Design and Development	77
12.2	Deployment	78
12.3	Marketing.....	78
12.4	User Experience.....	81
12.5	Privacy.....	82
12.6	Institutional Issues.....	82
12.7	Conclusions.....	84
13	PROVIDING MULTI-MODAL TRAVEL OPTIONS TO TRAVELERS	86
13.1	Design and Development	88
13.2	Deployment.....	90
13.3	Marketing.....	92
13.4	User Experience.....	95
13.5	Privacy.....	101
13.6	Institutional Issues.....	101
13.7	Conclusions.....	103
14	PROVIDING IN-VEHICLE SAFETY ALERTS IN END-OF-QUEUE SITUATIONS	105
14.1	Design and Development	105
14.2	Deployment.....	108
14.3	Marketing.....	109
14.4	User Experience.....	110
14.5	Privacy.....	112
14.6	Institutional Issues.....	112
14.7	Conclusions.....	113

15 CONCLUSIONS AND LESSONS LEARNED 115
ACKNOWLEDGEMENTS..... 120

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LIST OF FIGURES

Figure 1. California Connected Traveler Test Bed Regional Map.....	5
Figure 2. Location of I-95 Test Bed Applications	7
Figure 3. Screenshot of the PATH2Go Networked Traveler Web Site.....	32
Figure 4. PATH2Go Smart Phone Application – Distracted Driving Alert.....	34
Figure 5. Sample Screenshot of Average Delay by Lane	47
Figure 6. Fredericksburg Welcome Center Screen.....	54
Figure 7. Traveler Information Screens at Tysons Corner Center.....	55
Figure 8. I-95 Corridor Travel Time Information Website Homepage.....	61
Figure 9. Diagram of PTMD	64
Figure 10. Map Representation of a PTMD Application on I-95.....	65
Figure 11. Work Zone in NC Where PTMDs Were Tested	65
Figure 12. Bay Area Bridges	66
Figure 13. PTMD Installation on Bay Bridge.....	67
Figure 14. Floor Sticker and Bezel Used to Generate Interest in Tysons Corner Screens.....	79
Figure 15. Media Coverage of Tysons Corner Screens.....	80
Figure 16. Display Shows the Next Feature to be Shown to Viewers	82
Figure 17. Principal Means of Transportation to Work, 2009.....	86
Figure 18. Example of Information Provided on <i>BWI Ground Access Information System</i> Website Application.	91
Figure 19. Bezel for the Traveler Information Screens at TCC.	94
Figure 20. PATH2Go Smart Phone Application (Android platform).....	96
Figure 21. BWI Ground Access Information System Mobile Website.	98
Figure 22. Transit Schedules Content on the Traveler Information Screens at Tysons Corner Center.....	100
Figure 23. Audi Vehicle Used in the Test	106

LIST OF TABLES

Table 1. Summary of Applications Tested Under the SafeTrip-21 Initiative.	4
Table 2. List of Evaluation Reports generated as part of the National Evaluation of the SafeTrip-21 Initiative.....	10
Table 3. Index to the Part II Report Summaries and the Part III Evaluation Findings.....	12

ABBREVIATIONS

BWI	Baltimore Washington International Airport
Caltrans	California Department of Transportation
CHP	California Highway Patrol
CMS	Changeable Message Signs
DOT	Department of Transportation
I-880	Interstate 880
I-95	Interstate 95
ITS	Intelligent Transportation Systems
MTA	Maryland Transit Authority
MTC	Metropolitan Transportation Commission
NCDOT	North Carolina Department of Transportation
MOE	Measure of Effectiveness
METRO DC	Metropolitan Washington, DC
NT-FD	Networked Traveler – Foresighted Driving
NT-T/SP	Networked Traveler – Transit / Smart Parking
NCHRP	National Cooperative Highway Research Program
PATH	California Partners for Advanced Transit and Highways
PTMD	Portable Traffic-Monitoring Devices
RTID	Real-time Intersection Delay
SAFETRIP-21	Safe and Efficient Travel through Innovation and Partnerships in the 21 st Century
SAIC	Science Applications International Corporation
TCC	Tysons Corner Center
TOC	Traffic Operations Center
TIS	Traveler Information Screen
TCM	Traffic Conditions Map
TMC	Transportation Management Center
TTCT	Travel Time Calculation Tool
TYTRAN	Tysons Transportation Association
U.S. DOT	U.S. Department of Transportation
US 64	U.S. Route 64
VDOT	Virginia Department of Transportation
VTC	Virginia Tourism Corporation

EXECUTIVE SUMMARY

BACKGROUND OF THE EVALUATION

The U.S. DOT SafeTrip-21 (Safe and Efficient Travel through Innovation and Partnerships for the 21st Century) Initiative was established to test and evaluate integrated, intermodal, Intelligent Transportation Systems (ITS) applications. Of particular interest were those applications that did not entail extensive public sector infrastructure but could achieve immediate benefits and demonstrate the potential for sustainable deployment. The overall goals of the SafeTrip-21 Initiative were to:

- ❖ *Expand and accelerate the U.S. DOT's research in vehicle connectivity with the wireless communications environment.*
- ❖ *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 SafeTrip-21 Initiative sought to achieve these goals by selecting applications that provided the opportunity to:

- Effect the transition of ITS research into real-world use.
- Accelerate acceptance and adoption of ITS.
- Generate widespread awareness about the potential of deployment-ready ITS technology to provide transportation benefits to travelers, public agencies, and commercial vehicle operators.
- Test and evaluate multiple ITS applications in an integrated, multi-modal operational test setting relative to prospective benefits in terms of safety, mobility, commercial vehicle safety and operations, and e-payment services.
- Identify environmental and energy benefits of ITS.

To identify test beds for demonstration, the U.S. DOT issued a Broad Agency Announcement (BAA) to solicit proposals from across the country. Solicitations were requested for ITS applications that showed near-term potential for deployment or advancement that could address issues important to U.S. DOT's overall goals to improve safety, reduce congestion, and advance the nation's transportation system.

The U.S. DOT's Volpe Center made awards to establish two test beds: the **California Connected Traveler (CACT) Test Bed**, which involved integrated locations in the San Francisco Bay Area, and the **I-95 Corridor Test Bed**, which involved locations along the I-95 Corridor from North Carolina to New Jersey. Two independent applications, although not formally part of the test beds, were also tested in California and North Carolina. The eight applications are listed below.

1. **Mobile Millennium (CACT Test Bed).** This application was a real-time traffic information system for highways and arterials in the San Francisco Bay Area. Its major source of traffic information was participants' GPS-enabled smart phones, which generated traffic data as their owners drove.
2. **Networked Traveler - Foresighted Driving (NT-FD) (CACT Test Bed).** This application involved providing alerts of upcoming slow traffic to drivers operating instrumented vehicles in an effort to mitigate forward collisions on congested roadways.
3. **Networked Traveler-Transit/Smart Parking (NT-T/SP) (CACT Test Bed).** This application involved creating a multi-modal real-time trip planning tool for travelers in the US-101 corridor in the Bay Area. The test integrated real-time transit schedule information from several transit providers into one coordinated application and allowed travelers to compare modes of travel by cost, time, and environmental impact when planning a trip.
4. **Deployment of Real-Time Intersection Delay Monitoring (California).** This application was deployed in California to test the use of a traffic volume and signal timing information monitoring system as an alternative to manual systems for the purposes of signal retiming.
5. **Providing Multi-Modal Travel Information to Airport Users (I-95 Test Bed).** This application involved providing ground transportation trip planning information to travelers at Baltimore-Washington International (BWI) Thurgood Marshall Airport through a website, mobile website, and a kiosk located in the ground transportation area of the airport.
6. **Displaying Travel Times in Public Areas (I-95 Test Bed).** This application involved providing real-time information about traffic conditions on large flat-panel display screens installed at Tysons Corner Center and at two Virginia Department of Transportation (VDOT) Welcome Centers. The application was designed to provide travelers with real-time travel times and color-coded traffic congestion maps relevant to their immediate travel.
7. **Long Distance Trip Planning Using Real-Time Travel Time Data (I-95 Test Bed).** This application was a web-based trip planner system that provided travelers with current travel times and color-coded traffic congestion maps for roadways through and between major metropolitan areas along the I-95 corridor from Florida to Maine.
8. **Deployment of Portable Traffic-Monitoring Devices (PTMDs) (California, North Carolina).** This application was deployed in both California and North Carolina and used portable traffic monitoring devices to monitor traffic congestion in work zones.

Science Applications International Corporation (SAIC) was selected as the independent evaluator of these eight applications deployed under the SafeTrip-21 Initiative. The main evaluation objectives are listed below.

- Understand technical issues;
- Understand human-machine interface issues related to ease of use;
- Understand institutional issues;

- Measure usage technology (e.g., number of website hits);
- Analyze perceived accuracy, timeliness, and usefulness of information;
- Explore user needs and user-perceived benefits;
- Explore awareness of transportation options by consumers; and
- Explore reported changes in transportation behavior by consumers.

The eight application tests varied considerably in their purposes, technologies, users, and deployment timelines. These differences necessitated customized evaluation approaches. Even with these variations, several key lessons can be derived from the evaluation findings, and these are presented in the following section.

LESSONS LEARNED

Overall, the evaluation findings suggested that the SafeTrip-21 Initiative has advanced its goals of expanding research related to vehicle connectivity in the wireless communications environment; advancing ITS applications; and exploring benefits of deployment-ready applications that provide enhanced safety, real-time information, and navigation assistance. The main elements of the Initiative considered how to:

- Transition ITS research into real-world use.
- Accelerate acceptance and adoption of ITS.
- Generate widespread awareness about the potential of deployment-ready ITS technologies to provide transportation benefits to travelers, public agencies, and commercial vehicle operators.
- Test and evaluate multiple ITS applications in an integrated, multi-modal operational test setting relative to prospective benefits in terms of safety, mobility, commercial vehicle safety and operations, and e-payment services.
- Identify environmental and energy benefits of ITS.

Several applications successfully transitioned previous ITS research/deployments into real-world use for everyday travelers and practitioners. All of the I-95 and CACT Test Bed applications leveraged existing data sources such as private traffic data providers, public transit agency information, and/or existing data infrastructure to develop systems/applications that put traveler information directly in the hands of the public, allowing them to make more informed decisions about travel and operations. All eight SafeTrip-21 applications helped accelerate the understanding of the factors that help promote acceptance and adoption of ITS technologies by both users and operators. Two of the I-95 Test Bed applications provided real-time traffic information to travelers across various mediums including a website and at high-volume locations for long-distance and local travel (e.g., rest areas and shopping centers) which gave practitioners insights into where real-time traffic information is most useful. An application on the CACT Test Bed accelerated the understanding of vehicle connectivity concepts by using existing DSRC infrastructure to provide in-vehicle safety alerts to drivers via Vehicle to Infrastructure communication and explored the benefits of providing enhanced safety and real-time information. Development of another CACT Test Bed application involved close collaboration with transit agencies in a metropolitan area to collect real-time transit information across all major transit providers and deliver it directly to users via the web and smart phones.

By fully deploying these applications, many of the SafeTrip-21 tests generated greater public awareness around the types of travel information ITS technology can offer. The evaluation

resulted in valuable feedback and a better understanding of the perceived benefits of ITS technologies to travelers and public agencies. Several SafeTrip-21 tests also showed that ITS technology is capable of collecting the data needed by traffic and transit operations agencies to collaborate and better understand mode shift and travel demands across modes. Several applications resulted in the opportunity to test and evaluate methods for providing integrated, multi-modal information to travelers including the ability to compare travel modes using factors such as cost, time, and environmental impact using ITS to help users realize the environmental and energy benefits of choosing alternate modes.

Additionally, the SafeTrip-21 Initiative was significant because it demonstrated that a variety of ITS technologies can be deployed in parallel by partnerships composed of public and private sector organizations. By design, the Initiative included existing technology and data combined with new data sources and tools. The number of applications, the diversity of technologies, and the complexity of the partnerships made some aspects of the evaluation challenging. In particular, it was difficult to make inferences about how specific evaluation conclusions might apply to future tests, different technologies, or other situations. Here, the Evaluation Team reports the key messages derived from months of observations, dozens of interviews and surveys, and extensive data collection. What is presented is a rich set of lessons regarding the successes and challenges observed during these ITS deployments, with the ultimate goal of promoting and advancing solutions for safer and more efficient travel. The lessons are organized around the following categories.

The SafeTrip-21 Initiative:

- Identified risks related to large-scale collaboration and mitigating factors to promote effective partnerships;
- Demonstrated the feasibility of alternative approaches to collect and use traffic data;
- Identified aspects of information delivery and design which appeals to users and improves the user experience;
- Developed new approaches to address distracted driving concerns;
- Explored issues of privacy related to user acceptance;
- Indicated success factors related to effective development and meaningful deployment;
- Highlighted the increasing role of traditional and innovative marketing in transportation systems;
- Explored ways to support users in making cross-mode travel decisions; and
- Suggested future research ideas.

Each category is described in more detail in the following sections.

The SafeTrip-21 Initiative identified risks related to large-scale collaboration and mitigating factors to promote effective partnerships.

The SafeTrip-21 Initiative involved stakeholders across multiple organizations in existing and new partnerships crossing public, private, and academic boundaries. The evaluation of the SafeTrip-21 technologies provided insight as to how these delicate relationships are best negotiated and how long-established relationships facilitated successful deployment of technologies. The SafeTrip-21 Initiative highlighted how successful partnerships can leverage the respective capabilities of public, private, and academic partners in pursuit of a shared vision.

- **Established and respectful working relationships facilitate a shared team vision and a sense of ownership, which serves as a solid foundation for a successful**

deployment. Shared vision brings positive working relationships in which team members are supportive of the same overall goals. Mobile Millennium offers a good example of this principle. The project team was mature and demonstrated excellent working relationships respectful of individual strengths and a shared vision among Caltrans, Nokia, and CCIT. Their experiences working on earlier phases of the concept had a positive influence on the partnership. Likewise, cooperation from local transit agencies was critical to the NT-T/SP test, as PATH needed to install various forms of tracking devices on trains and buses. Established working relationships facilitated this process, as the PATH project team was therefore sensitive to the demands on the transit agencies and the availability of their key staff.

- **Documenting the vision through a concept of operations is one way to keep stakeholders on the same page.** It is extremely important to develop a clear concept of operations. Enlisting the help of an outside neutral party to lead this activity can be helpful. For instance, the public displays in Tysons Corner Center involved numerous stakeholders (State DOT, transit agencies, mall management, and local transportation association). In order to overcome the lack of agreement on issues of system development, the partners found it helpful to put their goals in writing with the help of an external contractor, who took on the task of writing the concept of operations for the system.
- **It is not sufficient to find consensus at the concept formation stage; sustaining regular communications among partners is needed.** Planning for frequent communication among many partners supports stakeholder buy-in. This was evidenced in both of the I-95 traffic information applications, for which the team held weekly developer calls as well as weekly project management calls. These allowed the team to resolve quickly any issues that had arisen in the past week. Project goals and design requirements are often fluid at the beginning of a project. Setting a clear communication plan involving all stakeholders throughout the project lifecycle ensures that goals and requirements are well-documented and achieved.
- **Conflicts in collaborative relationships can carry directly into the technology.** Stakeholder priorities are reflected in the design of the applications. This observation was particularly vivid in observing how the screen's "real estate" was allotted to each piece of content in the public displays in Tyson's Corner Center. There was some competition for display time, and the project team had to balance entertainment and mall-relevant content with traveler information content. In the end, a compromise solution was reached in which different portions of the screen were reserved for different content.
- **Formal agreements are necessary to establish working relationships and communication protocols.** In the case of the I-95 applications, prior relationships eliminated many potential complications in the development process. While it is important to note that the initial solicitation required agreements to be in place, this turned out to be a key aspect regarding project success. For example, there was no need to establish agreements between the various partners involved (member States and the private data provider), because such agreements were already in place through the I-95 Corridor Coalition (i.e., the private data provider could supply data directly to the States via the I-95 Corridor Coalition). As another example, the stakeholders who need to be involved to deploy a piece of technology in an airport can be quite diverse, but not

all players may be obvious at first, and not all are likely to have a background or interest in transportation. When planning for that type of project, it is important to work with the airport staff early on to identify all potential stakeholders and to have a formal written agreement or memorandum of understanding between all involved parties, including those who will maintain the unit. Involving all stakeholders early will allow them to voice opinions up front for inclusion in the initial system requirements versus trying to address these requests once the system is already in place.

- **Interactions between commercial and non-commercial entities require unique understanding and planning.** Commercial entities may have different considerations when it comes to deploying traveler applications. For example, in the public displays of travel information project, unexpected challenges arose. One example of this is that advertising, a traditional source of revenue to help cover the costs of some real-time traveler information systems, was not permitted in the commercial shopping center environment in which they were working due to existing advertising agreements between businesses and mall management.
- **Transportation professionals and system engineers need to develop a shared understanding and language.** Transportation professionals must adapt to managing new sorts of relationships with experts in system design and development. Systems engineering is becoming increasingly relevant in the transportation industry as new technologies offer solutions to transportation engineering issues, which results in transportation professionals and systems engineers working side-by-side. This requires an appreciation of unfamiliar work schedules, project management expectations, design techniques, and technical language. The result is an increase in demand for systems engineers with greater understanding of transportation and transportation professionals with a greater understanding of system design.

The SafeTrip-21 Initiative demonstrated the feasibility of alternative approaches to collecting and using traffic data.

One aspect of this evaluation was an exploration of alternative approaches to collect and utilize traffic condition data that did not involve expensive and extensive infrastructure installation. In some cases, applications demonstrated new sources of traffic condition data. In other cases, applications made use of traditional data in new ways. The SafeTrip-21 Initiative highlighted how the mass-market availability of GPS-enabled smart phones both complements traditional fixed sensors as a new data source and offers the potential to deliver personalized travel information.

- **Traffic model development can benefit from integrating traffic probe data with other sources for both freeways and arterials.** The Mobile Millennium project initially set out to build traffic models using only traffic probes as the source. Ultimately, this test successfully demonstrated that it is feasible to use traffic probes as an alternative to traditional traffic condition monitoring systems, at least with respect to travel information systems. However, it later tested how the integration of probe data with other sources of data increased the accuracy and reliability of the data.
- **There is potential for using traditional traffic data in new and innovative ways.** The Networked Traveler-Foresighted Driving (NT-FD) test demonstrated a completely new application for traffic information from a traditional traffic monitoring system by alerting motorists to upcoming traffic conditions that may lead to end-of-queue crashes.

Participants reacted favorably to the technology, and it demonstrated the potential for a system that one day could be commercialized by integrating it into an existing navigation or alert system.

- **The ability to deploy a traveler information concept is only as successful as the availability, timeliness, and accuracy of its data sources.** The challenge for the NT-FD concept was that it relied on the availability of a traffic condition monitoring system capable of providing accurate and timely speed data. Any problems in the data could lead to false or missed alerts. This was a major concern for the NT-FD test, in that the traffic condition monitoring system was external to the test and beyond the control of the PATH researchers. Clearly the future deployment of similar systems will need to address this issue.
- **ITS technology provides the means for remote monitoring and maintenance of traffic signal plans.** The Real Time Intersection Delay (RTID) system demonstrated how a traffic signal controller could be easily interfaced to capture real time traffic condition data and make it available for remote offline analysis. This would greater enhance the ability of transportation agencies to monitor timing signal plans and update these as traffic conditions change. At the present time, Caltrans is unable to do this as frequently as it desires because the current process is time consuming and labor intensive.
- **Practical concerns of transportation professionals governed their acceptance of traffic data devices.** For the RTID test, Caltrans required that the vendor's TrafMate product be installed in less than 30 minutes and not interfere with the normal safe operation of the traffic signal controller. Likewise, opinions of PTMDs were tied to criteria such as battery life and portability. Impact on daily operations and demand on limited staff resources are major factors for transportation agencies when considering implementation of ITS technologies.

The SafeTrip-21 Initiative identified customer-oriented aspects of information delivery and design that appeals to users and improves the user experience.

When presenting travel information to travelers, the user experience is critical to success. The SafeTrip-21 Initiative highlighted the importance of adopting a customer-oriented approach to travel information and recognized that customers had varying needs.

- **Stakeholder relationships will not necessarily be transparent to users.** Travelers are concerned with the quality of the travel information provided to them, not with the intricacies of the partner relationships or the process of sharing and integrating data. For example, in testing the provision of airport ground travel information to travelers, the project team worked closely with BWI Airport staff to determine the best approach for delivering the applications. BWI Airport posted a link on the home page of its website to advertise the new information available. From the user's perspective, BWI Airport was the agency delivering the service; therefore, a user's image of BWI Airport could be impacted by the quality of that service. Stakeholder satisfaction will likely be directly related to user satisfaction when developing applications for an industry as focused on customer service as air travel. Establishing expectations and user needs up front can satisfy both the stakeholder and the users.

- **The importance of assessing user needs early and often should not be underestimated.** Consideration of travelers as the end-user and the ultimate stakeholder is often overlooked early in the deployment process. Several SafeTrip-21 partners voiced the need to establish a means for identifying user needs before developing or deploying applications. Preliminary user needs assessments, beta testing, and forums for on-going user feedback are all popular methods for improving application design, identifying system bugs, and achieving better overall system performance and usefulness. The CACT projects demonstrated that participants were enthusiastic about providing feedback. The partners and the evaluation team conducted user surveys to obtain such feedback. In addition, the Networked Traveler-Transit/Smart Parking project provided users with the opportunity to make comments as they used the applications.
- **Users expect an efficient and usable interface for receiving travel information.** For example, when it came to a public information display screen that was not interactive, much of the user experience was driven by the user understanding of the information available. It was important to let users know what information would be displayed next versus leaving them waiting to find out. The stakeholders involved with the Tyson's Corner Center displays believed that mall patrons might grow impatient waiting to see the information of interest to them and subsequently choose to leave before the playlist reached the information that they needed. To address this concern, the team designed the display to include an area to the side of the main information listing the next several features to be displayed as well as content such as news and weather to keep them entertained while they waited.

The SafeTrip-21 Initiative developed new approaches to address distracted driving.

Organizations and individuals are becoming increasingly aware of the dangers associated with distracted driving. The U.S. DOT is a leader in terms of delivering this message to citizens and shaping the research that will advance techniques for mitigating distracted driving. In fact, several SafeTrip-21 tests were re-scoped during this evaluation to better address distracted driving concerns. As a result, the SafeTrip-21 Initiative advanced knowledge and technological solutions related to distracted driving.

- **“Geofencing” is a promising approach to limiting driver distraction.** NT-T/SP demonstrated that it is feasible to determine whether a smart phone user is traveling on a transit vehicle versus in a vehicle on a road. Consequently it is possible to provide travel information to smart phone users while minimizing the risk of causing distracted driving. However the trade-off that had to be made was adding a layer of complexity to the design of the NT-T/SP mobile application, which made the system somewhat less user-friendly.

The SafeTrip-21 Initiative explored issues of privacy related to user acceptance.

Concerns over relinquishing privacy can be a potential pitfall for many ITS-related technologies. The evaluation considered the ways in which the SafeTrip-21 partners addressed this and identified potential factors for success.

- **Creative privacy protection procedures can be reassuring to users of personal devices providing probe data.** The use of probe vehicles as an alternative to traditional fixed sensors raises the potential for privacy issues related to the tracking of

personal smart phones. Mobile Millennium addressed this issue by developing specific privacy protecting methods to generate traffic data at pre-set locations (referred to as virtual trip lines or VTLs) rather than by tracking individual mobile devices or using identification information. Users were generally positive about how Mobile Millennium protected their privacy: 68 percent of respondents trusted the system to protect the privacy of their travel data, 7 percent did not trust the system, and 25 percent either did not know or did not care.

- **Reciprocity and transparency related to the collection of personal information are potential success factor for ensuring acceptance by travelers.** As demonstrated in the Mobile Millennium deployment, participants seemed to see a benefit of receiving travel information in exchange for acting as a travel probe. Participants appear to have responded positively, recognizing the tradeoff between personal data collected by the respective tests and the quality of personalized services received in return. Nokia referred to this as an “ecosystem” inferring that all parties are interconnected and contribute in their own way.

The SafeTrip-21 Initiative indicated success factors related to effective development and meaningful deployment.

Several factors related to the applications and the process of deploying the applications can optimize the chance for success. These factors are usually reflected by the types of trade-offs and decisions made by partners during the development and deployment process.

- **Existing open-source data is becoming an important component of efficient system development.** There is efficiency associated with using open-source data from transportation agencies or existing traveler information from project partners and integrating it into the system to automatically update content when changes occur. This can cut down on development and maintenance costs of a system when multiple data sources must come together seamlessly. What is key is to look for opportunities to make use of any synthesized data already available from other systems. In many cases the exact data may already be available, eliminating the need to receive and manipulate raw data.
- **Keeping solutions simple enables progress and optimizes chances for success.** Often a simple solution provides the biggest impact in terms of meeting a project’s objectives, whereas a complex solution introduces challenges and pitfalls. For example, a design feature that simplified the design of the public displays application was the decision to use the Google® map API to generate maps for the system. This API is a free service that makes it easy to embed a map into a web application and to overlay the standard Google map with additional features, such as the color-coded travel time segments used on the screens. Another example of simplicity is the choice the project stakeholders made when it came to determining what data would inform the prediction of “current travel time.” While the travel time could have been based on a complex algorithm that estimates travel time based on historical patterns and current conditions, the team decided to go with a simpler approach of basing the information purely on current conditions along the route.
- **Redundancy in system design and monitoring minimizes failure risks.** Another important consideration in design of an information display is system redundancy. For

instance, this would be critical to ensure that user screens do not experience any down-time, which would cause users to perceive the system to be unreliable. The back-end system supporting the Tyson's Corner Center displays was designed with triple redundancy to avoid any failures. One server, the production server, was devoted exclusively to preparing and transmitting content to the displays. A second server hosted the content management system and also provided failover capability if the production server failed. A third server served as a spare. This provided triple-redundancy with the servers. In addition, the production server was designed to periodically transmit a message to a computer at the contractor's office verifying that the server was still operational. A web camera in the server room aimed at this display allowed the contractor to remotely monitor this display as an additional safeguard against a system problem.

- **It is challenging to develop ITS applications as an aftermarket addition to consumer products due to design variations in the absence of an industry standard.** For example, one result of the NT-FD test was that the team gained a greater appreciation for the variability of the different on-board computer data access from the two vehicle manufactures. 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. The associated delays resulted in unanticipated costs and associated budget issues.
- **Performance monitoring during deployment facilitates technical improvements.** For example, in the I-95 traffic information applications, mechanisms for detailed website usage monitoring were important (i.e., how often users were making use of the option of inputting an origin and destination pair, and for those who did, what origins and destinations users were most often selecting). The project team feels that this was an important factor in development as it allowed the team to make improvements to the site over time based on user needs. Performance monitoring is also useful in understanding the effectiveness of targeted marketing efforts. For example, the BWI Ground Access Information System project team integrated usage tracking prior to launch and was able to observe the results of marketing efforts immediately, while the NT-T/SP test did not begin collecting usage information until after launch and did not have the opportunity to analyze and make decisions based on initial usage.
- **Frequency of use is not always an indicator of value.** In terms of understanding deployment effects, the data analysis is not always straightforward. For example, while the frequency of use was low for the BWI Ground Access Information System applications, it was clear that a low return rate was not necessarily an indicator of user acceptance but more a sign of how often users need the multi-modal information provided. Providing multi-modal information about ground transportation options at an airport, users reported that the trip planning website increased their satisfaction with and perception of the airport.
- **When considering how to proceed following a test deployment, it is important to clarify the roles of the private and public sector.** The fact that partnerships between the public and private sector during testing can be complex was already discussed. However, this complexity must also be considered for sustained or future deployment of an application. 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 SafeTrip-21 Initiative highlighted the increasing role of traditional and innovative marketing in transportation systems.

Marketing related to the SafeTrip-21 deployments turned out to be a more significant issue than anticipated. Marketing entails a variety of techniques for making users aware of opportunities to access a particular application, including traditional press releases, advertisements, or direct invitations for participation. Marketing of travel information systems was critical to success regardless of the method by which the information is accessed by the public.

- **Providing travel information in public places necessitates creativity to make potential users aware of the service.** For example, with static public displays of information such as those in the Virginia Welcome Centers and at Tysons Corner Center, it is critical to “advertise” the service to passersby so that they will be enticed to stop and take a look. In most public places information screens will be competing with many other signs, advertisements, and information sources, so it is critical to in some way inform the public of what information can be found on the screens. In this case the screens in the Welcome Centers are located alongside a variety of information including travel brochures and other television screens displaying travel information, while the screens in Tysons Corner Center are competing with storefronts, advertisements, sounds, and lights. The Tysons Corner Center stakeholders found it helpful to create a floor sticker to draw attention up to the screens as well as a bezel to surround the screen to advertise that the screen includes “Live Traffic Information.”
- **Social media is an increasingly powerful tool, especially in promoting mobile applications.** The initial targeted marketing efforts for the NT-T/SP applications were on the MTC 511 website, distributing a press release, and handing out flyers at transit stops/stations. These were effective in attracting users and increasing awareness of all PATH2Go applications. However, the most significant increase in usage of the website applications came as the result of a Twitter post. The website traffic generated by the Twitter post increased the total number of absolute unique visitors to the website by 104 percent and the total number of visits by 66 percent in the span of 5 days.
- **Traditional press releases are still effective in reaching large media outlets.** For example, the I-95 Corridor Coalition prepared and distributed a press release a few days prior to the Thanksgiving holiday encouraging holiday travelers to use the Trip Planner website to help them with their travel plans. The press release was picked up over the following days by a large number of mainstream media outlets including USA Today, National Public Radio (NPR), ABC, and FOX, as well as by several social media networks and blogs. This marketing push brought a record number of visitors to the website during the week of Thanksgiving and had a significant effect on the size of the website user base.
- **Marketing efforts should not only be directed at consumers but at transportation professionals’ networks.** In the case of the Trip Planner website, the I-95 project team took several strides to generate awareness about the website beginning with the

website's launch at the ITS America Annual Meeting in June 2009, where the website received immediate exposure. Additionally, there were two initial major efforts coordinated by the project team. The first was to reach out to transportation and travel-related organizations such as AAA Mid-Atlantic, which posted information about the website along with a link to the site on its "Cars & Driving" blog in June 2009. Additional exposure was made to the trucking community when an article about the website was published in the August 2009 issue of OverDrive Magazine. The second major effort the team undertook was to reach out to all of the States covered on the site, requesting that they consider posting a link to the website on their DOT and/or 511 websites. This effort resulted in nine websites posting a link to the I-95 Corridor Travel Time Information website.

The SafeTrip-21 Initiative explored ways to support users in making cross-mode travel decisions.

Promoting transit alternatives is a continuing transportation need. The SafeTrip-21 Initiative focused on trying to make travelers aware of their options and make it easy for them to plan trips than minimize the use of a personal vehicle.

- **Travelers place value on being able to compare real-time choices from a single source in part because it increased their confidence in their decisions.** Travelers generally reported the ability to access multiple transit services and have reliable real-time arrival and departure information was important. Many reported that having the transit information available to them made them more confident about using transit. While many users reported learning about new travel options, there was not significant evidence that having this information resulted in choosing an alternative mode to their usual transportation.
- **It is difficult to assess mode shift.** Mode shift is hard to assess because it is difficult to directly observe. Examining ridership rates is often misleading because it is difficult to find a causative link between application use and changes in ridership. In a test situation, user feedback is one way to assess mode shift, but it is dependent on a high response rate from a representative group of travelers.

The SafeTrip-21 Initiative suggested future research opportunities.

Several topics were identified in the evaluation that would benefit from future investigation and research.

- **Arterial model development is a complicated issue that would benefit from continuing research and the development of new techniques.** Mobile Millennium advanced the understanding of how to develop useful arterial models. The evaluation observed that the highway model, as might be expected, was less complex than the arterial model. There is probably no single universal model that could apply to all arterial scenarios. Instead, specific customized arterial models may be required depending on the type of arterial roads being modeled and the traffic patterns they exhibit. Arterial traffic monitoring is typically much more challenging than highway traffic, given many factors that influence arterial traffic such as traffic signals, frequency of (and turning movements at) intersections, pedestrians, loading/unloading passengers and goods, parking, and widely varying performance characteristics of vehicles.

- **Transportation agencies will have to address the need for new procurement methods to acquire data and information services.** Agencies have traditionally procured hardware, software, and systems that allowed them to collect, analyze, and produce traffic data, which likely proved to be a laborious effort. An emerging alternative is to procure data and/or information services as a more cost-effective, resource-efficient alternative to developing the data and/or end product internally. An increasing number of private sector companies already collect, or have access to, transportation data such as travel time, origin and destination, and other measures on a regional or national scale. However, transportation agencies do not typically have experience purchasing transportation data, meaning that new approaches to procurement need to be explored in more detail. Such research could include reasonable value, property rights, quality control, privacy, and comparative evaluation.
- **To maximize the potential of using transit data, there is a need for a national standard.** During deployment interviews for the NT-T/SP test, PATH developers identified the need for a national standard format for traffic operations data. Companies like Google who offer transit information via their Google Maps website have established a good starting point for a standardized data format. If transit agencies provide open source data meeting their standards, Google will incorporate the transit services offered into the information provided to travelers via Google Maps. However, Google transit standards are more focused towards users and application development. Transit agencies should consider what standards are necessary for transit operations, in addition to user information and application development when defining a national standard, as well as how this could support open-source access.
- **Continuing research is needed to identify contributing factors and the cost-benefit balance required to induce mode-shift.** Research that can clearly identify the various benefits of choosing transit or other alternative modes is essential for transportation agencies to understand. If an agency knows what motivates its travelers to consider their services, they can leverage that knowledge to make their operation more appealing to users. While a long list of factors like cost, time, environmental impact, oil dependence, convenience, and many others are known considerations, little is known about the relationship between these factors and the proper balance required to change travel behavior. SafeTrip-21 showed that ITS applications like the NT-T/SP test can provide cost, time, and emissions impact comparisons across modes to allow users to make decisions based on those factors. The test also showed that users find this type of information useful and important. However, understanding the delicate balance between the cost incurred and benefit achieved when a traveler considers an alternative mode is essential to increasing rates of mode-shift.
- **Further innovation is needed to provide timely and useful travel information at the fingertips of travelers while keeping drivers from being distracted.** U.S. DOT is cognizant of the risks of distracted driving. However, as in-vehicle technology continues to develop, supporting safe driving habits will continue to be a challenge. U.S. DOT will likely need to explore avenues for advancements in technology to prevent driver distraction as well as instilling a safety culture with the goal of behavioral changes.
- **The potential impact of social networking related to travel and transportation is not well-understood.** Transportation agencies have traditionally on websites, 511, mass media, and press releases to provide information to travelers. In doing so, they

effectively control the “message.” Transportation agencies are embracing social networking sites such as Facebook, Twitter, and blogs, but these same applications also empower users to share highly targeted real-time information on travel conditions. In some cases, private citizens are developing their own smart phone applications using open source data. The extent to which such approaches are becoming commonplace is not well documented. More importantly, the extent to which, and how, they are used is unknown, although in general they appear to be increasingly popular.

PART I: INTRODUCTION

This report serves to synthesize the various activities and findings achieved during the National Evaluation of the SafeTrip-21 Initiative. This document is organized in three main parts described below.

PART I: INTRODUCTION. The current section introduces the SafeTrip-21 Initiative and its evaluation. The section also describes the organization of the remainder of the report and provides indices for identifying topics of interest. This part includes the following chapters:

1. Overview of the SafeTrip-21 Initiative and the National Evaluation
2. Guide to Report Organization and Search Indices

PART II. SAFETRIP-21 APPLICATIONS. The second section provides a summary of the different applications that were evaluated under the SafeTip-21 Initiative. This part includes the following chapters:

3. Mobile Millennium
4. Networked Traveler – Foresighted Driving
5. Networked Traveler – Transit / Smart Parking
6. Deployment of Real-time Intersection Delay Monitoring
7. Providing Multi-modal Travel Information to Airport Users
8. Displaying Travel Times in Public Areas
9. Long Distance Trip Planning Using Real-Time Travel Time Data
10. Deployment of Portable Traffic Monitoring Devices

PART III: EVALUATION FINDINGS SYNTHESIS. The final section describes findings derived from the evaluation in terms of the goals of the applications and topics of interest to the ITS community. This section attempts to, where appropriate, draw conclusions across applications and emphasizes lessons learned from each aspect of the test experience. This part includes the following chapters:

11. Alternative Approaches to Monitoring and Using Traffic Conditions Data
12. Providing Useful and Usable Real-Time Traffic Conditions Information
13. Providing Multi-modal Travel Options to Travelers
14. Providing In-Vehicle Safety Alerts in End-of-Queue Situations
15. Conclusions and Lessons Learned

1 OVERVIEW OF THE SAFETRIP-21 INITIATIVE AND THE NATIONAL EVALUATION

This chapter presents an introduction to the SafeTrip-21 Initiative and the independent evaluation activities that took place between 2009 and 2011. It describes the goals of the SafeTrip-21 Initiative and the process used to undertake tests of different applications as part of the Initiative. An overview of the application areas is provided, and the evaluation process is described.

1.1 THE SAFETRIP-21 INITIATIVE

In 2008, the United States Department of Transportation (U.S. DOT) Research and Innovative Technology Administration (RITA) established the Safe and Efficient Travel through Innovation and Partnerships for the 21st Century (SafeTrip-21) Initiative. The Initiative was established with the purpose of testing and evaluating integrated, intermodal ITS applications, particularly those that do not entail extensive public sector infrastructure requirements but could achieve immediate benefits and demonstrate the potential for sustainable ongoing deployment. These efforts and the resulting applications sought to support U.S. DOT goals to improve safety, reduce congestion, and advance the nation's transportation system, specifically focusing on the following:

- ❖ **Expand and accelerate the U.S. DOT's research in vehicle connectivity with the wireless communications environment.** This goal reflects U.S. DOT's desire to test the deployment of Vehicle-to-Infrastructure and Vehicle-to-Vehicle concepts using any number of communication technologies, such as dedicated short-range communications (DSRC). The SafeTrip-21 partners would explore how existing or innovative infrastructure and technology could quickly move research on vehicle connectivity into practice.
- ❖ **Build upon existing Intelligent Transportation Systems (ITS) research in advanced-technology applications.** This goal emphasizes U.S. DOT's desire to field deployment-ready technologies for SafeTrip-21, rather than to develop new technologies. U.S. DOT intended for SafeTrip-21 to accelerate the transition from research to product development. In addition, deploying these technologies would help publicize ITS developments to the general public, thereby raising awareness beyond the research and ITS communities.
- ❖ **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.** This goal expresses the desire of the U.S. DOT to involve everyday drivers and operators in ITS concepts in ways they had not previously experienced. Assessing user experiences and perceptions of the concepts would provide valuable feedback in understanding public use and acceptance of ITS applications. Their involvement would also help create a user base to foster enthusiasm for further development and refinement.

The SafeTrip-21 Initiative sought to achieve these goals by selecting applications that provided the opportunity to:

- Transition ITS research into real-world use.
- Accelerate acceptance and adoption of ITS.

- Generate widespread awareness about the potential of deployment-ready ITS technology to provide transportation benefits to travelers, public agencies, and commercial vehicle operators.
- Test and evaluate multiple ITS applications in an integrated, multi-modal operational test setting relative to prospective benefits in terms of safety, mobility, commercial vehicle safety and operations, and e-payment services.
- Identify environmental and energy benefits of ITS.

To identify test beds for demonstration, the U.S. DOT issued a Broad Agency Announcement (BAA) to solicit proposals from across the country. The solicitation did not request a specific system or hardware solution; its primary focus centered on scientific study and experimentation that would advance the state of the art or increase knowledge and understanding. The BAA allowed agencies and vendors to propose innovative ITS solutions based on their capabilities and needs. Solicitations were requested for ITS applications that showed near-term potential for deployment or advancement that could address one or more of the following objectives (Note – not all were addressed by SafeTrip-21):

- Reduce motor vehicle crashes;
- Alleviate traffic congestion;
- Improve emergency response times;
- Enhance transit use, modal shifts, and/or ride sharing;
- Improve traffic data and/or traveler information;
- Promote motor freight safety and efficiency;
- Enable convenient electronic payment options;
- Mitigate environmental impacts; and
- Reduce unnecessary motor fuel consumption.

Based on responses to the BAA, the Volpe Center made awards to establish two test beds: the **California Connected Traveler (CACT) Test Bed**, which involved integrated locations in the San Francisco Bay Area, and the **I-95 Corridor Test Bed**, which involved projects along the I-95 Corridor from North Carolina to New Jersey. Two independent applications, although not formally part of the two test beds, were also tested in both locations.

All eight applications are described in the following section.

1.2 THE SAFETRIP-21 APPLICATIONS

In total, eight applications were tested. These are summarized in Table 1 and described in detail below. Part II of this report will provide more detail about each application, its evaluation, and a summary of the findings. The relevant chapter within Part II is referenced for each application in Table 1.

Table 1. Summary of Applications Tested Under the SafeTrip-21 Initiative.

SafeTrip-21 Application	Test Location	Part II
Mobile Millennium	CACT Test Bed	Chapter 3
Networked Traveler – Foresighted Driving	CACT Test Bed	Chapter 4
Networked Traveler – Transit / Smart Parking	CACT Test Bed	Chapter 5
Deployment of Real Time Intersection Delay Monitoring	California	Chapter 6
Providing Multi-modal Travel Information to Airport Users	I-95 Test Bed	Chapter 7
Displaying Travel Times in Public Areas	I-95 Test Bed	Chapter 8
Long Distance Trip Planner	I-95 Test Bed	Chapter 9
Deployment of Portable Traffic Monitoring Devices	California, North Carolina	Chapter 10

1.2.1 California Connected Traveler Test Bed (CACT) Applications

The California Connected Traveler (CACT) Test Bed was led by the California Department of Transportation (Caltrans) in partnership with the University of California at Berkeley (UC Berkeley) and two organizations administered by its Institute of Transportation Studies. These were California Partners for Advanced Transit and Highways (PATH), whose mission is to develop solutions to the problems of California’s surface transportation systems through cutting edge research, and California Center for Innovative Transportation (CCIT), whose mission is to accelerate the implementation of research results and whose focus is on deployment. Additional partners for the test bed included the Nokia Research Center, the research arm of the major cell phone company, and TrafInfo, another independent application vendor.



Map courtesy of the Volpe Center.

Figure 1. California Connected Traveler Test Bed Regional Map.

The CACT Test Bed (Figure 1) was primarily focused on the San Francisco Bay Area in California. Originally focused on the US-101 Corridor, the primary route connecting San Francisco to other major metropolitan areas such as San Mateo, Palo Alto, and San Jose, the test bed was later expanded to cover the majority of the greater Bay Area. The San Francisco Bay Area is the fifth most populated metropolitan region in the United States and is an area with both major traffic congestion and widely available alternate transportation options. The region features densely populated residential areas and many major commercial and industrial centers located along the corridor.

The CACT Test Bed included the following three field test application areas:

- Mobile Millennium
- Networked Traveler – Foresighted Driving (NT-FD)
- Networked Traveler – Transit/Smart Parking (NT-T/SP)

1.2.1.1 Mobile Millennium

This application was 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, essentially serving as a large scale deployment of vehicle probes. Analysis of this application involved understanding user and institutional experience with the mobile application and assessing the highway and arterial models developed using smart phone data.

1.2.1.2 Networked Traveler - Foresighted Driving (NT-FD)

This application involved providing alerts of upcoming slow traffic to drivers operating instrumented vehicles in an effort to mitigate forward collisions on congested roadways. Analysis of this application area involved measuring the quantity and quality of alerts to drivers in terms of alert frequency, perceptions of usefulness and usability, and institutional experience. In part, the test explored the ability to integrate traffic speeds from sensor infrastructure with location, direction, and speed information from vehicles in real-time.

1.2.1.3 Networked Traveler-Transit/Smart Parking (NT-T/SP)

This application involved creating a multi-modal real-time trip planning tool for travelers in the US-101 corridor in the Bay Area. The test integrated real-time transit schedule information from several transit providers into one coordinated application and allowed travelers to compare modes of travel by cost, time, and environmental impact when planning a trip. The information was available to all travelers through a website and to registered users through a smart phone application. Analysis involved assessing usage and perceptions of usefulness and usability as well as institutional experience. Additionally, the evaluation considered "geofencing" a technique which allowed users access to the application only when not driving, enabling users to access the technology safely.

1.2.2 The I-95 Corridor Test Bed Applications

The I-95 Corridor Test Bed was led by the I-95 Corridor Coalition in partnership with the University of Maryland. The I-95 Corridor Coalition is a volunteer, consensus-driven organization that consists of a variety of State, local, and regional member agencies who work together to improve transportation system performance through interagency cooperation and coordination. Other project partners included the Virginia Department of Transportation (VDOT), Baltimore/Washington International Thurgood Marshall Airport, North Carolina Department of Transportation, and INRIX, a traffic information data provider.



Figure 2. Location of I-95 Test Bed Applications

The I-95 Corridor Test Bed (Figure 2) included transportation network coverage of nearly 2,000 miles of freeways and 1,000 miles of arterials in an area extending from New Jersey to North Carolina. Later, the test bed was further expanded to cover the whole of the I-95 corridor when one test application increased its coverage to include roadways from Maine to Florida. The I-95 corridor is a heavily traveled route by long-distance freight companies, recreational travelers and commuters, and includes the major metropolitan areas of New York City, Baltimore, Philadelphia, and Washington DC. Traveler information offered along the corridor is primarily provided by individual states or metropolitan areas and is limited in coverage. The I-95 projects aimed to expand the geographic scope and connectivity of traffic information as well as improve the availability and means for disseminating this information.

The I-95 Test Bed included the following three field test application areas:

- Airport Ground Transport Travel Information;
- Displaying Travel Times in Public Areas; and
- Long Distance Trip Planning Using Real-Time Travel Time Data.

1.2.2.1 Providing Multi-Modal Travel Information to Airport Users

This application involved providing ground transportation trip planning information to travelers at Baltimore-Washington International (BWI) Thurgood Marshall Airport. The information was

available to travelers through a website, a mobile website, and a kiosk located in the ground transportation area of the airport. Travelers could access cost and time information across several different modes of ground transportation to/from the airport. Analysis of this application area included assessing website usage, analyzing user-perceived benefits of real-time travel information, and understanding technical and institutional issues associated with deployment.

1.2.2.2 Displaying Travel Times in Public Areas

This application involved providing real-time information about traffic conditions on large flat-panel display screens installed at Tysons Corner Center and at two Virginia Department of Transportation (VDOT) Welcome Centers. The application was designed to provide travelers with real-time travel times and color-coded traffic congestion maps relevant to their immediate travel – interstate travel ahead at the Welcome Centers and traffic conditions on the arterial and interstate routes surrounding the shopping center. Analysis of this application area included assessing user-perceived benefits of the information through intercept surveys and focus groups as well as understanding technical and institutional issues associated with deployment.

1.2.2.3 Long Distance Trip Planning Using Real-Time Travel Time Data.

This application was a web-based trip planner system that provided travelers with current travel times and color-coded traffic congestion maps for roadways through and between major metropolitan areas along the I-95 corridor from Florida to Maine. The I-95 Corridor Coalition Travel Time Information website was designed to help the general public make better pre-trip planning decisions, with the primary focus on providing real-time information across state lines for long distance trips. Analysis of this application area included assessing website usage, user-perceived benefits of the information, and technical and institutional issues.

1.2.3 Independent Applications

The following two applications were proposed and selected independently from those applications proposed by the CACT and I-95 Test Beds. They were tested as part of an agreement among the Volpe Center, the Test Beds, and the vendors.

These two independent applications were:

- Deploying Real-Time Intersection Delay Monitoring; and
- Deploying Portable Traffic Monitoring Devices (PTMD).

1.2.3.1 Deployment of Portable Traffic Monitoring Devices (PTMD)

This application was deployed in both California and North Carolina, and used portable traffic monitoring devices to monitor traffic congestion in work zones. Stakeholder experience and perceptions of the usefulness of the data provided from the system were assessed.

1.2.3.2 Deployment of Real-Time Intersection Delay Monitoring

This application was deployed in California to test the use of a traffic volume and signal timing information monitoring system. Analysis of this application involved identifying how such a system could enable signal phase and timing information, together with lane by lane traffic count data, to be collected in real time and processed from remote locations via the Internet (as opposed to traditional manual procedures) for purposes of offline analysis for signal re-timing.

1.3 EVALUATION ACTIVITIES

Under the direction and funding of the Research and Innovative Technologies Administration's (RITA) ITS Joint Program Office, Science Applications International Corporation (SAIC) was selected to be the independent evaluator of the applications being deployed under the SafeTrip-21 Initiative. The SAIC Evaluation Team worked with the U.S. DOT and project partners to define evaluation objectives, hypotheses, and measures of effectiveness (MOEs) consistent with the goals of the Initiative. There was great variation in the characteristics of the applications and their users. Therefore, not all objectives were appropriate to consider for each technology.

The main evaluation objectives are listed below:

- Understand technical issues;
- Understand human-machine interface issues related to ease of use;
- Understand institutional issues;
- Measure usage technology (e.g., number of website hits);
- Analyze perceived accuracy, timeliness, and usefulness of information;
- Explore user needs and user-perceived benefits;
- Explore awareness of transportation options by consumers; and
- Explore reported changes in transportation use and mode-shift by consumers.

1.3.1 Data Collection and Analysis

Data collection and analysis were carried out separately for each application considered in the Initiative. The applications tested as part of the Initiative varied in several ways, which determined the types and methods of data collection and analysis. In general, the main sources of data were as follows:

- Interviews with deployment partners;
- Review of field test reports from partners;
- Archived application usage data;
- Web-based and intercept surveys with travelers; and
- Focus groups and interviews with travelers.

1.3.2 Reporting

At the conclusion of data collection and analysis for each application, the Evaluation Team developed an Evaluation Report describing the technology, deployment, testing, and evaluation findings. These reports are listed in Table 2.

Table 2. List of Evaluation Reports generated as part of the National Evaluation of the SafeTrip-21 Initiative.

Report Title	Report Number
National Evaluation of the SafeTrip-21 Initiative: California Connected Traveler Test Bed Final Evaluation Report: Mobile Millennium	FHWA-JPO-11-013
National Evaluation of the SafeTrip-21 Initiative: California Connected Traveler Test Bed Final Evaluation Report: Networked Traveler – Foresighted Driving	FHWA-JPO-11-012
National Evaluation of the SafeTrip-21 Initiative: California Connected Traveler Test Bed Final Evaluation Report: Networked Traveler – Transit / Smart Parking	FHWA-JPO-11-014
National Evaluation of the SafeTrip-21 Initiative: California Connected Traveler Test Bed Final Evaluation Report: Real Time Intersection Delay	FHWA-JPO-11-006
National Evaluation of the SafeTrip-21 Initiative: I-95 Corridor Coalition Test Bed Final Evaluation Report: Providing Multi-modal Travel Information to Airport Users	FHWA-JPO-11-011
National Evaluation of the SafeTrip-21 Initiative: I-95 Corridor Coalition Test Bed Final Evaluation Report: Displaying Travel Times in Public Areas	FHWA-JPO-10-061
National Evaluation of the SafeTrip-21 Initiative: I-95 Corridor Coalition Test Bed Final Evaluation Report: Long Distance Trip Planning Using Real-Time Travel Time Data	FHWA-JPO-10-060
National Evaluation of the SafeTrip-21 Initiative: I-95 Corridor Coalition Test Bed Final Evaluation Report: North Carolina Deployment of Portable Traffic-Monitoring Devices	FHWA-JPO-10-058
National Evaluation of the SafeTrip-21 Initiative: California Connected Traveler Test Bed Final Evaluation Report: California Deployment of Portable Traffic-Monitoring Devices	FHWA-JPO-10-059

Part II of this report summarizes each application report. However, the reader is referred to these individual application Evaluation Reports for more detailed information.

2 GUIDE TO REPORT ORGANIZATION AND SEARCH INDEX

This Combined Final Report is structured to synthesize the broad range of data collected during the evaluation. This information has been described in previously released application-specific Evaluation Reports (listed in Table 2). Beyond merely summarizing earlier findings, this report is designed to facilitate the communication of key messages resulting from application-specific findings and, where appropriate, across applications.

This report also reflects recognition that there are various audiences who might have interest in the evaluation and its findings (e.g., transportation engineers, transit agency professionals, policy makers, systems developers, researchers, and consumers), and that within each of these groups there might be multiple levels of interest. Thus, the report is designed to facilitate finding different types of information for which a reader might be searching.

Part I of this report provided an overview of the evaluation.

Part II of this report will provide a summary chapter for each of the applications tested as part of the SafeTrip-21 Initiative. These chapters are meant to present a snapshot of the technologies, users, tests, and key findings sufficient to provide a reader with an understanding of the application.

Part III of this report will present a synthesis of the evaluation findings. These evaluation findings are grouped by different topics of interest to the ITS community. The four ITS topics considered in Part III of this evaluation report included:

- Alternative Approaches to Monitoring and Using Traffic Conditions Data (Chapter 11)
- Providing Useful and Usable Real-Time Traffic Conditions Information (Chapter 12)
- Providing Multi-modal Travel Options to Travelers (Chapter 13)
- Providing In-Vehicle Safety Alerts in End-of-Queue Situations (Chapter 14)

Within each section, the evaluation findings also are categorized based on the main aspects of the test including:

- Design and Development;
- Deployment;
- Marketing;
- User Experience;
- Privacy; and
- Institutional Issues.

Table 3 provides an index showing the relationship between Part II and Part III of this report. Using this, the reader will be able to cross-reference the report summaries in Part II with the specific evaluation findings in Part III. Check marks indicate which applications are included in the findings and page numbers guide the reader to the starting point of the relevant sections of the report.

Table 3. Index to the Part II Report Summaries and the Part III Evaluation Findings.

PART III: EVALUATION FINDINGS (by chapter)	PART II: SAFETRIP-21 APPLICATIONS (by chapter)							
	3. Mobile Millennium	4. Networked Traveler – Foresighted Driving	5. Networked Traveler – Transit / Smart Parking	6. Deployment of Real-Time Intersection Delay Monitoring	7. Providing Multi-modal Travel Information to Airport Users	8. Displaying Travel Times in Public Areas	9. Long Distance Trip Planning Using Real-time Travel Time Data	10. Deployment of Portable Traffic Monitoring Devices
11. Alternative Approaches for Monitoring and Using Traffic Conditions Data (p. 70)	✓	✓		✓				✓
11.1 Design and Development	p. 72	p. 72		p. 72				p. 72
11.2 Deployment	p. 73	p. 73		p. 73				p. 73
11.3 Marketing								
11.4 User Experience	p. 74	p. 74						
11.5 Privacy	p. 75	p. 75						
11.6 Institutional Issues	p. 75	p. 75		p. 75				p. 75
12. Providing Useful and Usable Real-Time Traffic Information (p. 75)	✓					✓	✓	
12.1 Design and Development	p. 78					p. 78	p. 78	
12.2 Deployment	p. 79					p. 79	p. 79	
12.3 Marketing						p. 79	p. 79	
12.4 User Experience	p. 82					p. 82	p. 82	
12.5 Privacy	p. 83							
12.6 Institutional Issues	p. 83					p. 83	p. 83	
13. Providing Multi-Modal Travel Options to Travelers (p. 85)			✓		✓	✓		
13.1 Design and Development			p. 89		p. 89	p. 89		
13.2 Deployment			p. 91		p. 91	p. 91		
13.3 Marketing			p. 93		p. 93	p. 93		
13.4 User Experience			p. 96		p. 96	p. 96		
13.5 Privacy								
13.6 Institutional Issues			p. 102		p. 102	p. 102		
14. Providing In-Vehicle Safety Alerts in End-of-Queue Situations (p. 104)		✓						
14.1 Design and Development		p.106						
14.2 Deployment		p.109						
14.3 Marketing		p.110						
14.4 User Experience		p.111						
14.5 Privacy		p.112						
14.6 Institutional Issues		p. 113						

Part II: Safetrip-21 Applications

This section presents a summary of each application area evaluated in this project. An application-specific Evaluation Report is also associated with each application. These were previously listed in Table 2. The purpose of this section is to provide the reader with a high-level overview of each application and its key findings. The reader is directed to access the application-specific Evaluation Reports for more detailed discussions of this information.

3 MOBILE MILLENNIUM

3.1 OVERVIEW

The lead partner for Mobile Millennium was the California Department of Transportation (Caltrans). Caltrans' interest in Mobile Millennium was focused on the potential it offered as a cost-effective alternative to traditional traffic monitoring infrastructure, especially for arterials and other roadways with unusual travel demand patterns. Mobile Millennium was developed by the California Center for Innovative Transportation (CCIT), the Nokia Research Center (NRC), and the University of California (UC) at Berkeley. The partnership between CCIT and NRC can be traced back to 2006, when the National Science Foundation co-funded a joint US/European Union workshop in Helsinki, Finland.

The strategic objective of Mobile Millennium was to demonstrate the potential of cell phone GPS systems to alter the way traffic data is collected by leveraging the existing cell phone infrastructure to collect traffic data and transmit traffic information directly back to drivers.

Mobile Millennium was designed to accommodate up to 10,000 participants. This number reflects a design limit necessary to scale the information technology infrastructure rather than a target number of users. There was no intent for Mobile Millennium to achieve any specific level of probe penetration, and no expectation that even if 10,000 participants were recruited that this would be sufficient for Mobile Millennium to be able to generate comprehensive traffic information across the Bay Area.

Minimizing the potential for distracted driving was an important factor in the design and operation of Mobile Millennium. Test participants were cautioned about the use of Mobile Millennium while driving, in keeping with U.S. DOT policy, even though doing so was allowable under California's "hands free" law. Using Mobile Millennium required no driver action beyond launching the application at the outset of a trip (i.e., before driving).

Two traffic models were developed for Mobile Millennium: one for highways and one for arterials. Public sector funding for Mobile Millennium was targeted at the development of these traffic models by CCIT. The basis for the Mobile Millennium highway model was a traffic model developed for a previous, more limited test (known as Mobile Century) and this was subsequently refined through Mobile Millennium. The arterial model was developed for Mobile Millennium. Each model receives traffic data from multiple sources (including registered users' smart phones serving as traffic probes) and processes these data to generate real-time traffic information. The processed traffic information from each model is then merged with mapping information, and color coding is applied to represent congested and free-flow traffic conditions on highways and arterials. The real-time traffic map is then displayed on registered users' smart phones.

Mobile Millennium was launched in the Bay Area on November 10, 2008, and demonstrated live in New York City on November 18, 2008, at the 15th World Congress on Intelligent Transportation Systems. Consumer interaction was managed by NRC, although the free download software was managed by UC Berkeley. The software continued to be available until the public participation phase ended on November 10, 2009.

Mobile Millennium was somewhat unusual in that it not only provided a consumer service but also has the capability to function as a management or operational tool. Indeed, the concept of collecting traffic information from traffic probe systems such as Mobile Millennium is of ongoing interest to Caltrans as it provides an alternative to traditional traffic monitoring infrastructure.

While Mobile Millennium was a “beta” system—i.e., a pre-mass market application, with free participation for registered users—it nonetheless had to be managed in a rapidly changing product environment that demands high standards for customer service. Mobile Millennium has the ability to process traffic data inputs from fixed sensors and multiple types of probe devices. While the test bed was confined to the San Francisco Bay Area, Mobile Millennium was built on a national scale, as demonstrated at the 2008 World Congress on Intelligent Transportation Systems in New York City.

CCIT continued to enhance the arterial model throughout the public participation phase and thereafter, culminating in a series of validation tests through July 2010 to assess the accuracy (ground truth) of the models.

3.2 EVALUATION OBJECTIVES

The evaluation approach was driven by a series of objectives that align with the U.S. DOT’s goals for the SafeTrip-21 initiative:

- Observe the consumer response to Mobile Millennium;
- Understand the technical and institutional issues associated with gathering probe-based traffic data, and distributing traffic information to smart phone users;
- Measure usage of the probe-based traffic information; and
- Measure the accuracy of the traffic information generated by the system.

3.3 EVALUATION ACTIVITIES

To achieve the objectives above, the evaluation team implemented the following key activities:

1. Analyzed usage statistics provided by partners;
2. Reviewed ground truth analysis undertaken by partners;
3. Conducted interviews with deployment and operational partners; and
4. Analyzed user survey results provided by partners.

These activities are discussed below.

3.3.1 Usage Statistics

In order to gain truly comprehensive information about the use of Mobile Millennium, the evaluation team analyzed usage statistics gathered by the project partners:

1. Trends in the number of registered users;
2. Distribution (by zip code) of registered users; and
3. Mobile devices used.

Consideration was given to collecting usage statistics for Mobile Millennium’s website. However, after downloading the free application software, users have no reason to return to this website. Real time traffic information is sent directly to the users’ smart phones and is not available at the website.

3.3.2 Ground Truth Analysis

In order to improve their understanding of the accuracy of traffic information provided to Mobile Millennium users, CCIT undertook an analysis of historic and new data for the highway and arterial models, respectively. The evaluation team reviewed the findings of this analysis with the CCIT staff members responsible for the work.

3.3.3 Interviews with Deployment and Operational Partners

The evaluation team interviewed participating agencies and project partners to identify operational experiences and lessons learned during development and deployment of Mobile Millennium. 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.

3.3.4 User Survey

In the early stages of evaluation planning, the evaluation team had planned to design and administer a web-based survey of registered users and conduct follow-up interviews with a selected number of these users. However, the operational phase of the Mobile Millennium concluded in November of 2009 during a period when evaluation team activities were on hold due to U.S. DOT's distracted driving concerns. Consequently, it was not possible to interact with users to gain any understanding of their perceptions of Mobile Millennium. However, NRC did agree to make available for publication the results of two user surveys conducted by NRC in January and June 2009. These surveys were undertaken to support NRC's internal development activities, and do not directly support the evaluation objectives. While the surveys were not collected independently, they do provide some insights regarding user perceptions.

3.4 EVALUATION FINDINGS

3.4.1 Consumer Response

Usage statistics indicate that the software application was downloaded 2,241 times to unique mobile phone numbers between November 10, 2008, and November 10, 2009. The daily rate of downloads peaked at more than 70 per day in November 2008 (post-launch), tailing off to less than 4 downloads per day in each of the final 11 months. Given that the primary outreach effort was concentrated on the initial launch period, this is not unexpected. Indeed, apart from some minor outreach by NRC and CCIT at the 2009 AASHTO Annual Meeting during late October 2009 in Palm Desert, California, there were no specific outreach campaigns after the launch. Despite the absence of any additional outreach efforts, users continued to download the application software throughout the operational period.

The majority of users were infrequent users. The number of users that used Mobile Millennium daily (6 or more uses in the past 7 days) declined from 33 percent in January 2009 to 11 percent in June 2009. On the subject of privacy, 68 percent of respondents trusted the system to protect the privacy of their travel data, 7 percent did not trust the system, and 25 percent either did not know or did not care.

Overall, the combination of usage statistics and user surveys provides an insight into the consumer response to Mobile Millennium. The test achieved public participation in the thousands, with users geographically dispersed across the Bay Area and Sacramento region. Clearly the potential existed for much higher participation levels had the system been more

widely available. Mobile Millennium was only available to select Nokia smart phones, select BlackBerry® models, and a few other smart phones. However it is recognized, particularly from NRC's perspective, that this was a beta test as part of product development and testing process.

Users were enthusiastic about providing feedback, as even those who had registered but never used the system responded to the survey invitation. One of the main reasons for this desire to provide feedback was their smart phone was not one of those supported by Mobile Millennium.

Respondents provided a range of perspectives on why and how they used the system, and offered suggestions on how to improve it. Users took comfort from knowing traffic conditions, and the ability to make more informed travel decisions. The majority of users indicated they open the application to view traffic data before driving, although a sizeable minority (almost one in five) admitted to viewing traffic data while driving when encountering traffic.¹ Many users expressed an interest in more features, including personalized traffic information, as a way to improve the system.

While many of those who had downloaded the software application were occasional users, it is apparent that Mobile Millennium also had a core group of users who used the system intensively. That said, an unexpected behavior reported by respondents to the user survey was that one-third closed the application after viewing traffic conditions, meaning their mobile phones no longer acted as traffic probes.

These findings have addressed several evaluation objectives. First, the findings address the evaluation objective to observe the consumer response to Mobile Millennium. The test demonstrated that large numbers of users registered to download the system, and in many cases subsequently chose to use the system. While most users registered in the first few months of the operational phase in late 2008, registrations did continue throughout 2009. This occurred in the absence of any sustained public relations initiatives (after the November 2008 launch) and despite the limited range of smart phones supported by the system due to it being a test and not a full product deployment.

The hypothesis statement associated with this objective is that traffic information gathered from traffic probes will continue to grow throughout the San Francisco Bay Area. The observed growth in the number of registered users implies a corresponding growth in the number of traffic probes, which in turn implies growth in traffic information gathered from traffic probes. However, this relationship is not entirely straightforward as one-third of users close the application after checking traffic conditions, effectively preventing their smart phones from acting as traffic probes. Perhaps more importantly, the majority of users were willing to provide data in exchange for information given a sufficient assurance of privacy. Clearly, outreach and promotion are key factors in maximizing the number of registered users.

Second, the findings address the evaluation objective to measure usage of the probe-based traffic information. The test demonstrated that large numbers of users registered to download the system, and in many cases subsequently chose to use the system. While many of those who had downloaded the software application were occasional users, it is apparent that Mobile Millennium also had a core group of users who used the system intensively.

¹ It is unknown whether this comment refers to viewing traffic data as the user approaches traffic congestion or when the user is in traffic congestion.

The hypothesis statement associated with this objective is that usage of the probe-based traffic information will be an indication of user acceptance, and that usage will increase over time. While it is likely that intensive users of Mobile Millennium demonstrated user acceptance through their actions, they are in the minority. It is unclear whether the majority of users who used the system less often did so because their travel behavior was such that they had less need for the traffic information or because they were less accepting of the traffic information. The best evidence of user acceptance comes from the January 2009 user survey, which indicated that 88 percent of respondents would definitely or probably use the system in the future, versus 12 percent who would definitely or probably not use the system in the future.

3.4.2 Ground Truth Analysis

Based on the data collected by CCIT, the real-time highway model estimates of travel times were a good representation of actual conditions as measured by the independent observations of travel times. This was for an 8 hour period on February 8, 2008, along northbound Highway I-880. Based on the data collected, it is not possible to make any statements regarding the accuracy of the highway model for other time periods along this section of I-880, or for other freeways in the Bay Area.

Based on the data collected by CCIT, the arterial model estimates of travel times did not consistently provide a good representation of actual conditions as measured by the independent observations of travel times. There are several possible reasons for this, mostly related to the design and management of the ground truthing test:

- In a congested urban area with short blocks where vehicles stop frequently for traffic signals, the passage of vehicles over short distances can be heavily skewed by whether they reach an intersection when the light is green or red, whether a lane is blocked by a parked vehicle, and the level of local knowledge drivers apply in anticipating the best lane to be driving in. The only way to address this is to collect considerable amounts of data.
- The Bluetooth[®] tracking technology is robust, but in a congested urban area a single vehicle may generate multiple readings at a single reader location, requiring extensive data checks and filtering assumptions.
- When drivers are recruited to drive probe vehicles to represent general traffic, it is essential that they do not drive in a manner that is inconsistent with the general traffic. This can include choice of lanes, speed, and arrangements for taking breaks.

The above factors appear to have influenced the results of the arterial tests. The accuracy of the arterial model developed by CCIT appears to be dependent on the type of arterial road used for ground truth data collection. When the arterial under consideration is located parallel to a highway with no other major streets nearby, the model provided accurate estimates of the travel time distribution. When the arterial is part of a dense city grid with all streets in the network heavily used, the arterial model did not consistently provide accurate long-distance travel time estimates.

The lessons learned by CCIT from the arterial ground truthing test are potentially valuable should CCIT decide to undertake a more comprehensive test of the arterial model in the future.

These findings are not inconsistent with comparable GPS-based traffic information systems with regard to arterial travel times. The arterial model development work conducted by the Mobile Millennium test has highlighted the importance of probe penetration rates, identified practical

issues associated with estimating travel times across a metropolitan area in real time, and has advanced the state of knowledge on modeling techniques.

3.4.3 Implementation Challenges and How They Were Overcome

While distracted driving was not such a prominent issue at the time Mobile Millennium was implemented as it is now, Nokia took the issue seriously and tried to reduce the risks. For example, the Mobile Millennium application used the “5” key to enable audible messaging. While this did not provide the full range of Mobile Millennium features, it did provide some functionality without drivers having to take their eye off the road. The application was designed to comply with California’s “hands free” law from the outset. No driver interaction was required for the generation and transfer of traffic data once the application is launched. No alerts were generated, and the cell phone screen would be blank unless refreshed by a user by a touch of any key or button. In addition, users were cautioned about viewing the screen while driving.

Given the nature of the Mobile Millennium test, there were no traditional infrastructure deployments planned. However, development and operation of the traffic models and management of the traffic data were immense challenges, which CCIT addressed by appointing a technical Project Manager with a background in software engineering and management. Challenges that developed during the test included:

- **Historical focus on the civil engineering field rather than software/systems expertise.** It is the opinion of the CCIT team that in the future this could be mitigated with updating curriculum and combining tracks for systems/computer/software engineers with civil engineers. With the rapid growth in data-driven systems, it is going to be more and more important for civil engineers to understand how to use that data. For Mobile Millennium, this problem was addressed by integrating expertise into the project; for example, involving UC’s Computer Science group. Future consideration for systems such as Mobile Millennium must be given to the need for 24/7 support for the traffic models so as not to lose credibility with consumers, which in turn means that reliability performance measures such as mean time to correct failures will be necessary.
- **Inefficiency of the procurement process.** This can be a long and slow process, particularly in today’s economy, where California is dealing with staff furloughs on a regular basis. The Caltrans procurement process underwent significant changes during the test period that stretched the time for processing agreements / amendments from days/weeks to week/months. Under such circumstances, proactive management of procurement needs is essential if project delays and deterioration in customer service is to be avoided.
- **High complexity and fast pace of managing software engineering staff and tasks in an academic environment.** Historically, traffic research projects had not needed software engineering management skills, and so CCIT did not have this capability. Prior to appointment of CCIT’s technical Project Manager, there was a lack of professional management skills in place, which meant that critical items such as documentation were not given a high priority. However, Mobile Millennium was such a large, fast-paced project that these materials had to be developed.

3.4.4 Methodologies for Determining User Needs

Nokia is consumer-focused and constantly looking to engage consumers. Nokia’s interest in consumers extends to the entire traveling public. In keeping with this philosophy, the process for

selecting Mobile Millennium users was an open invitation to download the application. Minimal information was collected about users, with the main requirements being that they be 18 years old or older and have a compatible smart phone. The majority of Mobile Millennium users did not use Nokia phones. BlackBerrys were the most popular, but iPhones were not supported. The focus was on consumers rather than just Nokia users.

Indeed the demographic profile of Mobile Millennium users was skewed towards older (25 – 45 years old) users, disproving a myth that older people will not adapt to technological advances. (NRC had anticipated that 18 – 24 year old users would dominate.) Nokia believes in the philosophy that if you provide a good service, consumers will use it. That said, this is the Bay Area, which is perhaps more tech-savvy than other regions, although Nokia believes there is a general trend in the broader market towards new technology and information services.

3.4.5 Institutional challenges

Working with Caltrans was a successful collaboration but Nokia realized that, while they shared objectives, and staff had similar working styles, the business models between the two organizations were different (an “impedance mismatch”). The differences were primarily focused on the very long time lines that exist in government; the government is typically looking 5-10 years ahead while private industry has to be very nimble and anticipate and react to changing market forces.

Nokia was very complimentary about how Caltrans is concerned with providing the best service to users. In what it described as an “ecosystem,” Nokia also sees an additional role for government: to get more participation from consumers by enabling them to provide information about their own behaviors to enable better services to be provided to them. Nokia considers Caltrans has demonstrated a recent shift to this way of thinking and does not consider consumers to be an afterthought. However, this does require government to move faster and be more nimble. “Consumers are information bearers, but structure and process can kill that.”²

3.4.6 Approaches for Managing Anonymity and Privacy

One of the potential pitfalls of Mobile Millennium was the issue of privacy, specifically the protection of the personal information of registered users. This concern was addressed prior to launch through UC’s normal process for such matters, and this resulted in minimal personal data being collected as part of the registration process, e.g., mobile phone number, home and work zip codes, and an email address for those who opted in to participate in future surveys. Individuals’ names and street addresses were not collected. In addition, the system architecture divided information among several different servers so that no information for one person was available in one location at one time.

The partners were clear and open about all details related to data gathering and storage, and considered this transparent approach greatly helped to mitigate users’ privacy concerns.

Nokia’s stance on privacy is that it is a customer’s right. When personal information is gathered in order to provide a more customized experience, this trade-off must be made openly. Nokia’s hypothesis was that usefulness and accuracy were at odds with privacy. While counter-intuitive, this was found to be false. The steps that Nokia took to protect privacy actually enhanced the quality of the data:

² Verbal comment recorded during a deployment interview with Lisa Waits, Director of Business Development at the Nokia Research Center, on July 29, 2010.

1. Any single vehicle is not indicative of conditions, and so data was aggregated to improve accuracy. By discarding isolated records, this made it more difficult to identify the behavior of individual drivers.
2. In a mobile system, efficiency is paramount for a range of topics such as battery life, load on communications system, servers, etc. Consequently, superfluous data should not be sent. This in turn reduces the risk that privacy is breached.

The flipside to this approach comes with customization, which requires the user to provide more personal information. Here it is important to make the customer aware of the risks and agree to them. Overall, on the spectrum of service ranging from “wrapping oneself in tinfoil” and getting no service, to getting full customization with lots of services, Nokia found that even when consumers only give a little information, they can get a lot back. Caltrans recognized that privacy is an important issue for Nokia. It can be difficult to regain trust and credibility should a breach of privacy occur.

Mobile Millennium was a groundbreaking test. Not only did it push the envelope on our understanding of how to use GPS-enabled smart phones as vehicle probes to generate traffic information on highways and arterials across the Bay Area, it did this as part of a 24/7 consumer service over a 12-month period. Another groundbreaking aspect of Mobile Millennium was its use of privacy-protecting methods to generate traffic data at pre-set locations (referred to as virtual trip lines or VTLs) rather than tracking individual mobile devices or using identification information.

With more than 2,000 registered users, most of whom were volunteer members of the public (i.e. consumers) rather than employees of the partners or paid recruits, the scale of Mobile Millennium was impressive. This would likely not have been possible were it not for the pre-existing public-private-academic partnership between Caltrans, the California Center for Innovative Transportation, the Nokia Research Center, and the University of California Berkeley, or without the benefit of earlier lessons from the 2008 Mobile Century project.

Mobile Millennium created the first region-wide consumer traffic application for smart phone users, implemented the privacy-protecting concept of virtual trip lines, and demonstrated that the concept of infrastructure-free traffic data collection is feasible for both highways and arterials. It did this while maintaining the trust of the majority of users that their privacy was being protected.

Mobile Millennium also highlighted some future challenges that need to be addressed by transportation agencies and businesses before similar systems become more commonplace. These challenges include new procurement approaches that are focused on purchasing information rather than equipment, defining the respective roles (and business models) of the public and private sectors in providing traffic information to consumers, and trade-offs between individualized information delivered to a smart phone and distracted driving.

It is perhaps a measure of the rapid pace of technology advances between 2008 and today that traffic applications for mobile phones, traffic data from vehicle probes, and the increasing involvement of “non-traditional” partners (information services providers, mobile device manufacturers, and mobile communication service providers) in traffic information services are becoming the norm. The Mobile Millennium test has much to contribute to this emerging sector.

3.5 CONCLUSIONS

More than 2,200 users registered to download the system, and in many cases subsequently chose to use the system. While most users registered in the first few months of the operational phase in late 2008, registrations did continue throughout 2009. The partners developed a range of targeted recruiting initiatives, but for various reasons they did not come to fruition. Consequently, the growth in registration occurred in the absence of any sustained public relations initiatives (after the November 2008 launch) and despite the limited range of smart phones supported by the system (due to this being a test not a full product deployment).

The observed growth in the number of registered users implies a corresponding growth in the number of traffic probes, which in turn implies growth in traffic information gathered from traffic probes. However, this relationship is not entirely straightforward as one-third of users closed the application after checking traffic conditions, effectively preventing their smart phones from acting as traffic probes. This result identified the need for an application design that can collect data from the traffic probes continuously without a major impact on battery life or normal device operation, which could increase the accuracy and reliability of the traffic information.

Mobile Millennium contributed significantly to the transportation industry's collective understanding of probe-based traffic information. The test demonstrated that the potential for using smart phones as traffic probes to collect vast amounts of traffic data is a viable alternative to traditional infrastructure-based traffic data collection. The algorithms developed and implemented in the Mobile Millennium system were designed to handle fixed and mobile sources of data. The system was developed such that either source of data could be turned on or off. Perhaps one of the most exciting areas was that arterial traffic data appears to be in reach as part of a comprehensive and integrated approach. The test also highlighted the potential for personalized traffic information, giving greater control and reassurance to the user.

In addition to the technical lessons learned, Mobile Millennium demonstrated the importance of an effective public-private-academic partnership, particularly one that had been active for several years leading up to the test. Despite their different organizational structures and strategic objectives, the partners brought complementary skill sets and a common consumer-orientated approach to the test.

Given the potential for automated tracking implicit with using GPS-enabled smart phones as vehicle probes, the partners considered that privacy was an issue toward which transparency was the best approach. As previously noted, Mobile Millennium used privacy-protecting methods to generate traffic data at pre-set locations (VTLs) rather than tracking individual mobile devices or using identification information. The great majority of users indicated that they trusted that Mobile Millennium protected their travel information.

While many of those who had downloaded the software application were occasional users, it is apparent that Mobile Millennium also had a core group of users who used the system intensively. It is unclear whether the majority of users who used the system less often did so because their travel behavior was such that they had less need for the traffic information or because they were less accepting of the traffic information. The best evidence of user acceptance comes from the January 2009 user survey, which indicated that 88 percent of respondents would definitely or probably use the system in the future, versus 12 percent who would definitely or probably not use the system in the future.

One possible area of concern regarding driver behavior was that one-third of users opened the application when they were in their cars as they started driving, and nearly 20 percent of users admitted to opening the application if they encountered traffic while driving. This apparent propensity to use the application while driving raises concerns about the potential for distraction. However, the relative level of distraction caused by Mobile Millennium compared to the regular operation of cell phones while driving, or by other electronic devices typically used in vehicles; e.g., navigation systems, was not studied.

Based on the ground truthing work undertaken by CCIT, the highway model appears robust, while the findings for the arterial model depended on the location for the test. This was not entirely unexpected, as the highway model was less complex than the arterial model and had had the benefit of a longer development period (dating back to the Mobile Century project). There is probably no single universal model that could apply to all arterial scenarios. Instead, specific customized arterial models may be required depending on the type of arterial roads being modeled and the traffic patterns they exhibit.

In addition, arterial traffic monitoring is typically much more challenging than highway traffic given the many factors that influence arterial traffic, such as traffic signals, frequency of (and turning movements at) intersections, pedestrian movements, loading/unloading passengers and goods, parking, and widely varying performance characteristics of vehicles.

4 NETWORKED TRAVELER – FORESIGHTED DRIVING

4.1 OVERVIEW

This Networked Traveler – Foresighted Driving (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. The test used four instrumented vehicles to provide the 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.

Partners for Advanced Transportation Technology (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.

The test methodology utilized a naturalistic, instrumented vehicle, field-test design. 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.

Four vehicles were instrumented for the test: two Nissan Altimas and two Audis. During the test, each driver had full use of an instrumented vehicle for 2 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 normally 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.

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.

4.2 EVALUATION OBJECTIVES

The evaluation was conducted to meet the following objectives:

- Understand the technical, human-machine interface, and institutional issues associated with gathering specific vehicle location and speed data, and distributing safety information to drivers;
- Analyze the perceived timeliness, accuracy, and usefulness of safety alerts; and

- Explore the user-perceived benefits of the safety alerts.

4.3 EVALUATION ACTIVITIES

Instrumented vehicles were picked up and returned to PATH's Richmond Field Station facility by each of the 24 participants. 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 was told what to expect. Participants also completed official paperwork.

The process for conducting the test was carefully designed to meet the experimental requirements of PATH and to address the evaluation objectives of the Evaluation Team. In addition, both PATH and the Evaluation Team received formal approval from their respective Institutional Review Boards (IRB) for the test protocol, which included provisions to protect the privacy of the 24 subject drivers. To discharge its responsibilities with respect to protecting the identities 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.

Participants drove the vehicles for 2 weeks; during the first week, data were collected, though the alerts were not yet activated (this served as the baseline period). The alerts were activated one week after the vehicle was picked up. 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 payments were made when each driver returned their vehicle at the end of their 2 week study period 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.

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, PATH helped each participant create a user ID and password that connected them to the survey. The participants were encouraged to access the site each evening and to 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.

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.)

4.4 EVALUATION FINDINGS

4.4.1 *User Perceptions*

Overall, the results of the experiment showed that the participants did consider the alert system to be 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, participants 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.

4.4.2 Implementation Issues

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:

- Record the vehicle’s location, direction, and real-time speed accurately, 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; and
- 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' onboard computers was subject to more restrictive terms and conditions than that of 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 considerably longer than anticipated to get into service than the Nissans. 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.

These technical issues were compounded by internal administrative issues with Caltrans and UC Berkeley (see below) specifically related to availability of funding to purchase equipment in a timely manner. PATH considers this to have been a major impediment to the timely execution of the experiment.

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 with the test participants, there were no 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 their 2 week study 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 would retain the need to track the vehicle's location, direction, and speed accurately, 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 tracking purposes while driving. Obviously if privacy was a concern, the user either would not purchase the system (if provided commercially) or would 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.

4.5 CONCLUSIONS

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, and their impact on driver behavior is unknown.

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 to be reassuring and a positive aid to the driving task. 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 slowdowns 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 immediately be identified by the Evaluation Team. However, the most plausible explanations for these false alerts include the possibility that test participants may have exited the freeway after receiving an alert but before reaching the location associated with the alert or that the conditions that caused the alert to be generated were resolved by the time the test participant arrived at the sensor location. Another possibility could have been that there were inaccuracies in the traffic speed information provided by the external speed sensor network or anomalies 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 unclear whether these are functionally adequate for this purpose. It is also unclear what the respective roles of the public and private sectors would be in the development, operation, and maintenance of a more widely available system. Regardless, the NT-FD test has much to contribute to the ongoing evolution of the traffic information services sector.

Based on the obtained results:

- The NT-FD test contributed significantly to the 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. 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 no more distraction than would be caused by listening to the radio.
- 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 expanded to all roadways and made into a marketable product. 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 that 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.
- 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.

5 NETWORKED TRAVELER – TRANSIT / SMART PARKING

5.1 OVERVIEW

The Networked Traveler – Transit / Smart Parking (NT-T/SP) test consisted of real-time transit information and trip planner applications that served travelers along the US-101 corridor in San Francisco, California. The primary purpose of the test was to provide information to travelers in real time across all transit agencies that serve the US-101 corridor. This “one-stop shop” for traveler information was designed to help travelers make better pre-trip planning decisions in terms of mode selection and to serve as a tool for planning transit trips from any origin to any destination considering all transit options available. The NT-T/SP test was unique in that it integrated a broad range of real-time, multi-modal transportation information, including transit and parking information. In fact, the multi-modal trip planner website was one of the first of its kind for the Bay Area.

It is important to note that this test was re-scoped in late 2009 to address concerns about distracted driving. PATH had originally planned to integrate real time traffic, transit, and parking information to compare the fastest mode from the drivers’ locations to their destinations during congested conditions. The re-scoping of the test resulted in a greater focus on pre-trip information for drivers and an increased emphasis on real-time transit information via the smart phone application. Alerts on transit status were provided by the smart phone application, but a technique referred to as “geofencing” was introduced to prevent the use of the smart phone application while driving. Unlike traditional geofencing, which is intended to provide alerts when individuals or assets deviate from a pre-defined route, zone, or time period, and other smart phone applications that are intended to prevent use of mobile phones while driving, PATH developed a geofencing technique that attempted to determine which mode the traveler was using in order to allow transit users to continue to receive updates while on the move while preventing them from using the information while driving. In this way, the level of distraction to the driver was substantially reduced while service to transit riders was maintained.

With the support of several regional partners, PATH developed a set of web-based and smart phone-based applications branded as “PATH2Go.” PATH made the applications available via its “Networked Traveler” project website,³ where users could access the multi-modal trip planner website, the transit smart phone application, and the transit and parking traveler information website. For the purposes of the evaluation, these were named as the Trip Planner, the Web Based Traveler Information, and the Smart Phone Application, which together make up the suite of tools branded PATH2Go.

The Networked Traveler website also provided detailed information about what each of the applications has to offer. Visitors to the project website had the option to register as a user by signing up and creating an account. Users were required to register in order to download the PATH2Go Smart Phone Application, but could use either of the web-based applications with or without registering. Users who created an account were asked to create a user name and password as well as fill out a short, optional survey with demographic, travel pattern, and marketing questions.

³ PATH Networked Traveler project website, “Transit Information and Trip Planning Tool for the San Francisco Bay Area.” Available at: <http://www.networkedtraveler.org/>

5.1.1 PATH2Go Web Based Traveler Information

The PATH2Go Web Based Traveler Information website⁴ provided real-time, detailed transit information for all Bay Area transit agencies that serve the US-101 corridor. The website provided a variety of transit information to travelers for train, commuter rail, light rail, BRT, and bus routes, including real-time schedule information. The transit agencies available in all three of the PATH2Go applications include:

1. Caltrain;
2. SF Muni;
3. VTA;
4. BART; and
5. SamTrans

The primary purpose of the PATH2Go Web Based Traveler Information website was to provide real-time arrival and departure times for all transit routes (where available) as well as real-time parking availability information for several instrumented Caltrain lots along the US-101 corridor. This allowed transit riders to browse transit options and plan trips across several providers versus going to each transit agency website individually. Users could view real-time information versus just schedule information, which could impact user perception of the convenience of riding transit.

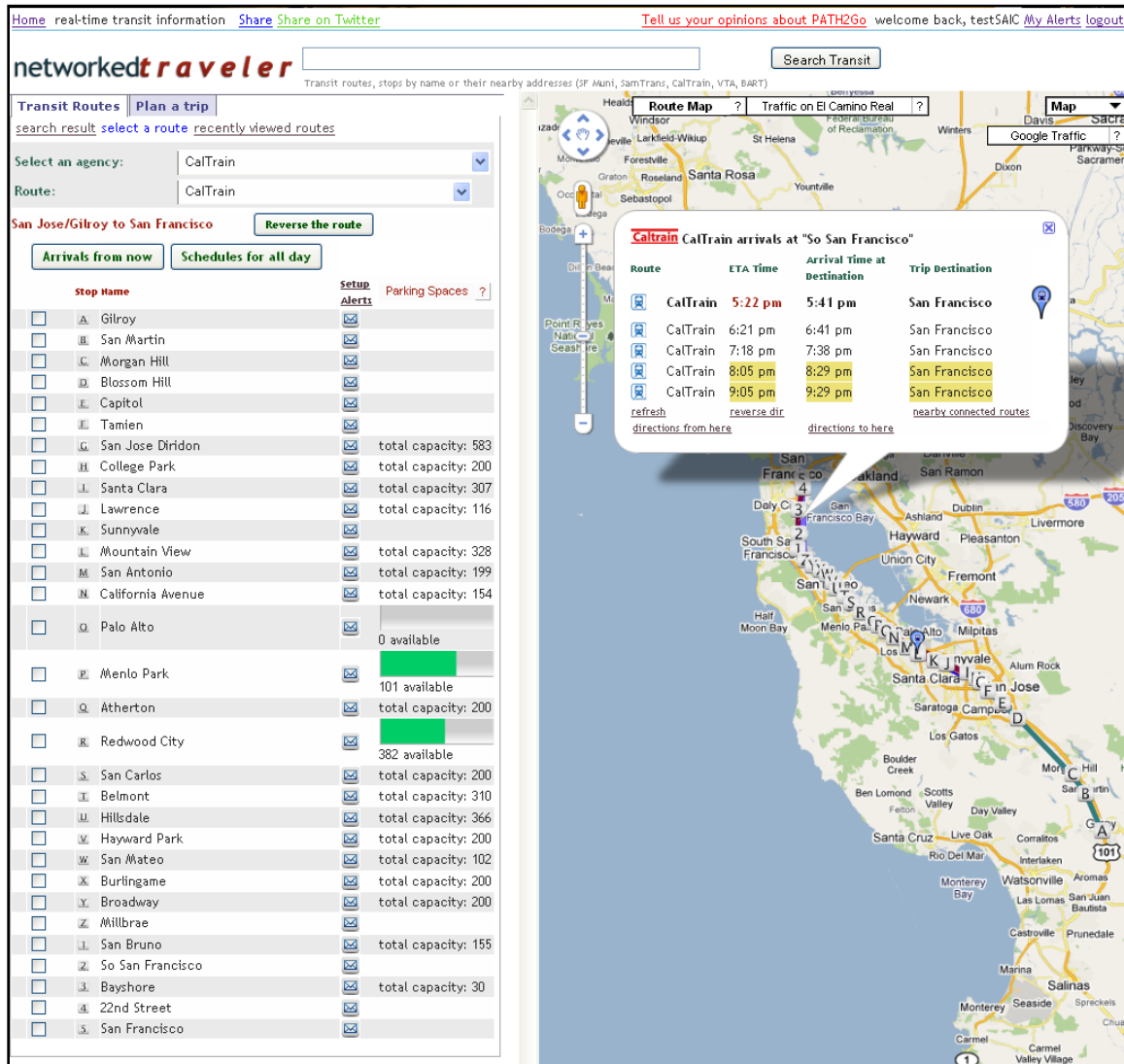
The website also offered parking lot capacity or real-time parking availability information for Caltrain Park-and-Ride lots to travelers who use Caltrain. As a test, four parking lots along the Caltrain route were instrumented with sensors to count the number of vehicles entering and exiting the lot in order to provide the available number of parking spots in real-time.

After a user identified a transit agency and a transit route, the website displays a full list of the stops along that route. A user could use the list of station/stop names or the map to select a specific stop and view all upcoming arrival and departure times for that stop in real-time. Because most transit trips have a direction associated with the route, users could also choose to reverse the route to view the schedule information in the opposite direction. Additionally, users could elect to view the real-time information or view the route schedule for the entire day by selecting the “Arrivals for now” or “Schedules for all day” buttons, respectively. As shown in Figure 3 below, the instrumented lots display the total number of parking spaces available at that location in real time, while other lots simply list total capacity. The times highlighted yellow in the South San Francisco station window represent “Baby Bullet” or express trains that only stop at specific stations to decrease long-distance commute times.

Users accessing the website can also plan a trip by entering an origin and destination in the form of a physical address, landmark, transit station/stop, or any other location recognizable by the system. In return, the system provides detailed information about the different transportation options available for the trip including benefit comparisons between options. For each trip option available, the system provides the total time required to complete the trip, the estimated total cost of the trip, and the expected carbon emissions or savings as the result of the trip; allowing travelers to make a decision based on which factor is most important to them for that trip. A trip summary is provided that allows users to consider the cost/benefit of choosing one option compared to another. For trips involving driving with a transfer to transit, the system provides the

⁴ Link to the PATH2Go Web Based Traveler Information website: <http://tlab.path.berkeley.edu/dpiVII/?p=false>

estimated cost of fuel for the driving leg of the trip, the actual cost of parking when the user will transfer to transit, and the actual fare for the transit leg of the trip. Users can even enter their vehicle’s fuel efficiency to update their itinerary with a more accurate estimate of fuel consumption. To help users consider the potential savings of considering alternate modes, the system displays a graphical representation of work/relax time versus driving time and driving emissions versus emissions saved by taking public transit for each trip option available.



Source: PATH, UC Berkeley

Figure 3. Screenshot of the PATH2Go Networked Traveler Web Site

5.1.2 PATH2Go Smart Phone Application

The PATH2Go Smart Phone Application is a multi-agency transit trip planner that provided real-time arrival and departure information and user location-based trip details for transit users in the Bay Area along the US-101 corridor. The application uses the GPS functionality of smart phones to help users identify transit options and guide them, step-by-step, through a planned transit trip

itinerary. The primary purpose of the application was to provide real-time transit information across multiple transit agencies for users on-the-go.

The application allowed users to view real-time transit schedules, plan transit trips by selecting nearby stops (based on their current GPS location), or create itineraries by providing origin and destination transit stops or locations. Users could select their current location or enter an origin and destination in the form of a physical address, landmark, transit station/stop, or any other location recognizable by the system, which uses a combination of the Google® Map API and its own transit database developed by PATH. The smart phone application used both the trip planner and traveler information servers developed by PATH to compile information and present it to the user.

The PATH2Go Smart Phone Application was available for download on smart phones with an iPhone, Android, or Windows Mobile software platform. Windows Mobile users had to download the application from PATH's Networked Traveler website after registering as a user. Although iPhone and Android users could technically download the application (from the Apple iTunes Store or Google's Android Marketplace) before registering, all smart phone application users had to register on the Networked Traveler website before they could gain access to the smart phone application. Once registered, users could begin sending transit trips planned with the PATH2Go Trip Planner website or the PATH2Go Web Based Traveler Information website to the smart phone application. Smart phone users received a notification within the application when it was time for the first leg of the planned trip to begin. Functionality between the website applications and the smart phone application gives users the benefit of working on a computer (i.e., bigger screen and faster internet speeds) while planning a trip or exploring transit options as taking the detailed itinerary with them to reference throughout their transit trip via their smart phone.

In addition to the compatibility between the websites and smart phone application, users could also use the smart phone application on its own to plan trips or view transit itineraries. Although the functionality and design of the smart phone application varies across the different software platforms, the basic information provided by the application is essentially the same for each.

Although the application was designed for use while traveling on transit, it is possible users accessed the transit information while driving and parking at or near a transit stop/station. As mentioned above, geofencing functionality was implemented into the PATH2Go Smart Phone Application design when the project was re-scoped to discourage use of this application while driving. The geofencing design compared transit route information stored on the traveler information server and speed and location data provided by the smart phone GPS to determine whether a user is traveling along a planned transit route or driving a vehicle. If the system determines that a user is driving, a warning message that reads "Warning! Application Disabled While Driving" appears and blocks users from the information provided on the application (see Figure 4).



Source: PATH, UC Berkeley

Figure 4. PATH2Go Smart Phone Application – Distracted Driving Alert

5.2 EVALUATION OBJECTIVES

The evaluation was conducted to meet the following objectives:

- Observe the consumer response to the NT-T/SP application;
- Understand the technical and institutional issues associated with distributing multi-modal information to smart phone users;
- Test the ability of geofencing as a method to prevent distracted driving;
- Understand the development process and institutional issues associated with implementing a server-based geofencing method versus a client-based method on mobile devices;
- Measure usage of the NT-T/SP application; and
- Analyze the perceived accuracy and usefulness of mode shift alerts and en-route transit information.

5.3 EVALUATION ACTIVITIES

5.3.1 Geofencing Test

The PATH project team developed a list of test scenarios that the smart phone application was capable of identifying when determining whether or not to block a user from the application. The test focused on assessing the ability of users to access information on the application while traveling in a vehicle. While conducting this test, no member of the evaluation team attempted to use a mobile device while operating a vehicle. The scenarios that involve driving were tested by the passenger, who attempted to access the information available on the application with a smart phone while the vehicle was being driven by another member of the evaluation team.

To assess the geofencing across different scenarios, the evaluation team ran test trips by traveling (i.e., driving in a vehicle, walking, or riding transit) to specific transit routes or along specific transit routes while using the PATH2Go Smart Phone Application. All test trips were conducted using iPhones, Android phones, and Windows Mobile phones. The test trips covered all transit agencies that have information available on the application and covered all types of

transit available from each agency (i.e., train, light rail, BRT, bus). Again, the focus of this test was to evaluate the ability of the geofencing design to prevent distracted driving. Therefore, the majority of the test trips involved driving to a transit route or along a transit route to assess whether or not the user was blocked from using the application while in a vehicle on a roadway.

The goal of the test was to push the geofencing design to its limits to understand exactly how it worked and whether or not it is effective in preventing distracted driving. After several discussions with the PATH project team, the evaluation team gained a solid understanding of the geofencing design, capabilities, and limitations and how those related to the test scenarios. Ultimately, the evaluation team set out to assess how the system could be “tricked” into not blocking the information available on the application while driving and whether or not those scenarios are likely to be repeated by actual users. The geofencing test was conducted over two consecutive days beginning on November 6, 2010.

5.3.2 Usage Statistics

To better understand how the PATH2Go applications were used, the evaluation team collected usage data for each of the applications and worked closely with the project team to determine the best method for tracking usage. The project team was able to establish tracking logs for each of the servers that provided information to the PATH2Go applications. The logs developed by PATH were useful for tracking the number of registered users as well as identifying the general usage of the applications. In addition to the tracking logs, the project team also used a web analytics tool called Google Analytics™ to track specific usage of the PATH2Go Trip Planner and PATH2go Web Based Traveler Information applications.

Although the PATH2Go applications were officially launched on July 29, 2010, not all usage information was available immediately. The number of registered users and number of anonymous user sessions for the PATH2Go applications were tracked from the beginning, but additional server logs and Google Analytics tracking were not implemented until mid-August 2010. The server logs developed by PATH were primarily used to identify the total number of registered users and to assess the general usage of the PATH2Go Smart Phone Application.

The Google Analytics data provided the opportunity to analyze more detailed usage information for the two website applications and was collected from mid-August to mid-November 2010, when the evaluation period came to an end. Google Analytics provided data on the frequency of visits, looking at whether users were returning or new to the website, and looking at where the majority of web traffic was originating. This information supplements other evaluation activities in determining how frequently the website applications are used and by what audiences.

5.3.3 User Perceptions

The evaluation team worked closely with PATH project team regarding possible options for surveying registered users. Initially, the teams decided on e-mailing all registered users to request their participation in the survey. The evaluation team developed an initial e-mail and a set of reminder e-mails, which PATH sent to registered users on its behalf. PATH also generously offered to extend the 100 dollar monthly drawing incentive offered on their own user survey to registered users who participated in the evaluation team survey. The survey was launched on October 11, 2010, when the first e-mail was sent to registered users.

The evaluation team closely monitored the response rate following the initial e-mail, and follow-up e-mails were sent when the number of survey responses declined. A total of four reminder e-

mails were sent only to registered users who had not responded to the survey. As the survey response rate declined from the initial spike of the survey launch, the evaluation team and project team began discussing additional ways to attract registered users to the survey. On November 1, 2010, the PATH project team added a link to the survey on both the Trip Planner website and the Traveler Information website that was only available when registered users were logged into the website. Additionally, they also implemented a pop-up box on both websites that appeared when registered users navigated to the site. The survey was closed on November 15, 2010.

5.4 EVALUATION FINDINGS

5.4.1 Geofencing

The 5 mph threshold set by the PATH project team appeared to block the application for all smart phones when the GPS signal was available. However, the evaluation team observed several instances where the Windows Mobile phone was not able to obtain a GPS signal for significant portions of time. During this time, the application was open for use. Although this was primarily due to limitations in smart phone capabilities, this situation (as well as others where satellite connections are limited) does identify a disadvantage to designing geofencing functionality that relies heavily on smart phone GPS data to prevent distracted driving.

Additionally, the evaluation team observed that the geofencing design with a 5 mph threshold is more effective at preventing distracted driving on certain types of roadways versus others. The geofencing status is constantly being checked and updated within the smart phone application by the system server. On roadways where there is mostly uninterrupted, free-flow traffic, like interstates and major highways, the geofencing design is very effective at preventing users from accessing information on the application because driving speeds tend not to vary as much and rarely drop to less than 5 mph, which would open the application for use. However, on arterials and local roads where speeds are more variable—due to greater occurrences of red lights at intersections, congestion, or stop and go traffic—the smart phone application was constantly being blocked and unblocked as driving speeds fluctuated above and below 5 mph. Although driver distraction may be less dangerous at lower speeds or when a vehicle is stopped, an unblocked smart phone application is another temptation among many that could direct driver attention to somewhere other than the roadway. Although it was known that the geofencing design would not be able to block the smart phone application at speeds less than 5 mph, it is still important to note that the ability to access information on the application while operating a vehicle at any speed is distracting. Moreover, it is possible that users could begin to recognize the opportunity to access the application at speeds less than 5 mph or when stopped, which could cause an even greater level of distraction if users adjust driving behavior to gain access to the application. Although unlikely, a geofencing design must address all situations where users may attempt to access information while operating a vehicle in order to truly prevent distraction by a smart phone application.

The team also tested whether the geofencing design could distinguish between users driving to a transit station and users walking to a transit station. The geofencing design's ability to identify this scenario relied on GPS speed data from the user smart phone. When the user was traveling at or above 5 mph while en route to a transit stop/station, the application was blocked. Alternately, when the user was walking to a transit stop/station, the application was not blocked. However, the same concerns about distracted driving in regard to the limitations of the geofencing design in terms of the 5 mph threshold also applied to this test.

The geofencing design uses a time and a distance constraint to determine whether or not a user is waiting at a transit station/stop. The evaluation team observed 10 instances where the

geofencing design successfully distinguished between users waiting at a station/stop versus users driving past a station/stop and one instance where it did not. Another test was conducted to determine if the geofencing design could distinguish between users driving along a transit route versus users taking transit. Testers took a transit trip on Caltrain and confirmed that the geofencing design could successfully allow actual transit riders to access the application while taking transit. They also attempted to mimic a transit trip by waiting near a transit station/stop and then following a bus/train along the transit route while driving in a car. Generally, the time and distance constraints as well as the route matching and trip history requirements implemented into the geofencing design successfully prevented drivers from mimicking transit trips to gain access to the applications. In several other transit trips, the evaluation team did observe several instances where the smart phone application was blocked while truly riding transit. Although unrelated to distracted driving, implementing a geofencing design into the smart phone application that primarily provides transit information may detract from the user experience of actual transit riders.

5.4.2 Usage Statistics

In summary, the PATH2Go applications generally experienced steady growth in registered users throughout the evaluation period, although daily use of the PATH2Go Smart Phone Application and the PATH2Go website applications fluctuated throughout the evaluation period. The initial targeted marketing efforts of advertising the applications on the MTC 511 website, distributing a press release, and handing out flyers at transit stops/stations were effective in attracting registered users and increasing awareness of the website applications. The most significant increase in usage of the website applications came as the result of a Twitter post on a popular account followed by transit riders that use Caltrain. The website traffic generated by the Twitter post increased the total number of absolute unique visitors by 104 percent and the total number of visits by 66 percent in the span of 5 days.

Over the course of the evaluation period, which began with the launch on July 29, 2010, and ended on November 15, 2010, the PATH2Go applications attracted over 900 registered users, 67 percent of whom downloaded and used the smart phone application at least once and may have also used the website applications. Thirty-four percent of the smart phone application users downloaded the app and only opened it once without returning, leaving 66 percent that used it more than once. Thirty-three percent of users registered on the project website, but only used the website applications. By the end of the evaluation period, the PATH2Go website applications attracted a total of 916 absolute unique visitors that accounted for 1,664 total visits to the website and experienced an average of 1.82 visits per user.

The usage analysis suggests that newer, more progressive forms of marketing like using social media websites such as Twitter can be significantly more effective in increasing awareness of real-time traveler information like the PATH2Go applications. Although still effective, more traditional forms of marketing, like preparing a press release, do not seem to generate the same level of exposure without being covered by a major media source as quickly as a targeted social media effort. Although the fluctuating website usage was greatly increased using Twitter, the impact was short-lived as usage quickly returned to its rolling pattern of approximately 5 to 30 website visits per day only a few days after the Caltrain tweet. While social media may have a greater ability to attract a large number of visits to a website quickly, it does not seem to be any more effective than traditional forms of marketing in establishing consistent website usage.

5.4.3 User Perceptions

Registered users were asked to provide feedback on the applications beginning in October 11, 2010, through November 15, 2010. Based on the information gathered, the respondents were predominantly male, and most were in the 18 – 40 year old age group. Approximately one-half reported their primary mode of transportation was transit and 40 percent reported they used a personal automobile or carpool/van pool. When asked how they heard about the applications, most reported a web-based source (e.g., a web search, the MTC website, a link from another transportation site, or from an electronic message). A high proportion, 30 percent, reported they heard it from a friend or colleague, which further indicates the importance of informing the public with “word of mouth” methods, especially if it comes from trusted sources.

Recent usage of the applications (within 1 week of completing the survey) showed relatively low usage patterns, especially for the web-based applications. At least one-half of respondents reported never having used the Trip Planner or Traveler Information site and approximately one-fourth had not used either site in the week before completing the survey. Use of the Smart Phone application was slightly higher, with only approximately one-half of respondents reporting they had never used it or had not used it in the past week. One-half of the respondents reported they use the applications to plan their transit trips for regular trips (e.g., commuting to work or school).

For those who had used the smart phone application, 58 percent had downloaded it to an Android device and 42 percent to an iPhone. One-half of the users reported having received the “Warning: Application Disabled While Driving” message, although two-thirds of those who got the warning reported that it occurred relatively infrequently – less than 25 percent of the time. However, when it was received it was reported as annoying by 70 percent of users. This observation was borne out by respondent comments that focused on trying to use the application while riding on transit vehicles or as passengers in automobiles and “being blocked.” Annoyance levels were slightly higher for those with iPhones when compared to Android users.

When considering the attributes and value of all three applications, users were generally pleased with them, although there were areas where the applications could be improved, such as in information retrieval. For instance, approximately one-third reported the applications were not trouble free, that it was not easy to find the information they were looking for, and the information was not well presented. However, one-half of respondents reported the applications provided them with the information they were looking for and slightly more than half reported that the information on the applications is valuable. Almost 40 percent also reported the information is well organized.

There was also strong agreement that the ability to access multiple transit services and having reliable arrival and departure information was important. Finally, most respondents reported that having the transit information available to them made them more confident about using transit, although there was not overwhelming evidence that having this information would lead to their choosing an alternative mode to their usual transportation method.

5.5 CONCLUSIONS

Based on the results of the evaluation, a number of conclusions should be considered, including:

- **Consumer responses to the NT T/SP applications need to be monitored.**
Consumers responded positively to the NT-T/SP test, as witnessed by the number of

registered users and website visits, and by the extent to which registered users provided feedback (including infrequent users and those who wished to provide constructive suggestions on how to enhance the initial beta system.)

- **It is important to understand the technical and institutional issues associated with distributing multi-modal information to smart phone users.** The test demonstrated the ability to integrate transit, traffic, and parking information across multiple agencies in real time. The test highlighted the potential for distributing personalized information via the internet and smart phones, and to do so without causing driver distraction.
- **Further testing of geofencing as a method to prevent distracted driving needs to be conducted.** With few exceptions, the geofencing technique developed by PATH was effective at blocking the use of the smart phone application in cars, and, by extension, was able to minimize distracted driving. However, the technique was not foolproof, in part because it depends upon smart phones being able to access a GPS signal. Without this signal, the geofencing technique will be unable to calculate whether the user is moving faster than the 5 mph threshold. Users with a detailed knowledge of the design of the geofencing technique may be able to mimic a transit vehicle while travelling in a car, although this is considered a remote possibility. What is more likely is for a user to be blocked from using the smart phone application while riding transit, as the user may not have planned a trip in accordance with the requirements of the geofencing design. Under these circumstances the application will assume any such riders are actually in a car, and consequently block access to the application.
- **Further understanding of the development process and institutional issues associated with implementing a server-based geofencing method versus a client-based method on mobile devices should be explored.** The NT-T/SP test adopted a design that implemented the geofencing technique that used a server-based method rather than a client-based approach on the smart phone devices. With any application design for smart phones, developers can decide whether to host the code and source information for certain application functionality on the server-side of the application or the client-side of the application. In other words, the decision-making can either take place on servers hosted by the developers or on the smart phone itself. The geofencing design was integrated into the PATH2Go Smart Phone Application using server-side logic, which allowed for a thin client-side design. Implementing a server-side geofencing design prevented the design team from having to address differences in the operating systems of Windows Mobile, iPhone, and Android smart phones that could have an effect on geofencing performance. Client-based functionality would have required wrapping up all of the code and sources into the application download, which would have been demanding on the smart phone in terms of application size, processor speed, and battery life, depending on its complexity.
- **The NT-T/SP application usage rates should be measured.** Overall, the PATH2Go tools experienced steady growth in the number of registered users – a possible indication of user acceptance. However it was clear that multiple approaches are necessary to raise awareness of the tools, rather than relying on a single approach. Equally, it was clear that repeated measures are necessary to retain momentum. It is likely that different techniques will have different responses from different user types.
- **Continue to analyze the perceived accuracy and usefulness of mode shift alerts and en-route transit information.** Well over half of respondents “strongly agreed” or “agreed” that the information was valuable in contrast with only 14 percent who “strongly disagreed” or “disagreed.” In fact, when using the applications, respondents felt that having information for multiple transit services was very useful. Almost two-thirds

“strongly agreed” or “agreed” that supplying information for multiple services (e.g., Caltrain, BART, SF Muni) was very helpful. This was especially true for those trips that were non-routine and may have involved multiple services or services they normally did not use. Additionally, there was relatively strong agreement from respondents that the real-time departure and arrival information supplied on the application was valid. While one-fourth reported they did not have enough experience to rate this, 40 percent reported they “strongly agreed” or “agreed” that the schedule information was reliable. Only 12 percent “strongly disagreed” or “disagreed” that the information was reliable.

6 DEPLOYMENT OF REAL-TIME INTERSECTION DELAY MONITORING

6.1 OVERVIEW

As part of the SafeTrip-21 initiative, the California Department of Transportation (Caltrans) tested the use of a traffic volume and signal timing information monitoring system. This system is referred to as the real time intersection delay (RTID) system. The test was proposed by the vendor of the system, TrafInfo Communications Inc., and tested on the Caltrans test bed in the Bay Area.

Caltrans uses two types of traffic signal controller.⁵ The most common is the 170 controller, and the other is the 2070 controller. The latter has more advanced functionality and is generally used to replace the 170 controller when new intersections are installed or existing controllers are damaged or upgraded. Statewide, 10-15 percent of the approximately 4,800 signalized intersections under Caltrans jurisdiction are controlled by 2070 controllers, mostly in District 3 (Sacramento region) and District 7 (Los Angeles region). Caltrans District 4, which covers the San Francisco Bay Area, currently has two signalized intersections at which 2070 controllers are used.

For a variety of reasons, the timing of traffic signals may become sub-optimal over time. This can occur because of changing patterns of traffic demand, changes in bus or pedestrian activity, changes in geometric layout, etc. When deterioration in performance occurs, signal retiming may be necessary. To keep pace with changing travel patterns, traffic signal timing should be reviewed and updated at a minimum of every 3 years, and even sooner if there is growth in the number of vehicles using the intersection or changes in traffic patterns.⁶ In order to retime traffic signals, a site visit is needed during which traffic patterns are observed during morning and afternoon peak periods. This information is collected manually and, when input into a traffic optimization tool, is used to estimate delay.⁷ From this data, improved timing plans can be developed and subsequently uploaded to the traffic signal controller.

Ideally, Caltrans would prefer to conduct a yearly survey of traffic signal timing at each intersection. Due to constrained resources, Caltrans is unable to review traffic signal timing issues as frequently as it would prefer, and often relies on reports from the public to identify traffic signal intersections with timing issues. The benefit the RTID system offers is the potential to reduce the manual effort required to undertake signal retiming, to focus resources on critical intersections (such as intersections that serve as master controllers for groups of intersections with coordinated signals), and to validate that any retiming activities lead to a subsequent reduction in delay. Consequently, the RTID system will result in operational improvements at traffic signal intersections, although the scale of these improvements will depend on the specific circumstances at each intersection or group of intersections.

⁵ A third type of controller not used by Caltrans is the NEMA controller

⁶ National Transportation Operations Coalition, *National Traffic Signal Report Card: Technical Report 2007*. Available at: http://www.ite.org/reportcard/technical_report%20final.pdf

⁷ Federal Highway Administration, *Traffic Analysis Toolbox Volume II: Decision Support Methodology for Selecting Traffic Analysis Tools*, "Appendix E.4 Traffic Optimization Tools," FHWA-HRT-04-039 (Washington, DC: June 2004). Available at: http://ops.fhwa.dot.gov/trafficanalysisistools/tat_vol2/sectapp_e.htm#top

6.1.1 How RTID Works

The RTID system comprises three components:

- A device known as TrafMate 6, which interfaces with the 2070 controller's RS-232 port;
- A wireless communication antenna connected to the TrafMate 6 device; and
- A remote server, hosted by the product vendor, where all information collection by the RTID system is stored and analyzed.

Typically, the information, which is collected automatically and continuously by the TrafMate 6 device, can only be gathered manually by Caltrans. This is done by traffic census staff visiting the intersection and observing traffic flows for each lane on each approach, during each phase and cycle. Traffic census staff typically collects this information during peak periods only. The information collected is subsequently processed by an office-based analyst using traffic optimization software.

6.2 EVALUATION OBJECTIVES

The purpose of the evaluation is both to learn how such a system can enable signal phase and timing information—together with lane-by-lane traffic count data that is to be collected in real time and processed from remote locations via the Internet—and to determine how that information can be used effectively by State Department of Transportation (DOT) staff to optimize the performance of signalized intersections.

The objective of the evaluation was to gather lessons learned from the test deployment of the RTID system in the San Francisco Bay Area. These lessons would serve Caltrans and other similar jurisdictions by providing guidance on successfully implementing RTID systems. In particular, U.S. DOT and Caltrans were interested in learning about the factors that influence which locations are best suited for such systems and, if widely deployed, the changes in existing management policies that may be required for such systems to enhance traffic operations within existing resources. The vendor originally proposed to install the RTID system at a series of signalized intersections along an arterial and provide real-time arterial travel time. The arterial travel time would be estimated using two components: the running time and the control delay.

- Running time is estimated based upon the free flow travel time and the traffic volumes. Free flow travel time is the distance between intersections divided by the speed limit (or prevailing speed). Traffic volume is collected by the RTID system.
- The control delay is estimated by the RTID system in real time (i.e., on a cycle-cycle basis) by collecting three major variables—signal timing, cycle length, and volumes—and then computing the delay using these variables and algorithms similar to those described in the Highway Capacity Manual.⁸

The vendor's concept was that this real-time arterial travel time information would be available to both public and private traveler information service providers. In practice the field test was unable to provide real-time travel time information because the RTID system was only deployed at a single intersection. Consequently the proposal was refined to focus on signal retiming.

⁸ Transportation Research Board, *Highway Capacity Manual 2000*. Available for purchase at: <http://www.trb.org/Main/Public/Blurbs/152169.aspx>

Caltrans did not intend to use the information from the RTID system test to update existing timing plans. Instead, it was interested in learning more about the potential efficacy of the system and its potential for improved targeting of staff resources for signal timing reviews. In general, the agency wanted to understand any technical issues associated with connecting the RTID system to an existing traffic signal controller and to gain practical experience with installation. The Caltrans test objectives were as follows:

1. Test the RTID system in conjunction with the 2070 controller as Caltrans works toward eventual replacement of the 170 controller;
2. Ensure the RTID system does not interfere with the normal operation of the 2070 controller; and
3. Understand the installation and operational costs of the RTID system.

In addition to the test objectives, Caltrans required that the TrafMate 6 device could be installed in 30 minutes or less.

6.3 EVALUATION ACTIVITIES

Lessons learned were analyzed and synthesized by conducting interviews with Caltrans headquarters and district staff and the vendor. Some of the headquarters staff were directly involved in conducting the test, and together they provided a statewide traffic operations perspective. Participation in the test at the district level was mostly limited to maintenance crews providing access to traffic signal controllers. However, a local perspective of the test was provided by the District Traffic Engineer for Caltrans District 4. Caltrans District 4 has jurisdictional responsibility for Caltrans' right of way in the Bay Area. An interview was also conducted with a representative from the California Partners for Advanced Transit and Highways (PATH). PATH's role was predominantly during Phase I of the test, when the RTID system was tested at PATH's research facility. PATH's role during Phase II of the test, when the RTID system was installed at a signalized intersection in the Bay Area, was to coordinate between staff at Caltrans headquarters and Caltrans District 4. The Evaluation Team aimed to gain an understanding of:

- The implementation of a device that communicates signal timing and traffic data without interrupting the signal controller;
- The technical and institutional issues associated with gathering real-time volume and signal timing information at traffic signals;
- The usefulness of the speed and delay estimates; and
- The ease of downloading the information.

6.3.1 *The RTID Test*

Caltrans tested the effectiveness of the RTID system to augment its signal retiming efforts. The test was conducted in two phases. **Phase I** was a bench test to demonstrate that the RTID system could be connected to a 2070 controller without interfering with the normal operation of the controller. A 2070 controller was selected for the test because use of this type of controller by the Caltrans Districts will become increasingly prevalent in future years, as the 170 type controllers are eventually phased out. The bench test was conducted on August 13, 2009, and

approval to commence planning for the second phase of the test was subsequently granted by Caltrans Headquarters on September 4, 2009.

Phase II of the test was to install the RTID system at a Caltrans District 4 signalized intersection that is controlled by a 2070 controller (El Camino Real at Dumbarton Road). Approval for the vendor to install the RTID system was granted by Caltrans District 4 on October 1, 2009. The RTID system was operational from October 22, 2009, through November 2, 2009, after which it was turned off but left in place until December 28, 2009.⁹ During the period when the system was operational, traffic volume and signal timing information was collected from the 2070 controller by the RTID system and transmitted to a remote server hosted by the product vendor. The vendor reported that the information was sent to the server at the end of each cycle, approximately once every 90 seconds. The server was then able to plot that information immediately. Delay calculations were performed on the remote server. The vendor provided access to the remote server via the internet for institutional partners and the evaluation team.

6.4 EVALUATION FINDINGS

Prior to installation of the RTID system at the El Camino Real/Dumbarton Road intersection, Caltrans required the vendor to demonstrate that the TrafMate 6 device could communicate with the 2070 controller without interrupting its normal function. The Trafmate 6 device must use the Caltrans prescribed AB 3418E communications protocol¹⁰ to communicate continuously with the 2070 controller so as to obtain information as to which signal phase is active at any given moment, which detection input is active, and the count information on the system detectors. The Trafmate 6 device communicates with the 2070 controller twice per second in order to determine the signal timing intervals of each phase, the signal cycle length, as well as additional information related to the presence of vehicles within the detection zone.¹¹

This **Phase I** test was required to last for 7 days in continuous operation. Originally, the vendor intended to demonstrate this at PATH's "Smart Intersection," located at the Richmond Field Station. Due to scheduling and logistics conflicts beyond the control of Caltrans and the vendor, this approach was not possible. Consequently Caltrans and the vendor agreed to undertake the bench test using a portable 2070 controller and a vehicle detection simulator. The simulator generates inputs to the controller that represent vehicles passing over the loop detectors. The 2070 controller in turn changes the signal faces (green, yellow, red) to control traffic flow. The problem with the bench test was that the simulator required manual toggling of some buttons to simulate a vehicle on an intersection approach. In other words, the inputs generated by the simulator to the 2070 controller required continuous human inputs to toggle the buttons. Without these human inputs the simulator would not generate any vehicle inputs, and hence would not generate communications between the 2070 controller and the TrafMate 6 device.

The bench test was functionally identical to the test that was previously planned at the Smart Intersection, although without a controller cabinet it was no longer feasible to demonstrate the

⁹ The RTID system was turned off after a discussion between the vendor and Caltrans, during which it was agreed that sufficient data (12 continuous days) had been collected to enable the vendor to analyze the data and finalize the webpage interface. The vendor's plan was to get back to the intersection and do some more testing, with refinements to the firmware if necessary. However this was determined to be unnecessary.

¹⁰ California Department of Transportation, "CTNET Field Protocol Specification AB3418 Extended (AB3418E)," http://www.dot.ca.gov/hq/traffops/electsys/reports/AB3418E_FieldProtocolSpec_2003.pdf The AB 3418E communications protocol is an "extended" version of the original AB3418 communications protocol for traffic signals in California (see <http://www.dot.ca.gov/hq/traffops/electsys/reports/ab3418sp.pdf>)

¹¹ See the vendor's revised SafeTrip-21 technical proposal, March 27, 2009.

30-minute installation requirement. With respect to the continuous 7-day operation requirement, it was not feasible to toggle buttons on the simulator manually for this length of time.

Consequently, Caltrans saw no reason to continue the bench testing for 7 days. Caltrans primarily wanted to ensure the interface between the 2070 and the TrafMate 6 device did not affect signal operation. Given that the TrafMate 6 device had been previously deployed elsewhere in a real-world environment (Massachusetts, for example), Caltrans was not unduly concerned about the 7-day requirement.

Under the supervision of a Caltrans employee over a period of several hours, and briefly observed by a representative of the evaluation team, the TrafMate 6 device demonstrated it could communicate with the 2070 controller without disrupting the controller's normal function. Despite the bench test conditions, the vendor was able to demonstrate the ease of installation of the TrafMate 6 device and the wireless communications antenna. The vendor claims that installation of the TrafMate 6 device takes 15 – 30 minutes. The normal connections are:

- TrafMate 6 connects to 2070 controller's RS-232 port;
- The antenna connects to a mini-UHF connector at the rear of the TrafMate 6 device; and
- TrafMate 6 has a DC power jack to plug in a standard AC adapter that can output 12V DC (1.5 Amps).

For the **Phase II** test, a small hole was drilled on the top of the controller cabinet for the antenna cable. After the cable was inserted into the hole, the antenna was stuck to the top of the cabinet (the antenna comes with a peel-off glue).

During the site inspection for the Phase II test, the vendor requested (and Caltrans agreed) that the loop detector cards that were installed in the controller cabinet be changed for the test. These cards interface between the inductive loops and the 2070 controller. While the installed detector cards were not defective, they did not provide the necessary functionality for the test because they did not count vehicles. Instead, they simply indicated the presence of a vehicle on the inductive loop. The RTID system cannot estimate delays reliably without vehicle counts covering all lanes. To address this issue, the vendor considered two options:

- **Reno Detectors:** These cards are essentially a four-channel replacement for a standard two-channel loop detector card. The additional two channels are used to mimic a traffic count loop. If the outputs of these two channels are connected to a 2070 controller, the controller considers it is receiving signal from a "system" loop which is typically used for traffic counting purposes. The advantage of this option is that the TrafMate 6 device only needs to communicate with the 2070 controller to get both the signal timing as well as the traffic count information. The disadvantage is that some additional wiring is needed within the controller cabinet to connect the two "extra" channels on the Reno detector to the 2070 controller.
- **Canoga Detectors:** These cards have a front serial port which allows extraction of traffic count information. The advantage of this is that there is no need to do any additional wiring between the detector and the controller. The disadvantage is that the TrafMate 6 device must communicate with the 2070 controller as well as each of the Canoga detectors.

While the Reno option was a potentially simple option, it placed most of the burden of field deployment on Caltrans District 4. This was not the case with the Canoga option, which placed

most of the burden of field deployment on the vendor, requiring minimal support from Caltrans District 4. Consequently Caltrans and the vendor agreed to replace the installed detector cards with the Canoga cards. It is noted that the possible need to replace detector cards depends on the specific configuration at the intersection, and may not be necessary in all situations.

The replacement Canoga cards took about 2 hours to install. This is because each channel on the four-channel Canoga card needed to be calibrated so that the vehicle counts were accurate. In total, five Canoga cards, provided by the vendor, were used.¹²

The vendor indicated that in the version of the TrafMate 6 device that was tested, the only way to know if there was a problem in the communication between the loop detector and the TrafMate 6 device was missing data. A more recent version of the device, however, can send out an email if any problems occur in communication either with the loop detector or the controller.

6.4.1 Technical Issues

No technical issues were encountered with communications between the TrafMate 6 device and the 2070 controller at the El Camino Real/Dumbarton Road intersection, or with the transfer of data to the remote server. This remained the case for the 12-day operational period, during which time there were no reports of abnormal traffic operations at the intersection. In summary, the RTID system depends on:

- Correctly working inductive loops in all approach lanes;
- Loop detector cards with the ability to count vehicles, not simply detect presence, for all approach lanes.

6.4.2 Institutional Issues

The only institutional issue encountered related to jurisdiction of the El Camino Real/ Dumbarton Road intersection, which falls under Caltrans District 4. Consequently, access to the controller cabinet, installation of the TrafMate 6 device, and swapping out the loop detector cards could not be accomplished without the involvement and approval of a responsible Caltrans District 4 employee. This is primarily to ensure the safety of the public by preventing any disruption to the safe operation of the intersection and to protect State property from theft or damage while the controller cabinet door is open. No problems were encountered in this regard. The role of formal partner was performed by Caltrans Headquarters – Division of Research and Innovation (DRI), which does not have jurisdiction over any district’s traffic signal controllers. A representative from PATH facilitated the coordination between the vendor and Caltrans District 4 on behalf of DRI. Being locally based in the Bay Area, PATH is very accustomed to working with District 4.¹³

6.4.3 Ease of Downloading

For the RTID test, the intent was to make information regarding real-time delay conditions at the El Camino Real/Dumbarton Road intersection available to any Caltrans employee with an interest in the test. This information was provided on the vendor’s website in the form of graphical

¹² Each Canoga card has an RS-232 interface on its front panel via a DB-9 connector. To connect the TrafMate 6 device to each of the five Canoga cards, the vendor built a simple serial splitter board, so that one serial port on the TrafMate 6 device could talk to each of the serial ports on each of the Canoga cards. The TrafMate 6 device also has a DB-9 connector that provides the RS-232 interface.

¹³ PATH received no funding for the test and its participation was voluntary.

representations of delay estimates.¹⁴ While the website did not require a secure login with an account and password, it was not on a page that could be directly accessed from the vendor's home page. Other than by chance or intuitive searching, the only way to access the website was for the vendor to provide a link to the specific webpage, which was done on request.

Ease of downloading is a somewhat subjective concept. In practice it was very easy for users with internet access to visit the project website after the vendor had provided the website's address. The information provided (delay estimates prepared by the vendor) could be viewed and searched, and the charts could be printed using a menu function. In addition, the actual data collected as well as the delay estimates can be downloaded in a tabular form. However, since it was not Caltrans' intent to use this information to develop and upload new timing plans, Caltrans made no request for the data collected from the intersection on which the vendor's estimates are based. Consequently it was not possible to assess the ease of downloading that data, other than to note that it was clearly available to the vendor.

6.4.4 Usefulness

The vendor's delay estimates are understood to be based on normal methods of delay estimation using procedures in the Highway Capacity Manual. Information is presented graphically, with plots of average delay against time of day for a 24-hour period for a given lane.

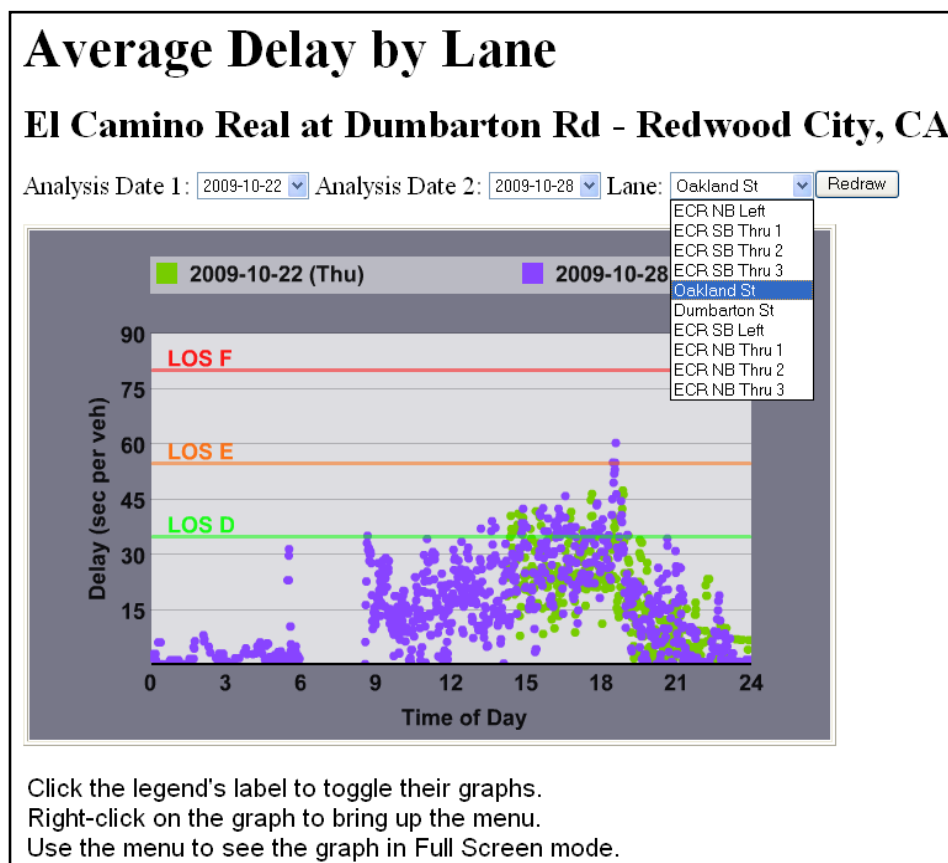


Figure courtesy TrafInfo Communications Inc

Figure 5. Sample Screenshot of Average Delay by Lane

¹⁴ TrafInfo Communications website, "Average Delay by lane, El Camino Real at Dumbarton Rd - Redwood City, CA," <http://www.trafinfo.com/delay.php?intid=5>

The user can select two dates, and the plot will compare the results for the two dates. In this way, it is possible to compare operations on different days. In the event that a new timing plan is uploaded to the 2070 controller, this feature can be used to make a before and after comparison.

Caltrans staff did not validate the delay estimates through any independent review by their own traffic operations or planning groups. This was primarily because there was no intent (as part of the test) to use the estimates to develop or upload new timing plans. As mentioned previously, the El Camino Real/Dumbarton Road intersection falls under the jurisdiction of Caltrans District 4, which was not an active partner in the test. Consequently, no definitive conclusions can be drawn regarding the usefulness of the information on the vendor's website.

6.5 CONCLUSIONS

The test met the vendor's objective of demonstrating that the RTID system could collect the three major variables required for estimating delay at signalized intersections—signal timing, cycle length, and volumes—on a cycle-cycle basis, and then use this information to compute the delay and make it available over the Internet for development and testing of signal retiming plans.

The RTID system met the Caltrans objective of being tested with a 2070 controller and demonstrating both in a simulation test and in the field that it did not interfere with the normal operation of the 2070 controller. The installation worked continuously through a 12-day period without disruption to traffic flow or any known performance failure. The RTID system also met Caltrans' requirement to be installed within 30 minutes.

With regard to the evaluation objectives, the RTID system demonstrated that it is possible to collect real-time volume and signal timing information at traffic signals, making such information available in a way that offers the potential to review and, if necessary, update timing plans to reflect current conditions. This addresses an issue that has been repeatedly raised within the transportation community: that inaction on signal timing and maintenance (including reliability of loop detectors) leads to avoidable delays, increased fuel consumption, greater safety concerns, and more pollution. The RTID system, however, requires working detectors on all lanes and all approaches, without which the system is unable to reliably estimate delays.

Within the constraints of the test, the information generated by the RTID system was useful and easy to access. While Caltrans never intended to use this information to review and update timing plans, senior traffic operations managers indicated their broad support for further exploring the potential of systems like RTID.

The benefits of the RTID system cannot be determined quantitatively, as no actions were taken as a result of the information generated by the system. However, it is possible to discuss the potential benefits in a qualitative manner. These benefits will most likely occur in three ways:

- More frequent review of traffic signal timing;
- Targeted use of resources; and
- Reduced delay to travelers.

These benefits are discussed below.

6.5.1 *More Frequent Review of Traffic Signal Timing*

As mentioned previously, to keep pace with changing travel patterns, traffic signal timing should be reviewed and updated at a minimum of every 3 years and even sooner if there is growth in the

number of vehicles using the intersection or changes in traffic patterns. In order to retime traffic signals, a site visit during which traffic patterns are observed during morning and afternoon peak periods is needed. Currently, this information is collected manually and then used to estimate delay by inputting these data into a traffic optimization tool. Once installed, the RTID system will automate this process; the system can even be left in place indefinitely if so desired. If improved timing plans are developed, they can be subsequently uploaded to the traffic signal controller using the RTID system versus being uploaded manually, as is the current practice. The RTID system can then be used to compare the effect of the new timing plan against the previous plan.

The vendor indicated that in the version of the TrafMate 6 device that was tested, the only way to know if there was a problem in the communication between the loop detector and the TrafMate 6 device was missing data. A more recent version of the device can send out an email if any problems occur in communication either with the loop detector or the controller.

6.5.2 Targeted Use of Resources

In addition to the potential benefit (described above) of using the RTID system to review traffic signal timing more frequently, the system also offers the potential to raise productivity and efficiency by better targeting resources at intersections where problems are known (or are more likely) to exist. Using the RTID system's feature to compare delay on different days, it is possible to validate remotely that any signal retiming activities have led to a subsequent reduction in delay.

6.5.3 Reduced Delay to Travelers

By uploading new timing plans, intersection delays may be reduced. NTOC has noted that transportation professionals have long recognized the value of effective traffic signal timing and maintenance to meet changing travel patterns and user characteristics. In addition to mitigating congestion and reducing delay, there is the potential for several positive secondary impacts, including reduced accidents, lower fuel consumption, and fewer air pollutants. However, as the scale of these improvements will depend on the specific circumstances at each intersection or group of intersections, it is not possible to estimate the magnitude of any such improvements.

7 PROVIDING MULTI-MODAL TRAVEL INFORMATION TO AIRPORT USERS

7.1 OVERVIEW

The Airport Ground Transport Travel Information project, or the BWI Ground Access Information System, was developed by the I-95 Corridor Coalition in partnership with the University of Maryland and INRIX, a travel information services provider. The primary purpose of the system is to provide information to travelers about ground transportation options to and from Baltimore-Washington International (BWI) Thurgood Marshall Airport in Baltimore, Maryland. The system provides information about different travel options including driving, taxi, and vanpool, as well as various public transit options including Amtrak, commuter rail, light rail, and buses. Additionally, the system provides estimated cost and travel time information for some of the ground transportation options, real-time traffic conditions information for major roadways surrounding the airport (via a color-coded map), and updates about construction or transit delays along the planned route. The system was designed to help make airport travelers more aware of all modal options available to/from BWI and to give travelers access to the information pre-trip, on-the-go, and inside the airport. The information system is available via a website and mobile website, as well as at a kiosk inside the airport.

7.2 EVALUATION OBJECTIVES

Taking U.S. DOT goals for the SafeTrip-21 Initiative into account along with the project team's more specific goals for the project, the team focused on the following evaluation objectives:

- Understand the institutional issues associated with making airport ground transport information available to the public.
- Understand the needs of customers with respect to airport ground transport travel information.
- Determine whether airport ground transport travel information improves awareness of travel options out of the airport.
- Analyze the perceived accuracy and usefulness of the three interfaces of the airport ground transport travel information.

For each evaluation objective, the team identified corresponding hypotheses, measures of effectiveness, and evaluation activities. The evaluation approach activities included: analyzing website usage statistics; administering a web-based survey of website users; and conducting interviews with the deployment partners to document institutional issues and lessons learned from the deployment experience.

7.3 EVALUATION ACTIVITIES

The BWI Ground Access Information System website was the first of the three BWI SafeTrip-21 applications to be developed and launched by the project team. Website visitors can enter their starting location for travel to the airport or end location for travel from the airport and they are presented with travel options available for their trip. The website was launched on October 14, 2009.

The next BWI SafeTrip-21 application to be launched by the project team was the BWI Ground Access Information System mobile website,¹⁵ which was developed to serve as an on-the-go trip planner for travelers who are looking for information about ground transportation options to and from BWI Airport using a mobile device. As mentioned previously, the mobile website accesses information from the BWI Ground Access Information System just as the website does, but presents it in a slightly different manner.

It is important to note that the mobile website is not an application that can be downloaded to a mobile device but rather a mobile-supported website accessible by browser. Because the application is simply a mobile website, it can be accessed by any mobile device that is browser-supported regardless of make, model, or data connection speed. Additionally, enhanced functionality is available on mobile devices that are GPS-supported. Instead of entering an origin or destination, users can select *My Location* on the *Enter an Address* tab and the system will automatically enter their approximate location using the mobile device's GPS capabilities. The mobile website was launched in March 2010 but was not widely publicized and therefore never saw many users.

The kiosk had the longest development period of the three applications for a number of reasons. It was initially launched and installed at BWI Airport on April 1, 2010. It was placed on the lower level of Concourse C across from baggage claim 13-14. A few months after installation, however, the kiosk was removed from BWI Airport for a number of reasons including:

- Location –The kiosk needed to be relocated to a location where more foot traffic takes place.
- Hardware – Airport staff felt that it was important that the kiosk be secured to eliminate any risk of it tipping over. Staff also desired to have the electrical plug secured to the wall such that it could not be unplugged.
- Software – Developmental changes were needed to prevent users from using the kiosk for reasons other than intended (e.g., browsing the Internet).
- Ownership – There was no agreement in place regarding which party owned the kiosk and which was responsible for maintaining the kiosk.
- Design – BWI Airport staff requested that the BWI Ground Access Information System be expanded to provide information about Maryland Transit Administration (MTA) local buses that serve Metro Subway and Light Rail stops in the Baltimore region.

Although the evaluation team planned to analyze usage data collected for the website, mobile website, and kiosk applications, usage analysis focused solely on the general trip-planning website as this is the only application that was fully deployed within the timeframe of the evaluation. Similarly, the web-based survey of users focused only on users of the general trip-planning website.

Over the course of the 8-month evaluation period beginning with the website launch in October 2009, the website experienced approximately 21,000 unique visitors. The survey was available to website visitors for a 3-month period of time spanning from December 10, 2009 to March 8, 2010. During this time the evaluation team obtained 85 completed surveys and 47 partially completed surveys, for a total of 132 surveys. It should be noted that a total of 342 surveys would be needed to capture a statistically valid sample size of users. The lack of a statistically

¹⁵ BWI Ground Access Information System mobile website: <http://69.33.199.95/safetripmobile/MobileHome.aspx>.

valid sample size was considered throughout the analyses, interpretations, and conclusions presented here.

7.4 EVALUATION FINDINGS

Based on the survey findings, much can be learned about designing future airport traveler information systems:

- **Targeted marketing is critical and social media can serve as a useful marketing and outreach tool.** It appears that the additional targeted marketing efforts including advertisements on the BWI Airport website home page were effective in continuing growth in the website user base and number of visits to the website. The initial launch was effective in growing the website user base and in establishing initial airport traveler exposure and the additional targeted marketing efforts including advertisements on the BWI Airport website home page were effective in continuing growth in the website user base and number of visits to the website. Interestingly, while there were several factors that affected website usage simultaneously, it appears that using Twitter may have been one of the more effective marketing tools in increasing awareness of the website.
- **Usage of an airport traveler information system can be driven in large part by weather events.** From the usage data it was clear that severe weather events drove up website usage, indicating that travelers looked to the website for alternate transportation options (or possibly to get a sense for current traffic conditions) at times when driving was not necessarily a desirable option for getting to/from the airport.
- **When it comes to planning air travel, travelers seem to expect more choices in planning their trip.** Although the large majority of respondents agreed that the website provided them with the information that they were looking for, that the website was well organized, that it was easy for them to find what they were looking for on the website, and that the website has improved their impression of BWI airport, many respondents reported that they encountered problems or frustrations while using the website. Fortunately many of these individuals took the opportunity to offer suggestions for improvement. Suggestions included allowing the user to input their flight departure or arrival time (and have the system automatically plan based on that); providing the user the option to input their desired arrival time (rather than only having the option of inputting the desired departure time); providing enhanced information (e.g., allow for more origins/destinations, include more public transit options, and include specific directions to access buses); providing the opportunity to save a trip for later reference; providing the opportunity for the user to select one option once presented with itinerary options to facilitate printing the itinerary of choice; and providing the option to reverse the trip to plan a return trip immediately after planning an outbound trip.
- **The survey results seem to indicate that the website has, in fact, improved air travelers' perceptions of BWI airport.** The large majority of respondents agreed that the information provided on the website was valuable information to have prior to traveling to/from BWI airport and that other major airports across the country should provide this type of ground transportation information. About half of respondents agreed that the information made them aware of a travel option that could make their trip to/from BWI less stressful, that the information made them aware of a travel option that could save them time getting to/from BWI airport, and that having this information has increased their satisfaction with travel to/from BWI airport.

- **Many users of an airport traveler information system will be infrequent users.** The vast majority of survey respondents indicated that they were likely to visit the website again or to recommend the website to someone they know, but very few felt that they would be very likely to start using the website on a regular basis. This is not surprising given that many of the respondents indicated that they fly into or out of BWI less than once a year and would therefore not need this type of information very often. This is an important user characteristic to take into account when designing the site. The majority of website users will not return to the site very often, making it all the more critical that the user interface be intuitive.
- **The survey results seem to indicate that the website has, in fact, increased awareness of alternate travel options.** Nearly half of respondents felt that they were very likely to use a travel option that they learned about from the website. Approximately one-third of respondents indicated that the website informed them of a new travel option for getting to or from BWI airport or that it informed them of a better travel option (as compared to the modes of which they were previously aware). For those who learned of a new travel option, however, not all felt that the travel options they learned about were better than the modes of which they were previously aware. Of those respondents who had used the website previously, nearly half reported that they had tried a new option after a previous website visit.

From an institutional perspective, much can be learned from this pioneering effort to deploy a multi-modal traveler information system that includes deploying a kiosk in an airport environment. When deploying equipment in an environment like an airport, there can be challenges not encountered when deploying ITS technologies in other environments. For example, the stakeholders who need to be involved to deploy a piece of technology in an airport can be quite diverse. Not all players may be obvious at first and all are not likely to have a background or interest in transportation. As a result it is important to work with the airport staff early on to identify all potential stakeholders and to have a formal written agreement or memorandum of understanding between all involved parties, including those who will maintain the unit. Involving all stakeholders early allows them to voice opinions up front for inclusion in the system requirements.

Another challenge with an airport environment is that it may not be possible to identify a location that can be monitored by a staff person. In the case of this project, the kiosk was not able to be regularly monitored. As a result, the system designers found that it was important to plan for any possible problems. For example, it is important to consider the need to periodically replace paper and to prevent users from bypassing the planned information system to access the Internet directly. Considering ways in which a system might fail and how the system will respond to those failures can result in a more robust system.

A final key institutional lesson is to look for opportunities to make use of any synthesized data already available from another agency or organization. This is especially important when pulling together diverse data sets from multiple organizations, as is the case with a multi-modal traveler information system. As more and more agencies and organizations move toward open source data, there will be increasing opportunities for this type of cost savings in the future.

8 DISPLAYING TRAVEL TIMES IN PUBLIC AREAS

8.1 OVERVIEW

The Public Traffic Map Displays project includes two applications, both of which involve providing the public with traveler information via a screen in a public place. The first application is provided at two Virginia Welcome Centers while the second is provided at Tysons Corner Center (TCC), one of the largest shopping centers in the country.

The screens inside the Welcome Centers provide long-distance travel information for drivers looking to get a glimpse of the traffic conditions ahead as they travel along Interstate 95 (I-95). One screen is located in Fredericksburg, Virginia (approximately 60 miles south of Washington, DC) and provides information for I-95 southbound into Georgia, while the other screen is located in Skippers, Virginia (just north of the North Carolina/Virginia border) and provides information for I-95 northbound into Pennsylvania and New York. The content for these screens was developed by the I-95 Corridor Coalition in partnership with the United States Department of Transportation, the University of Maryland, INRIX (a traffic information services provider), the Virginia Department of Transportation, and the Virginia Tourism Corporation (VTC). Figure 6 below shows the screen available at the Fredericksburg Welcome Center. The primary purpose of the screens is to provide travelers stopping at the two Welcome Centers with access to real-time information about traffic conditions and travel times for their trip ahead along major roadways on the I-95 corridor. The screen at both locations provides two major tools that use real-time travel time data to inform users about current roadway conditions. The first of these tools provides users with an estimate of the current travel time based on real-time conditions from the Welcome Center to various destinations along the I-95 corridor, which comprises the Travel Times content. The second tool, which uses Google® Map API, presents traffic congestion via a color-coded map, or the Traffic Conditions Map content. On this map, each segment of each interstate is color-coded according to whether the traffic on that segment is free flowing (green), is experiencing moderate congestion (yellow), is experiencing heavy congestion (red), or is stop and go (brown), with a separate color (black) used if that segment of roadway is closed.



Figure 6. Fredericksburg Welcome Center Screen.

The Tysons Corner Center application includes five large flat-panel display screens positioned at various locations throughout the mall. Although similar in concept, this project is quite different

than the effort put forth at the two Virginia Welcome Centers. The screens at TCC are the result of a coordinated effort by local, State, and national stakeholders to integrate existing traveler information resources into one system. The screens originated as a joint initiative between VDOT, the Virginia Department of Rail and Public Transportation (DRPT), and other partners in the Northern Virginia region in an effort to educate the public about major construction projects (termed “Mega Projects”) taking place in the region, and to educate the public about alternate transportation options. As a number of these projects were taking place in the Tysons Corner area, the partners selected Tysons Corner Center (TCC) as the location for the screens, given that it is a major destination for travelers in the surrounding area. VDOT took the responsibility for leading the effort to coordinate the development and installation of “traveler information screens” at TCC. The project team was later approached by the I-95 Corridor Coalition with an opportunity to incorporate real-time travel time data into the screens and become part of the I-95 test bed. One of the traveler information screen locations inside the shopping center is shown in Figure 7 below.



Figure 7. Traveler Information Screens at Tysons Corner Center.

There are several significant differences between the content developed for the traveler information screens at TCC and the content developed for the screens at the Virginia Welcome Centers. Because the TCC screens were developed to prepare for the potential impacts of major construction in the surrounding area, the content is centered on local travel, whereas the information provided at the welcome centers is directed at long distance travelers. Compared to the welcome centers screens, the screens at TCC provide a greater amount and variety of traffic and transportation information. The traveler information screens at TCC provide:

- Real-time freeway conditions via a color-coded map and corresponding estimated freeway travel times to selected locations in Metro DC;
- Traffic camera views covering roadways in the immediate vicinity of TCC;
- Transit map, bus route schedules, and other public transportation information for the surrounding area;
- Information about traffic incidents and construction activities on roadways in the immediate vicinity of TCC based on 511 Virginia updates;

- Information on Virginia Megaprojects, including the HOT Lanes and the Dulles Corridor Metrorail Projects;
- TCC information and advertisements about commuter programs; and
- Local time, news, and weather information.

8.2 EVALUATION OBJECTIVES

Taking U.S. DOT goals for the SafeTrip-21 Initiative into account, along with the project team's more specific goals for the project, the team identified the following three evaluation objectives:

- Explore the user-perceived benefits of public traffic map displays;
- Analyze the perceived accuracy and usefulness of public traffic map displays; and
- Understand the technical and institutional issues associated with making the public traffic map displays available to the public.

For each evaluation objective, the team identified corresponding hypotheses, measures of effectiveness, and evaluation activities. In order to conduct the evaluation, the evaluation team undertook the following activities: administering intercept surveys at Virginia Welcome Centers and Tysons Corner Center; conducting focus groups with employees and shoppers at Tysons Corner Center; and conducting interviews with the deployment partners to document institutional issues and lessons learned with regard to the deployment experience.

8.3 EVALUATION ACTIVITIES

Travelers using the display screen at two Virginia Welcome Centers had an opportunity to view real-time traffic conditions and travel times as they head southbound or northbound on I-95. Users could make better decisions about where and when to stop based on traffic conditions ahead along their route. Viewing the information available, long-distance travelers can make better trip decisions based on traffic conditions. With the traveler information screens available at Tysons Corner Center, shoppers, visitors, and employees could make better decisions about when to leave the shopping center based on traffic conditions on the surrounding roadways or the transit schedule information for the next or last available bus serving their trip.

8.3.1 *Virginia Welcome Centers*

To assess the Virginia Welcome Center screen deployments, the evaluation team conducted an intercept user survey on-site at both the Skippers and Fredericksburg locations. A total of 488 surveys were collected between both Welcome Centers, with 266 surveys collected from the Fredericksburg Welcome Center and 222 surveys collected from the Skippers Welcome Center. The evaluation team also conducted interviews with all project partners to understand the challenges faced when deploying this type of technology.

Overall, the deployment of the Welcome Center Travel Time displays went smoothly. One of the primary reasons for this was that pre-existing conditions (the existing stakeholder agreements and the existing travel time data DUAs) facilitated the development of the system backbone. Frequent communication between the stakeholders and a focus on keeping the system design simple were also key to the success of the project.

8.3.2 Tysons Corner Center

With the launch of the traveler information screens, there was an opportunity to evaluate the impact of providing traveler information for the surrounding area inside a shopping center like TCC. To assess the Tysons Corner Center traveler information screen deployments, the evaluation team conducted a brief, high-level intercept survey that focused on concept and user focus groups that would serve to gather more detailed feedback about the various information elements displayed on the screens.

The specific evaluation objectives addressed by the conceptual intercept survey were to: 1) assess the perceived importance of or interest in traveler information and 2) document the potential benefits of traveler information at a mall or large commercial shopping center. The survey distinguished between and explored the perceptions of employees working at TCC and shoppers visiting TCC by creating two slightly different versions of the survey. The evaluation team was successful at collecting a statistically valid sample size of 385 total surveys. However, as expected, a disproportionate amount of shopper responses were collected compared to employee responses: 364 and 21, respectively. The statistical validity of the sample size was considered when breaking down the data in identifying the findings, which are addressed in the following sections.

To address the evaluation objectives associated with user-perceived benefits of the Public Traffic Map Displays at Tysons Corner Center, the evaluation team designed and conducted a series of focus groups. These meetings were used to collect feedback from shoppers and employees about the information displayed on the screens and the concept of displaying that information. Participants were representative of a range of ages: 42 percent were between 18 and 30 years old, 35 percent were between 31 and 50 years of age, and 23 percent were 51 years or older. In terms of gender, there was an over-representation of females; almost two-thirds (65 percent) were female and one-third (35 percent) were male. Most participants reported they typically drive to TCC, whether they were shoppers or employees, though some had experience with transit. This was similar to the survey respondents where just 2.5 percent were transit riders. A total of 14 shoppers participated in the shopper focus group sessions, and a total of 12 employees participated in the employee focus group sessions.

Although there were a few obstacles, overall, the deployment of the TCC displays went smoothly. Some of the bigger challenges included: implementing the Travel Times screen content later in the development process, selecting satisfactory screen locations that both provided information at convenient locations within the shopping center and did not violate lease agreements with tenants, and working with a wide variety of partners with unique perspectives and goals. However, one of the primary reasons for success was that a clear agreement was laid out with all partners at the outset of the project and that a detailed concept of operations was created early on with the involvement of all parties. Frequent communication between the various stakeholders was key to the success of the project.

8.4 EVALUATION FINDINGS

8.4.1 Virginia Welcome Centers

The results of the intercept user survey and deployment experience assessment provide insight into the successes, lessons learned, and institutional issues associated with displaying travel times in public areas:

- **Traffic conditions and travel time information is useful and can help make travelers stopping at a rest area make better decisions about their trip.** Survey respondents seem to feel that the information provided by the traveler information monitors was useful. The large majority of survey respondents agreed that the information was useful for making decisions about their trip, that the information could help reduce the stresses associated with driving, that the information is very valuable to have while traveling, and that the information should be expanded to other rest areas across the country. Survey respondents did see ways in which they could use the information to make better-informed trip choices.
- **Traffic condition and travel time information may lead a traveler to choose an alternate route.** A large majority believed that they would seek out an alternate route if the monitors informed them about delays ahead. About half of respondents believed that they would stop nearby to rest, eat, or shop, or that they would alter their travel plans (e.g., stop for the night). Fewer (less than one-third of respondents) thought that they would remain at the rest area until the traffic delays subsided.
- **Travelers taking long trips use traffic condition and travel time information differently than those taking short trips.** The length of the trip and the distance into the trip did not appear to affect how respondents rated the usefulness of the information. However, these factors did appear to affect how respondents felt they would use the information. Those making a short trip and those who were far along in their trip were less likely to feel that they would remain at the rest area if they observed from the screens that they would encounter traffic. Those who were far along in their trip were also less likely to agree that they would alter their travel plans to stop for the night. Those making long trips were the most likely to alter their travel plans to stop for the night. Finally, those making short trips were more likely to believe that they might try alternate routes.

8.4.2 Tysons Corner Center

The results of the conceptual intercept survey, focus groups, and the deployment experience assessments provide insight into the successes, lessons learned, and institutional issues associated with displaying travel times in public areas like a shopping center:

- **Shoppers, visitors, and employees find traveler information useful to have before leaving a shopping center.** Overall, survey respondents reported that the traveler information screens provide some type of information that is either important to have before leaving TCC or interesting to view on one of the screens.
- **Information related directly to travel to and from a shopping center should be the most frequently displayed.** The Travel Tools information that gives insight into current roadway conditions (i.e., Travel Times, Traffic Incidents, and Traffic Cameras content) was rated the most important information for visitors to obtain before leaving TCC on the intercept survey. Confirming this result, the focus group participants felt that the travel time information, transit maps and bus schedules, and the traffic camera screens were most useful.
- **Even with a low number of users, transit information is useful in a shopping center environment.** The survey findings indicate that although there were few such respondents, public transportation users rated the Transit Map and Transit Schedules content very important to obtain before leaving TCC.
- **Traveler information in a shopping center environment is more useful and clear to frequent visitors.** Shoppers who only visit TCC occasionally may have difficulty

understanding the actual locations of the live traffic camera views being provided. The survey analysis suggests that the Traffic Camera content is more important for regular visitors to TCC than for those who travel to the shopping center less often.

- **The importance of providing other transportation-related information on traveler information screens varies.** Of the other transportation-related information available on the traveler information screens, survey respondents were most interested in obtaining the HOT Lanes content from one of the traveler information screens. Respondents rated their interest in the Dulles Rail content at one extreme or the other (i.e., not interested or interested). Half of the survey respondents were impartial to “updates on the progress of the Dulles Rail Extension project” while the other half were interested in viewing the information on the screens. Respondents were least interested in “updates on the progress of other major VDOT projects” (Megaprojects content) and “information about commuter assistance programs” (Travel Options, Commuter Services, and Access Tysons content). Respondents’ interest in obtaining other types of transportation-related information from one of the screens depended on how often they visit TCC, where those that visit on a regular basis are more interested and vice versa. Additionally, it appears that respondents’ interest in other types of transportation-related information also depends on how close they live to TCC, where those that closest are more interested and vice versa.
- **In a shopping center-type environment, users expect to be able to view traveler information quickly.** Most participants said they would wait “a minute at most” or “a few minutes” to see the screens they felt were most useful. One suggestion made was to make the screens interactive so that travelers could get to the information they needed when they needed it.

9 LONG DISTANCE TRIP PLANNING USING REAL-TIME TRAVEL TIME DATA

9.1 OVERVIEW

The Long Distance Trip Planner application was a website developed by the I-95 Corridor Coalition in partnership with the United States Department of Transportation, the University of Maryland, and INRIX (a traffic information service provider). The I-95 Corridor Travel Time Information website was designed to help the general public (long-distance travelers, intercity travelers, and intra-city travelers) in making better pre-trip planning decisions, with the primary focus being on long-distance trips. It was expected that users would most likely use the application from their home or office where they can take note of current traffic conditions that may affect their travel plans. The website provides information that, for example, may help a family traveling from Durham, NC to Richmond, VA to identify potential heavy-traffic areas along their route. It could also prove useful for the commuter who is curious to know how the traffic looks in the region for the commute home. The website provides coverage in and between major cities along the I-95 corridor from Florida to Maine as well as other major cities along various major roadways adjacent to the corridor, such as Atlanta, GA and Pittsburgh, PA. It should be noted that the traffic congestion information is not available via mobile devices, nor is it available through any other method (e.g., 511).

9.2 EVALUATION OBJECTIVES

Taking U.S. DOT's goals for the SafeTrip-21 Initiative into account along with the project team's more specific goals for the project, the team identified the following three evaluation objectives:

- Measure the usage of the Long Distance Trip Planner;
- Obtain and analyze perceptions about the accuracy and usefulness of the Long Distance Trip Planner; and
- Understand the technical and institutional issues associated with deploying a Long Distance Trip Planner.

For each evaluation objective, the team identified corresponding hypotheses, measures of effectiveness, and evaluation activities. The evaluation approach activities included: analyzing website usage statistics from the initial website launch through the end of the evaluation period; administering a web-based user survey; and conducting interviews with the deployment partners to document institutional issues and lessons learned with regard to the deployment experience.

9.3 EVALUATION ACTIVITIES

The primary purpose of the I-95 Corridor Travel Time Information website is to provide travelers with access to real-time information about traffic conditions and travel times on major roadways along the I-95 corridor. The website essentially provides two major tools that use real-time travel time data to inform users about current roadway conditions. The first of these tools allows users to request an estimate of the travel time between select cities along the I-95 corridor, which is referred to throughout this document as the Travel Time Calculation Tool (TTCT). The second tool presents traffic congestion via a color-coded map using Google® Map API and is referred to throughout this document as the Traffic Conditions Map (TCM). On this map, each segment of each road is color-coded according to whether the traffic on that segment is free flowing (green), is experiencing moderate congestion (yellow), is experiencing heavy congestion (red), or is stop

and go (brown), with a separate color (black) used if that segment of roadway is closed. Figure 8 is a screen capture of the homepage of the I-95 Corridor Travel Time Information website accessed using Microsoft Internet Explorer.

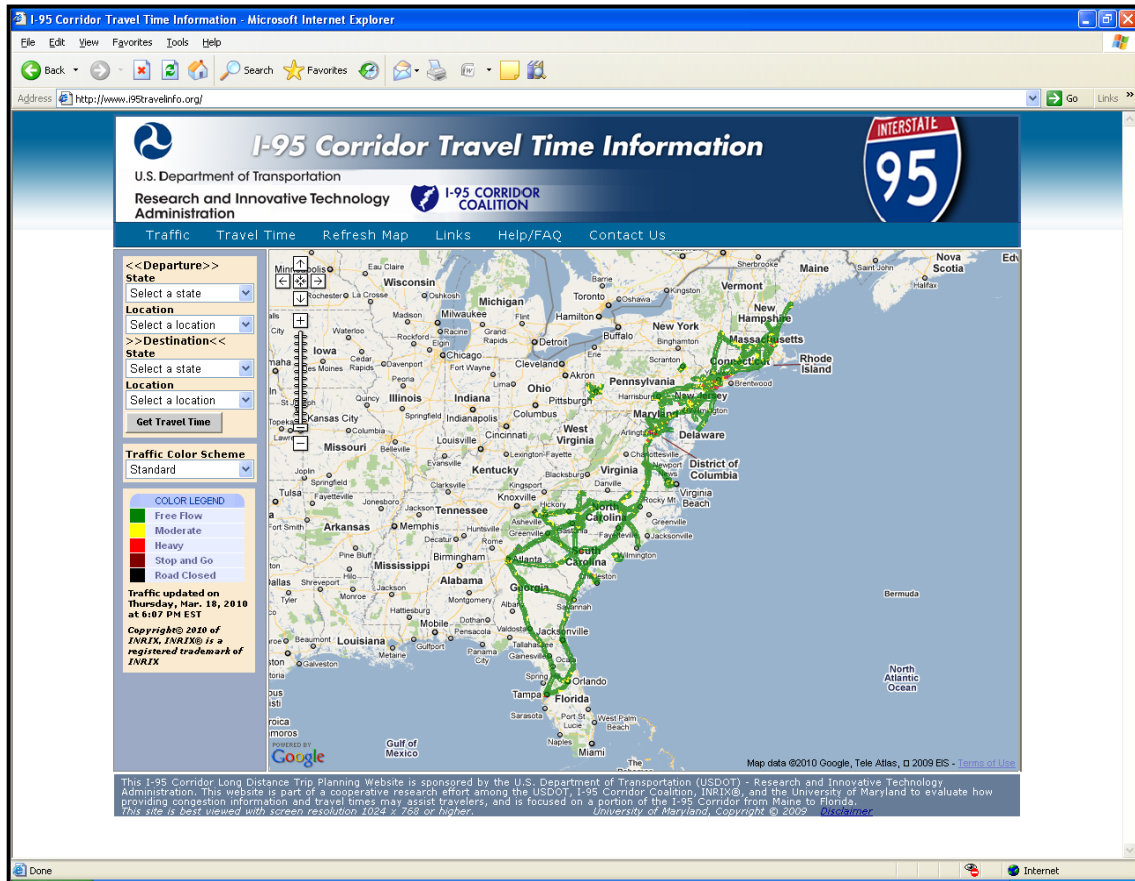


Figure 8. I-95 Corridor Travel Time Information Website Homepage.

Over the course of the 9-month evaluation period beginning with the website launch on June 1, 2009, the website experienced over 39,000 unique visitors. The web-based user survey was available to website visitors for a 1.5-month period of time spanning from November 20, 2009, to January 5, 2010. During this period, the evaluation team obtained 175 completed surveys and 76 partially completed surveys, for a total of 251 surveys. It should be noted that a total of 342 surveys would be needed to capture a statistically valid sample size of users. The lack of a statistically valid sample size was considered throughout the analyses, interpretations, and conclusions presented here. The evaluation team also conducted interviews with all deployment partners involved in the test. These data collection efforts resulted in a better understanding of user-perceived benefits and perceived accuracy and usefulness of the I-95 Corridor Travel Time Information website as well as challenges associated with deploying this type of technology.

9.4 EVALUATION FINDINGS

The results of the website usage statistics analysis, the web-based user survey, and the deployment experience assessment provide insight into the successes, lessons learned, and institutional issues associated with long distance trip planning using real-time travel time data:

- **Travelers make decisions based on long-distance trip planning information.** The survey findings indicate that website visitors are making decisions based on the information, in particular for longer trips. Of those who reported they had used the site before (only 14 percent), one-third reported that they had changed their travel route or their departure time based on information they obtained on the website. The survey findings indicate that website visitors feel that the website provides information that can help them make decisions about trips. Although only 14 percent of survey respondents had visited the website previously and had the option of indicating whether or not they had made a decision in the past about their trip, one-third of those reported that they had changed their travel route or departure time based on information from the website. Furthermore, when asked about using the website in the future to make decisions about their trip, approximately 75 to 85 percent of respondents indicated they would.
- **Targeted marketing efforts are essential in establishing user exposure to a website.** The website experienced significant growth from its initial launch on June 1, 2009, through the end of the evaluation period on March 12, 2010. After implementing a minor developmental change and an extensive expansion in coverage, the project team issued a major press release directed to holiday travelers the week of Thanksgiving in November 2009. This effort had a significant effect on the size of the website user base, growing it from approximately 6,000 users to more than 18,000 users in a matter of 2 weeks. The result of these targeted marketing efforts was significant user exposure to the website, which essentially tripled the size of the website user base. Once exposure is achieved, usage statistics can be analyzed to determine the type of significant events that drive website usage, essentially identifying the scenarios where the website information proves to be most useful.
- **Real-time traffic conditions and travel times appear to be more useful to travelers when roadways are expected to be congested.** In the case of real-time travel information, such as that provided on the I-95 Corridor Travel Time Information website, historically high traffic volume travel days and significant weather events drove up usage on the website, suggesting that users find the information most useful during these types of events. High usage related to weather events occurred when several areas in the mid-Atlantic region of the United States were crippled by a severe winter storm in December 2009 and February 2010. Significant spikes in website usage occurred in the days prior to, during, and following this storm, and usage even eased in conjunction with the impact of the storm. Other significant usage events occurred during the historically high traffic volume travel days surrounding Christmas Day and New Years Day. Website usage corresponded with typical travel patterns on these days, where the greatest volume of travelers is on the roadway in the days surrounding these holidays.
- **Long distance information appears to be more useful to weekend travelers.** Users primarily accessed the website on Thursdays through Sundays, which suggests that the information on the website is most useful for weekend trips where longer distance travel is more likely.
- **Survey results indicate that travelers would like to see real-time traffic conditions and travel time information expanded across the nation.** Website visitors seem satisfied with the website overall. The large majority of survey respondents felt that the information on the website was valuable. Approximately 90 percent of respondents indicated that they would like to see this kind of information expanded to other major travel routes around the country, and the majority of respondents reported that they were

likely or very likely to visit the website again, start using or continue using the website on a regular basis, or recommend the website to a friend or colleague.

- **Perception of the accuracy of real-time information increases with familiarity.** The survey findings indicate that website visitors who are more experienced with the site are more likely to agree that the information is accurate than those who have less experience with the site.

From a deployment perspective, the implementation of the I-95 Corridor Travel Time Information website went smoothly overall. One of the primary reasons for this was that pre-existing conditions (the existing stakeholder agreements and the existing travel time data DUAs) facilitated the development of the website. Frequent communication between the stakeholders and a focus on keeping the website design simple also helped. Contracts, agreements, and data were a key to success. In this case, pre-existing conditions eliminated many potential complications from the development process. There was no need to reach agreements between the various partners involved (the I-95 Corridor Coalition member States and the private data provider) because such agreements were already in place through the I-95 Corridor Coalition. There was no need to consolidate travel time data because all travel time data was being provided from a single source. These factors shortened the schedule and lowered the risk associated with the website development process. The result was a website development for which the initial launch occurred on-time and under budget. Completing the development under budget then gave the partners the ability to address user comments received on the initial website while still remaining within the planned budget for the project.

10 DEPLOYMENT OF PORTABLE TRAFFIC MONITORING DEVICES

10.1 OVERVIEW

Many roadways across the country are equipped with traffic-monitoring devices that provide State DOTs with information about real-time conditions on their roadways. Real-time traffic monitoring is not as common in work zones, however, due to the fact that the investment required to install and maintain temporary equipment can be cost-prohibitive due to the ever-changing nature of the traffic situation. Even if ITS devices are included in the initial temporary traffic control design, they are often removed from the plan before or during construction due to the associated installation and maintenance costs. Furthermore, in work zones where permanently installed traffic-monitoring devices are already present, the devices are often rendered useless for monitoring traffic in the construction area either because they are temporarily moved during construction or because the travel lanes are temporarily shifted outside of the detection area of the devices.

Recent technological advances in traffic-monitoring technologies, battery power, and communications are removing this barrier and making it possible to manage work zones cost-effectively in real-time with the use of portable traffic-monitoring devices (PTMDs). PTMDs have the potential to allow transportation personnel to monitor traffic conditions actively without a large investment of resources.

10.2 EVALUATION OBJECTIVES

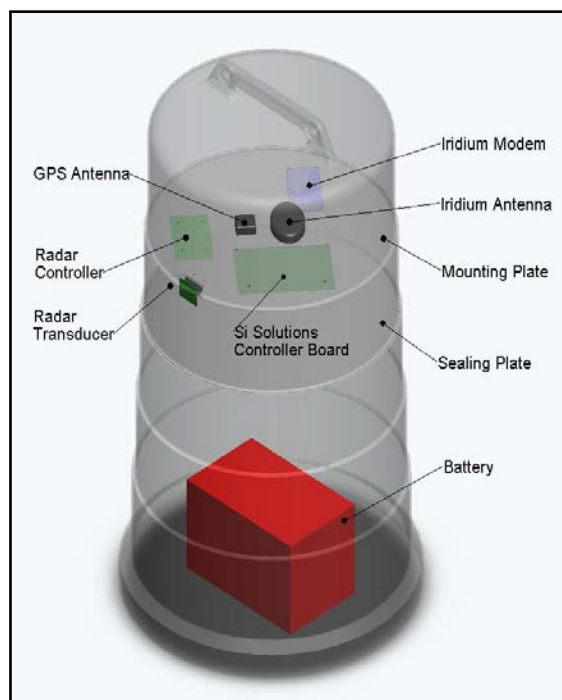
The objective of the evaluation was to gather lessons learned from the test deployment of PTMDs in North Carolina and California through interviews with NCDOT and Caltrans staff. The Evaluation Team aimed to gain an understanding of:

- The institutional issues associated with collecting and making use of real-time information about traffic conditions in work zones.
- How real-time information about traffic conditions in work zones can be used effectively by a State DOT to actively manage work zones.

10.3 TEST SITES

Through the U.S. Department of Transportation's (U.S. DOT) SafeTrip-21 initiative, the California Department of Transportation (Caltrans) and the North Carolina Department of Transportation (NCDOT) tested the use of portable traffic-monitoring devices (PTMDs) in work zones.

The PTMD under study in this evaluation uses a single K-band radar unit to obtain information about traffic conditions. The device can be set



Source: Calmar Telematics

Figure 9. Diagram of PTMD

to collect either vehicle speeds or traffic volumes. The PTMD is housed inside a National Cooperative Highway Research Program (NCHRP) 350-compliant traffic channelizer (i.e., a construction drum), as shown in Figure 9, so it can be placed anywhere along the roadway where it would be appropriate to place a channelizer. The device has a range of up to 300 feet for speed detection and approximately 100 feet for traffic counts. To install, the user simply places the device on the roadside and aligns the arrow at the top of the PTMD either to point *toward* traffic (to collect speed data), or to point *perpendicular* to traffic (to collect traffic counts). Although the device is battery powered and does not require an external power source, it does require regular battery charging.

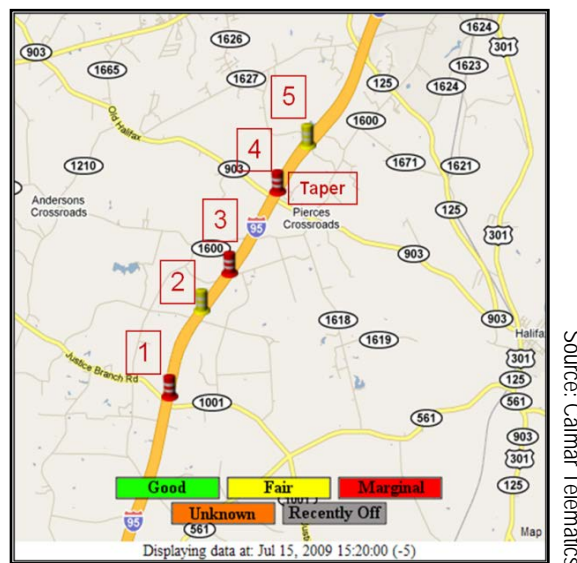


Figure 10. Map Representation of a PTMD Application on I-95

Data collected from the PTMD is available to users on a web-based map, and historical data can be downloaded into spreadsheet or chart format so that the data can be viewed or manipulated as desired.

10.3.1 NCDOT Test Sites

Going into this test, NCDOT personnel aimed to make use of the PTMD system to better understand where queuing most frequently occurs in their work zones (i.e., either upstream or downstream of the merge point), and to understand how far the queues typically extended in either scenario. NCDOT tested the PTMDs in two work zones along I-95 during their 2009 construction season. NCDOT also planned to test the units in a third work zone located on US 64 near Raleigh where the PTMD would be used in conjunction with existing changeable message signs (CMS), but the units could not be integrated with the CMS as planned due to the age and legacy software of the CMS equipment.

The two sites that were tested both involved static setups along I-95 – one in Nash County and one near Roanoke Rapids. Figure 11 depicts one of the test corridors along I-95 along with the deployment of the five PTMDs. This I-95 application took place between mile markers 166 and 172. The work performed along I-95 consisted of a 4-lane interstate resurfacing job. Lane capacity was reduced from two lanes to one lane in the active work direction.



Figure 11. Work Zone in NC Where PTMDs Were Tested

10.3.2 Caltrans Test Sites

Caltrans had 12 PTMDs available for study purposes over a test period of 5 months beginning in September 2009. The devices were distributed to District 2 in Northeastern California, District 4 in the San Francisco Bay Area, and District 12 in Orange County. Districts 2 and 12 had the units for a brief time, where they tested the travel time and traffic counting features of the PTMDs, respectively. The PTMDs were then provided to District 4 for conducting additional testing for the remainder of the test period. As a result, the majority of the findings in this document represent findings from testing by District 4 staff in the San Francisco Bay Area.

Caltrans District 4 staff elected to deploy the units at a number of locations during the test period, choosing to use the devices on multiple short-term projects rather than on one large construction project. This approach provided them with the flexibility to move the PTMDs quickly without disrupting a large-scale operation, and enabled the staff to learn about the value and limitations of the PTMDs in a variety of situations.

Caltrans District 4 used the PTMDs in a variety of ways during the 5-month test period. The two most significant deployments had direct connection with the Bay Bridge between Oakland and San Francisco. Other deployments involved various interstates and U.S. highways in the Bay Area. The test sites are described in further detail below.

10.3.2.1 Interstate 680

The Interstate 680 project was a short, 1-day construction job on a six-lane section of the freeway in the Walnut Creek area where there are numerous ramps and interchanges connecting the Interstate to other major routes in the region. One of the six-lane connector ramps was reduced to one lane during the mid-day, and Caltrans staff had concerns that the queues at this location might exceed Caltrans' thresholds for delay, so they used the PTMDs to monitor queue lengths in the work zone.

10.3.2.2 Bay Bridge Closure over Labor Day Weekend

For the past 3 years Caltrans has closed the Bay Bridge between San Francisco and Oakland to complete maintenance activities over Labor Day Weekend. During this time, a significant amount of traffic is diverted to the two major bridges to the south: the San Mateo Bridge and the Dumbarton Bridge. For the Labor Day 2009 bridge closure, Caltrans deployed PTMDs to collect traffic data along the Bay Bridge, along the San Mateo Bridge, at the 92 & 880 interchange, and at the 101 & 580 interchange. While the Bay Bridge was closed, Caltrans used the PTMDs to monitor the queue on the San Mateo Bridge. When the queue reached a point on the San Mateo where motorists would be better served to use the Dumbarton Bridge (a 30-minute detour to the south), the TMC staff encouraged drivers to use the Dumbarton detour via messages on changeable message signs (CMS).



Figure 12. Bay Area Bridges

10.3.2.3 Highway 101 - Golden Gate Bridge

During this large-scale bridge closure, Caltrans placed PTMDs near the bridge at a traffic camera location, north beyond the typical daily queue, and over a nearby hill. At this location Caltrans used the PTMDs to supplement traffic cameras in monitoring queue lengths.

10.3.2.4 Bay Bridge Reverse Curve

Caltrans also deployed PTMDs on the Bay Bridge periodically during the test period to respond to a safety issue. In early November, a fatal crash occurred involving a large truck missing a 35-mph reverse curve and driving off the Bay Bridge. Caltrans responded to safety concerns after this event by temporarily placing a PTMD at the curve location to collect speed data as an enforcement support tool. Using the PTMD, Caltrans and the California Highway Patrol (CHP) monitored speeds at the curve in real time, and CHP officers were dispatched to the bridge to provide active enforcement when speeds exceeded a set threshold.

10.3.2.5 Interstate 880

After the Bay Bridge closure over Labor Day weekend, District 4 moved six of the PTMDs to Interstate 880 (I-880) in Oakland in support of a bridge rehabilitation project that was expected to result in severe back-ups. When the PTMDs showed that the traffic queue on I-880 extended beyond Caltrans' limits for delay in work zones, the Lane Closure Manager contacted the TMC staff, who used California's 511 system and CMS to encourage traffic to divert to I-580.

10.3.2.6 Event Management in Pasadena

Caltrans also made use of the PTMDs to support the management of special event traffic surrounding the Tournament of Roses festivities and the Bowl Championship Series (BCS) National Championship football game held in January 2010. The City of Pasadena deployed 10 devices at various locations around the city both before and after these two events.



Photo courtesy Caltrans

Figure 13. PTMD Installation on Bay Bridge

10.4 EVALUATION FINDINGS

The findings presented here are based on a series of interviews that the Evaluation Team conducted with NCDOT and Caltrans staff from October 2009 through April 2010.

Based on their experience during this test, both agencies reported that the PTMDs were easy to install and to maintain. They felt that the devices enabled them to focus their activities on the areas that needed the most attention while still monitoring areas that needed less active involvement. They are hopeful that the data gathered during the test will help them better understand queuing activity in and around their work zones and help them to better plan work zone activities in the future.

The device appears to have many other potential uses and applications for the future to support incident and evacuation management, the development of expanded work windows, capacity studies, law enforcement efforts, and the collection of travel time data for both recurring and non-recurring bottlenecks. In addition, data from PTMDs can be used to supplement data gathered through permanent ITS devices in the field to improve the accuracy of the information available to traffic management center staff.

There are a few challenges with using the device related to portability. One challenge is that, depending on usage, the batteries typically last only a few weeks, and recharging the batteries can be a somewhat cumbersome process as the devices have to be transported to a power source and then back to the field. Another challenge is that because the devices are so highly portable, they can easily be moved, intentionally or unintentionally, by contractors, maintenance workers, or the public.

Overall, based on the experience of NCDOT and Caltrans, the devices appear to be a cost-effective and flexible means for an agency to remotely monitor traffic conditions on their roadways.

PART III: EVALUATION FINDING SYNTHESIS

The intent of Part III of this report is to identify themes across the diverse application areas tested under the SafeTrip-21 Initiative and highlight the most consistent and interesting findings. The chapters contained within this Part III are structured to reflect the different ways in which the applications are representative of ITS solutions. That is, the chapters, listed below, are structured to reflect topics of interest to the ITS community.

11. **Alternative Approaches to Monitoring Traffic Conditions Data.** This chapter contains a discussion of the “traffic data collection” aspect of ITS. In what ways did the SafeTrip-21 applications advance technology and understanding of needs related to traffic conditions data?
12. **Providing Useful and Usable Real-Time Traffic Conditions Information.** This chapter contains a discussion of how to present real-time travel information data to travelers in an effective way. In what ways did the SafeTrip-21 applications effectively present information to drivers?
13. **Providing Multi-Modal Travel Options to Travelers.** This chapter contains a discussion of how to present data to travelers with a focus on transit options. In what ways did the SafeTrip-21 applications effectively present modal information to travelers?
14. **Providing In-Vehicle Safety Alerts in End-of-Queue Situations.** This chapter moves from providing mobility related information to travelers to providing safety related information. In what ways did a SafeTrip-21 application effectively provide safety information to drivers?
15. **Conclusions Lessons Learned.** This chapter summarizes the key messages from the evaluation.

Chapters 11 to 14 are subdivided to describe findings related to different processes of deployment and areas of interest, including:

- Design and Development;
- Deployment;
- Marketing;
- User Experience;
- Privacy; and
- Institutional Issues.

11 ALTERNATIVE APPROACHES FOR MONITORING AND USING TRAFFIC CONDITIONS DATA

Traditionally, transportation agencies have used fixed sensors to monitor traffic conditions (speed and volume), especially on freeways. Technologies include sensors embedded in the pavement, such as induction loops, and above ground sensors, such as microwave devices. These sensors provide speed, volume, and other data, which are typically fed into automated traffic monitoring systems such as Performance Measurement System (PeMS), and other advanced traffic management systems. Closed circuit television cameras are another form of above ground sensor that provides video feeds that are used by traffic managers and others. Sensors require power supply and communication subsystems to transmit data. Installation and maintenance of traffic condition monitoring systems can be disruptive to traffic, although above ground sensors have mitigated this to some extent.

For arterial and local streets, traffic condition monitoring is mostly comprised of detection systems for traffic signals. As with freeways, sensors can be embedded in the pavement or above ground. These sensors detect the presence of vehicles, and these data are fed to traffic signal controllers to support traffic signal operations. For the most part, traffic managers do not use these data for traffic monitoring purposes. In many cases they may not have direct access to these data, instead relying on citizen reports to identify problems. Unlike freeways, traffic managers can be blind to real-time traffic conditions on arterial and local streets due to the lack of traffic monitoring systems.

The SafeTrip-21 Initiative contributed to a new understanding of how:

- a) Traditional traffic condition data can be used in innovative ways and
- b) Innovative traffic condition data can support traditional engineering tasks.

Overall, all four projects contributed to the pool of knowledge related to traffic condition monitoring.

Mobile Millennium demonstrated that it is feasible to use traffic probes as an alternative to traditional traffic condition monitoring systems, at least with respect to travel information systems. This is not to say that traffic probes alone would be sufficient to achieve appropriate accuracy levels, particularly on routes (or at times of day) when few traffic probe vehicles are passing. (Mobile Millennium did not set out to achieve any particular level of accuracy, but to test the approach with considerably more traffic probes than previously tested.) To address this, Mobile Millennium was successful at integrating other sources of traffic data into its traffic models. Mobile Millennium made considerable inroads into the important area of arterial traffic model development, but highlighted the challenges that remain, particularly in modeling downtown areas versus single arterial routes. This is an area worthy of continuing research.

The **Portable Traffic-Monitoring Devices (PTMDs)** test used sensors incorporated into construction barrels, effectively creating a portable sensor so that traffic conditions could be better monitored through work zones.

The **Networked Traveler-Foresighted Driving (NT-FD)** test demonstrated a completely new application for traffic information from a traditional traffic monitoring system by alerting motorists to upcoming traffic conditions that may lead to end-of-queue crashes, a technology demonstration which garnered favorable response from participants. While the system does not always generate accurate alerts, it clearly demonstrated the potential for a system that one day

could be commercialized via integration into an existing navigation or alert system. The challenge for the NT-FD concept is that it relies on the availability of a traffic condition monitoring system capable of providing accurate and timely speed data.

The **Real Time Intersection Delay** (RTID) system demonstrated how a traffic intersection controller could be easily interfaced to capture real-time traffic condition data and make it available for remote offline analysis. This would greatly enhance the ability of transportation agencies to monitor timing signal plans and update these as traffic conditions change. At the present time, Caltrans is unable to do this as frequently as it desires because the current process is time consuming and labor intensive.

Each test described provides insight into approaches for monitoring traffic conditions on roadways. All four tests have comparable features and resulted in valuable lessons learned on the topic of collecting and using traffic conditions information. The lessons learned are organized and presented according to the following processes:

- Design and Development
- Deployment
- Marketing
- User Experience
- Privacy
- Institutional Issues

11.1 DESIGN AND DEVELOPMENT

Mobile Millennium and the NT-FD test were applications submitted as part of the California Connected Traveler (CACT) test bed. Both were demonstrated in November 2008 at the ITS World Congress in New York City. The PTMDs and the RTID system were subsequently included in SafeTrip-21 as independent applications and tested using the CACT test bed. All four projects were substantially developed by the outset of SafeTrip-21. However, due to U.S. DOT's concerns regarding distracted driving, the NT-FD test was extensively re-scoped in 2009/2010 to avoid the need for drivers to interact with the system (using their smart phones) while driving. This meant it was also no longer possible to determine location, speed, and direction data using drivers' smart phones. Instead, specially instrumented vehicles were developed to capture these data. Consequently only 24 drivers could participate in the test, compared to the many hundreds originally planned (and the several thousand users who participated in Mobile Millennium.) Despite this re-scoping, the NT-FD test was still able to broadly test the same concept as originally intended, i.e. is it possible to alert drivers to slower traffic ahead? While the NT-FD test used a traditional traffic monitoring system, it did so to generate specific alerts targeted individual drivers.

Mobile Millennium was based upon an earlier collaboration between its partners called Mobile Century. Both Mobile Century and Mobile Millennium sought to provide real-time traffic information using vehicle probes rather than traditional traffic monitoring systems. Mobile Millennium went further, both in terms of scale (more than 2,000 participants versus 100 for Mobile Century) but more importantly in coverage. Mobile Millennium provided traffic information across the Bay Area, not just a short section of a single freeway. The greatest development challenge for Mobile Millennium therefore was the need for an arterial traffic model to fuse probe and other data in such a way that accurate travel time information could be provided to users. Unlike the highway model, which already existed as a product of the earlier Mobile Century test, the arterial model had to be developed from scratch for Mobile Millennium.

Based on the ground truthing work undertaken by CCIT, the highway model appears robust, while the findings for the arterial model depended on the location for the test. This was not entirely unexpected, as the highway model was less complex than the arterial model and had had the benefit of a longer development period dating back to the Mobile Century project. There is probably no single universal model that could apply to all arterial scenarios. Instead, specific customized arterial models may be required depending on the type of arterial roads being modeled and the traffic patterns they exhibit.

In addition, arterial traffic monitoring is typically much more challenging than highway traffic, given many factors that influence arterial traffic such as traffic signals, frequency of (and turning movements at) intersections, pedestrians, loading/unloading passengers and goods, parking, and widely varying performance characteristics of vehicles.

By comparison, the PTMD and RTID tests were smaller, more localized tests. The PTMDs provided work zone traffic data to Caltrans and RTID was tested at a single intersection. The RTID data was only accessed by the vendor (although it was available to Caltrans.)

11.2 DEPLOYMENT

Keys to successful deployment of Mobile Millennium can be attributed to three factors:

- The project was institutionally mature, with excellent working relationships and a shared vision among Caltrans, Nokia, and CCIT. Working together previously on Mobile Century had had a positive influence on the partnership. Also important was the recognition among the partners of their respective (but different) strengths and organizational goals.
- Mobile Millennium provided a service that attracted a lot of users. Specifically, users appeared to be attracted to the concept of receiving travel information in exchange for acting as a traffic probe. Nokia reported much enthusiasm among users to provide feedback on how to enhance the system, even among those who registered but never used the system. Many users expressed an interest in more features, including personalized traffic information, as a way to improve the system. Nokia referred to this as an ecosystem, with the inference that all parties are interconnected and contribute in their own way.
- Finally, while Mobile Millennium was a beta product, it was operated as if it were a consumer service. This was a huge commitment by the partners, as it entailed maintaining the service around the clock. When the test was concluded, some users wanted it to continue even though they knew it was a test.

For the NT-FD test, the different nature of the test means the keys to successful deployment were different than those for Mobile Millennium:

- Despite any accuracy concerns, availability of real-time data from a traffic condition monitoring system covering Bay Area freeways was critical. This system had been deployed by the Metropolitan Transportation Commission for the region's 511 travel information system. Data needed not only to be available in real time, but also to be updated at sufficiently frequent intervals.
- In addition to the traffic condition monitoring system, the NT-FD test was critically dependent on the ability to track the location, speed, and direction of the instrumented vehicles accurately.

- The NT-FD test then had to be able to merge the traffic and vehicle data to calculate upcoming traffic conditions that could justify an alert to be issued, typically within 60 seconds of a vehicle reaching the back of the slower moving traffic. If these conditions were met, the NT-FD system then needs to be able to transmit an alert to the correct vehicle in a timely fashion.

For the RTID test, Caltrans required that the vendor's TrafMate product be installed in less than 30 minutes and not interfere with the normal safe operation of the traffic signal controller. TrafMate achieved these requirements, although during deployment it was agreed that loop detector cards inside the controller needed to be replaced for the test, as they did not perform the function of counting vehicles. A key to successful deployment in this case was having a mature product that was compatible with existing signal controller technology.

When it came to the PTMDs, there are a few challenges with using the device related to portability. One challenge is that, depending on usage, the batteries typically last only a few weeks, and recharging the batteries can be a somewhat cumbersome process as the devices have to be transported to a power source and then back to the field. Another challenge is that because the devices are so highly portable, they can easily be moved, intentionally or unintentionally, by contractors, maintenance workers, or the public.

11.3 MARKETING

Marketing was not evaluated for these applications.

11.4 USER EXPERIENCE

Users did not directly interact with either the PTMDs or RTID. Mobile Millennium attracted more than 2,000 users over a 12 month period and NT-FD recruited 24 users, each of whom experienced the alert system for a one-week period. (They each drove an instrumented vehicle for two weeks, but the system did not broadcast alerts during the first week.)

In terms of traffic condition monitoring, users of NT-FD were generally positive about the system, even though there were issues related to accuracy. 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 was that test participants may have exited the freeway after receiving an alert but before reaching the location associated with the alert; the conditions that caused the alert to be generated were resolved by the time the test participant arrived at the sensor location; inaccuracies in the traffic speed information provided by the external speed sensor network, or anomalies 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. This highlights the major constraint for the NT-FD test, in that the traffic condition monitoring system was external to the test and beyond the control of the PATH researchers. Clearly the future deployment of similar systems will need to address this issue.

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.

11.5 INSTITUTIONAL ISSUES

Mobile Millennium, NT-FD, and the RTID tests faced institutional challenges, but none that adversely affected traffic condition monitoring. Each test highlighted some future challenges that need to be addressed by transportation agencies and businesses before similar systems become more commonplace. These challenges include new procurement approaches that are focused on purchasing information rather than equipment, defining the respective roles (and business models) of the public and private sectors in providing traffic information to consumers, and trade-offs between individualized information delivered to a smart phone and distracted driving.

Most participants liked the NT-FD 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.

11.6 PRIVACY

The use of probe vehicles as an alternative to traditional fixed sensors raises the potential for privacy issues related to tracking personal smart phones. Mobile Millennium addressed this issue by developing specific privacy protecting methods to generate traffic data at pre-set locations (referred to as virtual trip lines or VTLs) rather than by tracking individual mobile devices or using identification information. A large majority of users were positive about how Mobile Millennium protected their privacy, with 68 percent of respondents trusting the system to protect the privacy of their travel data, 7 percent not trusting the system, and 25 percent either not knowing or not caring about personal travel data privacy.

In its re-scoped format, the NT-FD test did not need to address the issue of privacy related to the use of personal smart phones. However, the instrumented vehicles used for the test were equipped with similar functionality to track the participants at all times, as well as a camera recording the drivers' responses at all times. 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.

Both tests were quite transparent with participants as to what personal data would be collected and why. Participants appear to have responded positively, recognizing the tradeoff between personal data collected by the respective tests and the quality of personalized services received in return. Obviously with the more personalization desired by consumers, there will be a greater likelihood that they will need to provide more personal data.

11.7 CONCLUSIONS

The four applications described above demonstrated progress in applying ITS solutions to transportation needs related to monitoring and using traffic conditions data.

- Mobile Millennium illustrated alternative ways to collect traffic data for both traveler information and as input into models, particularly arterial models for which there is often insufficient data.
- RTID demonstrated an approach to monitoring and controlling signal timing remotely which could alleviate burdens on state and local transportation agencies.
- NT-FD was largely successful at provided real-time safety alerts to drivers using the existing infrastructure to gather traffic data.
- PTMDs were viewed as a promising and flexible addition to the roadside arsenal in terms of monitoring road conditions.

12 PROVIDING USEFUL AND USABLE REAL-TIME TRAFFIC INFORMATION

A number of State DOTs and other transportation agencies across the country have been providing a variety of real-time traffic information to travelers for a number of years now and many are looking for ways to improve the information they provide. As agencies look to improve their existing systems by changing the way in which they present information to travelers, or as they develop new systems to offer information through different means, prior deployments can offer valuable lessons learned to inform these future deployment decisions.

The SafeTrip-21 Initiative offered fascinating insights into ways to better the mechanisms by which information is provided to drivers. Three of the SafeTrip-21 field test applications focused on providing real-time information on traffic to motorists:

Mobile Millennium functioned as 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.

The I-95 **Long Distance Trip Planning Using Real-Time Travel Time Data** provided a web-based trip planner that gave travelers cross-jurisdictional, real-time information about current travel times between key destinations along the I-95 corridor from Florida to Maine. The website includes a color-coded traffic conditions map of the entire corridor but also includes a "travel time calculation tool" that allows users to input an origin city and a destination city along the I-95 corridor to obtain an estimate of the travel time for their trip.

The I-95 project for **Displaying Travel Times in Public Areas** created applications that provided the public with real-time traffic information via flat-panel screens at two Virginia Welcome Centers along I-95 as well as at Tysons Corner Center, one of the largest shopping centers in the country. The screens inside the Welcome Centers in Fredericksburg, VA and Skippers, VA provide a color-coded map for drivers looking to get a glimpse of the traffic conditions ahead as they travel along Interstate 95 (I-95). The screens also provide current travel times to key destinations along I-95. At Tysons Corner Center there are five screens positioned at various locations throughout the mall that provide a regional color-coded traffic conditions map as well as current estimated freeway travel times to major destinations in the region.

All three of these applications provide real-time traffic information, but through different mediums: the Long Distance Trip Planning application provides information to travelers via a website, serving as a pre-trip information source, while the Public Traffic Map Displays application provides information to travelers while en-route. In contrast, the Mobile Millennium application provides information to travelers via a smart phone, meaning that the information can be used both pre-trip and en-route. All three serve as examples of different and meaningful ways to reach travelers, and all offer lessons learned that can inform future deployments. The lessons learned are organized and presented according to the following processes:

- Design and Development

- Deployment
- Marketing
- User Experience
- Privacy
- Institutional Issues

12.1 DESIGN AND DEVELOPMENT

When it comes to development of a real-time traffic information system, one lesson that can be taken from the I-95 test bed is that keeping the design simple can help to avoid deployment delays down the road. When faced with choices between a simple solution and a more complex solution that might provide more options for users, the developers of the I-95 applications consistently selected the simpler solution.

One key design feature that simplified the design of the public displays application was the decision to use the Google® map API to generate maps for the system. This API is a free service that makes it easy to embed a map into a web application and to overlay the standard Google map with additional features, such as the color-coded travel time segments used on the screens. Another example of this is the choice the project stakeholders made when it came to determining what data would inform the prediction of “current travel time”. While the travel time could have been based on a complex algorithm that estimates travel time based on historical patterns and current conditions, the team decided to go with a simpler approach of basing the information purely on current conditions along the route.

Key design features that simplified the design of the trip planner website application included the fact that the design team elected to design the website to report current travel times rather than to forecast future travel times, as well as the fact that the website uses a pre-defined list of departure and destination locations rather than allowing users to specify any location. Also, the system uses a single route between departure and destination pairs rather than providing travel times for multiple routes between those pairs.

All of these design choices simplified the two deployments, resulting in fewer risks on the technical side. This focus on keeping it simple allowed the initial launch to occur on-time and under budget.

Another lesson that can be taken from the I-95 traffic information applications is that it is helpful to build in mechanisms for detailed website usage monitoring when developing an interactive website. One potential capability of the website that was not included in the design for the I-95 trip planner website was the ability to track the travel time requests that were being made (i.e., how often users were making use of the option of inputting an origin and destination pair, and for those who did, what origins and destinations users were most often selecting). In retrospect, the project team feels that this should be an important factor in design as it would have allowed the team to make improvements to the site over time based on user needs.

Another important consideration in design of an information display is system redundancy. This is critical to ensure that the screens do not experience any down-time, which would cause users to perceive the system to be unreliable. The back-end system supporting the Tysons Corner Center displays was designed with triple redundancy to avoid any failures. One server, the production server, was devoted exclusively to preparing and transmitting content to the displays. A second server hosted the content management system and also provided failover capability if the production server failed. A third server served as a spare. This provided triple-redundancy with the servers. In addition, the production server was designed to periodically transmit a

message to a computer at the contractor's office verifying that the server was still operational. A web camera in the server room aimed at this display allowed the contractor to monitor this display remotely as an additional safeguard against a system problem.

Mobile Millennium highlights one success factor related to partnership. This test benefitted from an earlier collaboration between its partners called Mobile Century. Both Mobile Century and Mobile Millennium sought to provide real time traffic information using vehicle probes rather than traditional traffic monitoring systems. Mobile Millennium went further in terms of scale (more than 2,000 participants versus 100 for Mobile Century) and, more importantly, coverage. Mobile Millennium provided traffic information across the Bay Area, not just a short section of a single freeway. The greatest development challenge for Mobile Millennium therefore was the need for an arterial traffic model to fuse probe and other data in such a way that accurate travel time information could be provided to users.

12.2 DEPLOYMENT

When it comes to deployment of a real-time traffic information system, one lesson that can be taken from the I-95 project is that contracts, agreements, and data are a key to success. In the case of the I-95 applications, pre-existing conditions eliminated many potential complications from the development process. For example, there was no need to establish agreements between the various partners involved (that is, the I-95 Corridor Coalition member States and the private data provider), because such agreements were already in place through the I-95 Corridor Coalition. As another example, there was no need to consolidate travel time data because all travel time data was being provided from a single source.

Keys to successful deployment of Mobile Millennium can be attributed to three factors. First, as mentioned above, the project was institutionally mature, with excellent working relationships and a shared vision among Caltrans, Nokia, and CCIT. Working together previously on Mobile Century had had a positive influence on the partnership. Also important was the recognition among the partners of their respective (but different) strengths and organizational goals.

Next, Mobile Millennium provided a service that attracted a lot of users. Specifically, users appeared to be attracted to the concept of receiving travel information in exchange for acting as a traffic probe. Nokia reported much enthusiasm among users to provide feedback on how to enhance the system, even among those who registered but never used the system. Many users expressed an interest in more features, including personalized traffic information, as a way to improve the system. Nokia referred to this as an "ecosystem," inferring that all parties are interconnected and contribute in their own way.

Finally, while Mobile Millennium was a beta product, it was operated as if it were a consumer service. This was a huge commitment by the partners, as it entailed maintaining the service around the clock. When the test was concluded, some users wanted it to continue even though they knew it was a test.

12.3 MARKETING

For a real-time traffic information system, marketing is critical to success regardless of the method by which the information is accessed by the public. The marketing methods will differ, however, depending on the way in which the information is accessed. For example, with static public displays of information such as those in the Virginia Welcome Centers and at Tysons Corner Center, it is critical to "advertise" the service to passersby so that they will be enticed to stop and take a look. In most public places information screens will be competing with many

other signs, advertisements, and information sources, so it is critical to inform the public in some way of what information can be found on the screens. In this case the screens in the Welcome Centers are located alongside a variety of information including travel brochures and other television screens displaying travel information, while the screens in Tysons Corner Center are competing with storefronts, advertisements, sounds, and lights. The Tysons Corner Center stakeholders found it helpful to create a floor sticker to draw attention up to the screens (shown in Figure 14) as well as a bezel to surround the screen advertising that the screen includes “Live Traffic Information.”

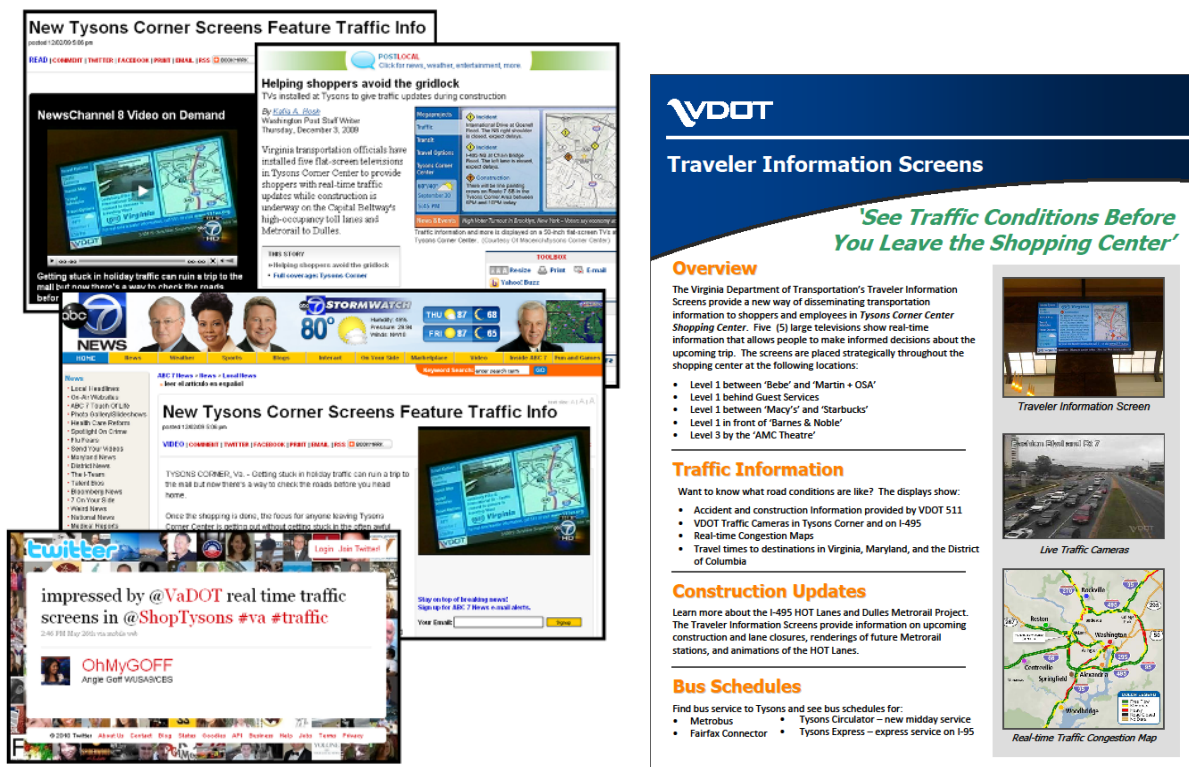


Image of floor sticker courtesy VDOT; photo courtesy SAIC

Figure 14. Floor Sticker and Bezel Used to Generate Interest in Tysons Corner Screens.

For a display screen that is located in a public place that will be visited on repeat occasions by local patrons (such as a shopping mall), local media outlets are another way to market and generate interest in the system. In the case of the Tysons Corner screens, the Virginia Department of Transportation developed a flier on the system that was distributed to local households with the local paper. The Tysons Corner stakeholders also managed to get exposure about the project through a variety of media outlets as shown in Figure 15. These methods would not have been as successful for the Welcome Centers where travelers originate at various locations around the east coast.

In the case of a website or smart phones application, a very different approach to marketing is needed. Targeted marketing efforts are essential in these cases to establish a user base.



Screenshots on left courtesy SAIC; fact sheet on right courtesy VDOT

Figure 15. Media Coverage of Tysons Corner Screens.

In the case of the trip planner website, the I-95 project team took several strides to generate awareness about the website beginning with the website’s launch at the ITS America Annual Meeting in June 2009 where the website received immediate exposure. Additionally, there were two initial major efforts coordinated by the project team. The first was to reach out to transportation and travel-related organizations such as AAA Mid-Atlantic, which posted information about the website along with a link to the site on its “Cars & Driving” blog in June 2009. Additional exposure was made to the Commercial Vehicle Operations community when an article about the website was published in the August 2009 issue of OverDrive Magazine. The second major effort the team undertook was to reach out to all of the States covered on the site, requesting that they consider posting a link to the website on their DOT and/or 511 websites. This effort resulted in nine websites posting a link to the I-95 Corridor Travel Time Information website.

Lastly, the I-95 Corridor Coalition prepared and distributed a press release a few days prior to the Thanksgiving holiday, encouraging holiday travelers to use the website to help them with their travel plans. The press release was picked up over the following days by a large number of mainstream media outlets including USA Today, National Public Radio (NPR), ABC, and FOX, as well as by several social media networks and blogs. This marketing push brought a record number of visitors to the website during the week of Thanksgiving and had a significant effect on the size of the website user base. The site saw 7,921 visits in one day on the day before Thanksgiving whereas the prior high was only 325 visitors in one day. The website user base grew from approximately 6,000 users to over 18,000 users in the 2 weeks following the Thanksgiving holiday.

12.4 USER EXPERIENCE

For Mobile Millennium, the evaluation team was unable to conduct its own user survey, but was granted permission to publish the findings of two user surveys conducted by Nokia, the major private sector partner. For the January 2009 survey (370 responses, response rate 28.5 percent), respondents who had decided not to use the system in the future suggested that the following improvements would convince them to try the system again:

1. Better user experience (16 comments)
2. More accurate travel data (10 comments)
3. Higher quality traffic incident data (10 comments)
4. Traffic data on more roads (8 comments)
5. Personalized traffic information for the routes I drive (7 comments)
6. Driving directions (7 comments)

This indicates some concerns regarding accuracy, but generally at a low level.

For a real-time traffic information system, regardless of how the information is delivered to users, the user experience is critical to success. Even if marketing efforts are successful and travelers visit a website, look at an information screen, or download an application for their smart phones, they will not seek out the information again in the future if they do not have a good experience. When it comes to a website or a smart phone application, it is most essential that the content be presented in such a way that the user can find the information they need and that the information be perceived as useful and accurate.

The majority of users were infrequent: only 11 percent used Mobile Millennium 6 or more times in 7 days in June 2009. One behavior that emerged from the June 2009 survey (286 responses, response rate 18.5 percent) was that while almost two thirds of users kept the application open for at least the duration of their trip, the remaining third closed the application after viewing traffic conditions. This is important because by closing the application, the mobile phone no longer acts as a traffic probe, significantly reducing probe penetration and most likely reducing the accuracy of the traffic information provided by Mobile Millennium. This behavior occurred more often among less frequent users, so it is likely that less than one third of trips are affected. The reasons for users closing the application are unknown.

Respondents provided a range of perspectives on why and how they used the system, and offered suggestions on how to improve it. Users took comfort from knowing traffic conditions, and the ability to make more informed travel decisions. The majority of users indicated they open the application to view traffic data before driving, although a sizeable minority (almost one in five) admitted to viewing traffic data while driving when encountering traffic.¹⁶ Many users expressed an interest in more features, including personalized traffic information, as a way to improve the relevance of the information to their travel. When it comes to an information display screen that is not interactive, much of the user experience is driven by the user's expectations of what information will be provided, and their expectations can be shaped by marketing efforts.

Also important with a display that is not interactive is letting the public know what information is coming "next," again setting expectations. The stakeholders involved with the Tysons Corner Center displays believed that mall patrons might grow impatient waiting to see the information of

¹⁶ It is unknown whether this comment refers to viewing traffic data as the user approaches traffic congestion or when the user is in traffic congestion.

interest to them and subsequently choose to leave before the playlist reached that information. To address this concern, the team designed the display to include an area to the side of the main information listing the next several features to be displayed (see the words listed down the left side of the screen shown in Figure 16).



Figure 16. Display Shows the Next Feature to be Shown to Viewers

12.5 PRIVACY

The use of probe vehicles as an alternative to traditional fixed sensors raises the potential for privacy issues related to the tracking of personal smart phones. Mobile Millennium addressed this issue by developing specific privacy protecting methods to generate traffic data at pre-set locations (referred to as virtual trip lines or VTLs) rather than by tracking individual mobile devices or using identification information. Users were positive about how Mobile Millennium protected their privacy, with 68 percent of respondents indicating they trust the system to protect the privacy of their travel data, 7 percent indicating they did not trust the system, and 25 percent indicating they either did not know or did not care about their travel data privacy.

Mobile Millennium was transparent with participants as to what personal data would be collected and why. Participants appear to have responded positively, recognizing the tradeoff between personal data collected by the respective tests and the quality of personalized services received in return. Obviously with the more personalization desired by consumers, there will be a greater likelihood that they will need to provide more personal data.

12.6 INSTITUTIONAL ISSUES

When it came to institutional issues, the SafeTrip-21 test beds provide some interesting lessons for others considering similar deployments. Interestingly, mobile millennium had relatively no institutional issues and actually benefited from long-standing institutional partnerships. With the traveler displays project at Tysons Corner Center, the number of stakeholders involved posed some challenges.

One challenge that can come into play when working with a large set of diverse stakeholders is that they may not all have the same vision for the project. As a result, it is extremely important to come to agreement regarding the concept and vision for the system and to develop a clear concept of operations. Enlisting the help of an outside neutral party to lead this activity can be helpful. The public displays in Tysons Corner Center involved numerous stakeholders ranging from the State Department of Transportation, to transit agencies, to the mall management, to a local transportation association. At times these various stakeholders did not necessarily agree on what should be a priority in terms of the information provided to patrons and travelers. The various partners found it helpful to put their goals in writing with the help of an outside contractor who took the lead in writing the concept of operations for the system.

Working with multiple stakeholders on a traveler information display can make it challenging to determine how much real estate should be allotted to each piece of content – since the content on a display is not interactive for the user, the stakeholders have to determine which content is most important to users when designing the system. When it came to the displays in Tysons Corner Center that involved multiple stakeholders providing content to the system, there was some competition for display time. The project team had to balance entertainment and traveler information content. Mall management wanted to include entertainment content on the displays and preferred that a significant amount of screen space be reserved for this content. VDOT, in contrast, wanted the focus of the system to be the traveler information. A compromise solution was reached in which a portion of the screen was reserved for weather and news feeds, with the majority of the screen space reserved for other information. As for ensuring that the traffic information would have sufficient coverage, a solution was devised by which the system cycled through a playlist of items to display, with the traffic information screens recurring frequently in this display list to ensure that a viewer never had to wait long to receive traffic information.

One final challenge that can be encountered when working with a large group of stakeholders is communication. Planning for frequent communication throughout the duration of the planning phase and into the deployment phase is key to success. With both of the I-95 traffic information applications, the team held weekly developer calls as well as weekly project management calls, and these allowed the team to quickly resolve any issues that had arisen in the past week.

Another interesting lesson that can be taken from the Traveler Displays project is that there can be unexpected challenges encountered when deploying traffic information in a commercial environment. One example of this is that advertising, a traditional source of revenue to help cover the costs of some real-time traveler information systems, was not permitted in the commercial environment in which they were working. VDOT was interested in including advertising on the displays as a potential revenue source so that the system could be self-supporting. However, this type of arrangement was not permitted in the shopping center due to existing advertising agreements various businesses have with the mall management. Through discussions, an agreement was reached in which no advertising was allowed, although information on stakeholders and stakeholder programs would be permitted.

Another example is that identifying workable screen locations in the mall was somewhat challenging. The final locations for the screens were not necessarily those that the project team might have selected if given the option of placing them anywhere within the shopping center. Locations near mall entrances and exits were initially considered, but there were concerns that people viewing the displays might impede traffic entering and exiting the mall. Also many prime locations are leased and used for advertising space, so these locations were not available for traveler information displays. There were also restrictions regarding blocking the line-of-sight to existing signs, which eliminated additional locations from consideration. The final five locations

were selected so as to be in high-traffic locations, but with these other concerns taken into consideration. Reaching consensus on these locations required many different site visits and numerous discussions with the mall management.

12.7 CONCLUSIONS

The SafeTrip-21 Initiative added to the body of knowledge regarding providing real-time traffic information to drivers. The most notable finding related to this topic has to do with the people and processes involved in deployment. Strong partnerships and formalization of relationships can go a long way toward producing an ITS application which can truly have a positive impact. Further, there needs to always be awareness that the end-users (i.e., travelers) are a “partner” to the test. Incorporating their needs in an ongoing manner from early on in the development process through to the marketing activities is key to a successful deployment.

The importance of assessing user needs early and often should not be underestimated.

Consideration of travelers as the end-user and the ultimate stakeholder is often overlooked early in the deployment process. The project partners involved in developing the applications explained above voiced the need to establish a means for identifying user needs before developing or deploying applications. Preliminary user needs assessments, beta testing, and forums for on-going user feedback are all popular methods for improving application design, identifying system bugs, and achieving better overall system performance and usefulness. It is also clear that **users expect an efficient and usable interface for receiving travel information.** For example, when it comes to the public information display screens that were not interactive, much of the user experience was driven by the user understanding of the information available. It was important to let users know what information would be displayed next versus leaving them waiting to find out. The stakeholders involved with the displays at Tysons Corner Center believed that mall patrons might grow impatient waiting to see the information of interest to them and subsequently choose to leave before the playlist reached the information that they needed. To address this concern, the team designed the display to include an area to the side of the main information listing the next several features to be displayed as well as content such as news and weather to keep them entertained while they waited. Additionally, survey results from the Mobile Millennium test showed that users sought a better user experience when accessing the application and that improvements would encourage them to continue using the information.

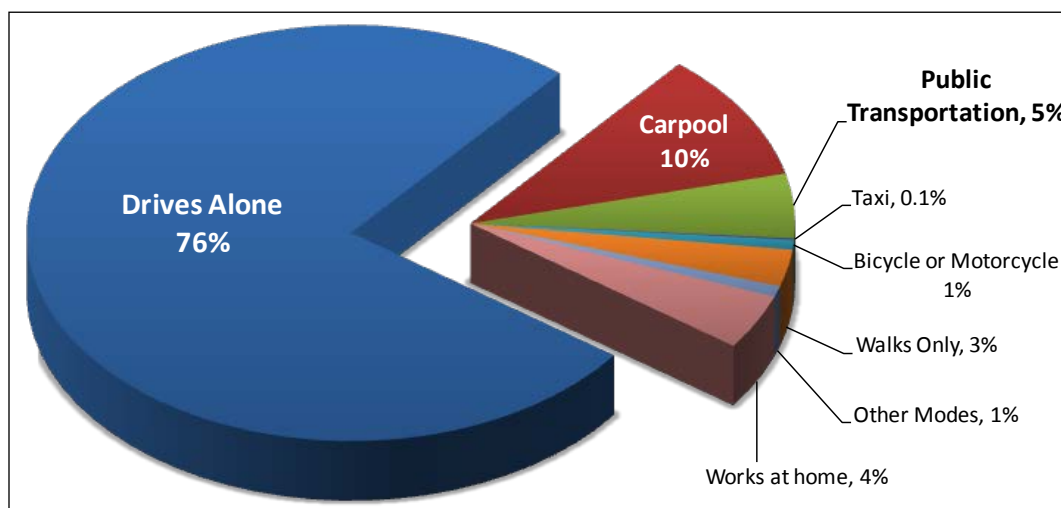
Another major lesson learned related to providing a useful and usable real-time traffic information system is that marketing is critical to success regardless of the method by which the information is accessed by the public. **Providing travel information in public places necessitates creativity to make potential users aware of the service.** For example, with static public displays of information such as those in the Virginia Welcome Centers and at Tysons Corner Center, it is critical to “advertise” the service to passersby so that they will be enticed to stop and take a look. In most public places information screens will be competing with many other signs, advertisements, and information sources, so it is critical to in some way inform the public of what information can be found on the screens. In this case the screens in the Welcome Centers are located alongside a variety of information including travel brochures and other television screens displaying travel information, while the screens in Tysons Corner Center were competing with storefronts, advertisements, sounds, and lights. The Tysons Corner Center stakeholders found it helpful to create a floor sticker to draw attention up to the screens as well as a bezel to surround the screen advertising that the screen includes “Live Traffic Information.” **Traditional press releases are also still effective in reaching large media outlets.** For example, the I-95 Corridor Coalition prepared and distributed a press release a few days prior to the Thanksgiving holiday, encouraging holiday travelers to use the Trip Planner website to help them with their

travel plans. The press release was picked up over the following days by a large number of mainstream media outlets including USA Today, National Public Radio (NPR), ABC, and FOX, as well as by several social media networks and blogs. This marketing push brought a record number of visitors to the website during the week of Thanksgiving and had a significant effect on the size of the website user base.

This experience with developing applications that provide useful and usable real-time traffic information also provided insight into future research needs. **Further innovation is needed to put timely and useful travel information at travelers' fingertips while keeping drivers from being distracted.** U.S. DOT is cognizant of the risks of distracted driving. However, as in-vehicle technology continues to develop, supporting safe driving habits will continue to be a challenge. U.S. DOT will likely need to explore avenues for advancements in technology to prevent driver distraction as well as instilling a safety culture mindset to support the goal of a change in driver behavior.

13 PROVIDING MULTI-MODAL TRAVEL OPTIONS TO TRAVELERS

In metropolitan areas around the country, information about alternative modes of transportation is becoming more readily available and accessible to the public. As traffic congestion continues to plague major cities and use of our nation's roadways exceeds capacity in many areas, transportation agencies are encouraging travelers to consider or choose travel options other than driving alone. Carpool, vanpool, public transportation, walking, bicycling, and private transportation like taxis are all examples of the different modes that can reduce the burden of commuter and daily travel on roadways. Figure 17 from the American Community Survey conducted by the US Census Bureau shows the principal means of transportation to work for commuters nationwide. At 76 percent, the great majority of Americans are choosing to drive alone to work.



Source: Data from American Community Survey conducted by the US Census Bureau. Figure developed by SAIC.

Figure 17. Principal Means of Transportation to Work, 2009¹⁷

However, in major metropolitan areas like New York City and San Francisco where alternative modes are more available, use of public transportation for commuting to work is 31 percent and 15 percent, respectively.¹⁸ As travelers have shifted from commuting via personal automobile to taking public transportation or other modes over the years, benefits of this shift have been realized and researchers and stakeholders have developed an interest in trying to better understand the cost-benefit factors that motivate those who do choose alternative modes. There are a number of possible benefits, both personal and holistic, when travelers choose other travel options including:

- Reduced traffic congestion
- Lower costs
- Shorter travel time
- Increased safety

¹⁷ 2006-09: U.S. Department of Commerce, U.S. Census Bureau, *American Community Survey*, available at <http://factfinder.census.gov> as of Oct 22, 2010.

¹⁸ McKenzie, Brian S. *Public Transportation Usage Among U.S. Workers: 2008 and 2009*. Issue Brief no. ACSBR09-5. American Community Survey Briefs, U.S. Census Bureau, Oct. 2010. Available at: www.uscensus.gov/prod/2010pub/acsbr09-5.pdf.

- Health benefits (e.g., less stress, more exercise, increased energy level, etc.)
- Environmental benefits (e.g., lower fuel costs, cleaner air.)

While encouraging commuters to consider alternate travel options is nothing new, the SafeTrip-21 initiative provides several examples of technologies that promote the use of alternative modes of transportation for personal and commuter travel by providing multi-modal travel information to travelers. Two of these applications provide specific cross-mode comparison information to allow travelers to consider alternative modes based on the factors that are most important to them (i.e. possible benefits listed above). The three tests listed below focused on providing multi-modal travel information to travelers and can offer lessons learned to other agencies interested in providing similar information:

This **Networked Traveler – Transit /Smart Parking (NT-T/SP)** test consisted of real-time transit information and trip planner applications that serve travelers along the US-101 corridor in San Francisco, California. The primary purpose of the test was to provide information to travelers in real-time across all transit agencies that serve the US-101 corridor. This “one-stop shop” for traveler information was designed to help travelers make better pre-trip planning decisions in terms of mode selection and to serve as a tool for planning transit trips from any origin to any destination considering all transit options available. The NT-T/SP test is unique in that it integrated a broad range of real-time multi-modal transportation information, including transit and parking information. To provide this information to travelers, the project team developed three applications to allow users to access traveler information pre-trip or on-the-go: 1) a multi-modal trip planner website, 2) a transit and parking traveler information website, and 3) a transit smart phone application, which allowed users to access the information pre-trip or on-the-go. Using the trip planner website, users could input any origin and destination along the US-101 corridor and receive detailed information about the different transportation mode options available for the trip while considering each option based on time, cost, and/or carbon emissions.

The primary purpose of **Providing Multi-modal Travel Information to Airport Users** was to provide information to airport travelers about the available ground transportation options to and from Baltimore-Washington International (BWI) Thurgood Marshall Airport in Baltimore, Maryland. The project team developed the *BWI Ground Access Information System*, which provides information about the different travel options to/from BWI Airport including driving, taxi, and vanpool as well as various public transit options including Amtrak, commuter rail, light rail, and buses. Additionally, the system provides estimated cost and travel time information, traffic conditions information for major roadways surrounding the airport (via a color-coded map), and updates about traffic congestion or transit delays along the planned route, all of which aim to help airport travelers better plan their trips to and from BWI Airport. The system was designed to help make the airport travelers more aware of all modal options available to/from BWI and to give travelers access to the information pre-trip, on-the-go, and inside the airport via a website, mobile website, and kiosk, respectively.

The test involving **Displaying Travel Times in Public Areas** includes two applications, both of which involve providing the public with traveler information via a screen in a public place like an interstate rest area or local shopping center. The first application is available at two Virginia Welcome Centers and focuses on providing long-distance travel information to drivers traveling on Interstate 95 looking to get a glimpse of traffic conditions ahead. The second application, which is relevant to multi-modal information, is available at Tysons Corner Center (TCC), one of the largest shopping centers in the country, located in metropolitan Washington, DC (metro DC). The TCC application includes five large flat-panel display screens positioned at various locations throughout the shopping center. Although similar in concept, this project is quite different than

the effort put forth at the two Virginia Welcome Centers. The screens at TCC are the result of a coordinated effort put forth by local, State, and national stakeholders to integrate existing traveler information resources into one system. The screens originated as an effort to update the public on major construction projects taking place in the region and educate them about the alternate transportation options available. The traveler information screens allow shoppers, visitors, and employees to view multi-modal information by rotating through a variety of content including:

- Real-time traffic conditions and travel times;
- Traffic camera views for surrounding local roads;
- Transit map, bus route, schedules, and other public transportation information; and
- Other local transportation, construction, and advertisement information.

With the information available, users can make better decisions about when to leave the shopping center based on traffic conditions on the surrounding roadways or the transit schedule information for the next or last available bus.

With these three tests, the SafeTrip-21 Initiative explored ways to provide multi-modal travel information that allows travelers to consider alternative modes and make more informed travel decisions. All three tests have comparable features and resulted in valuable lessons learned on the topic of providing multi-modal travel information to travelers. The lessons learned are organized and presented according to the following categories:

- Design and Development
- Deployment
- Marketing
- User Experience
- Privacy
- Institutional Issues

13.1 DESIGN AND DEVELOPMENT

In terms of development, there were similarities and differences in how each project team approached developing the applications for each test and several lessons learned related to providing multi-modal travel information.

The NT-T/SP test was developed by the California Partners for Advanced Transit and Highways (PATH) and the University of California at Berkeley in partnership with the California Department of Transportation (Caltrans). With the support of several regional partners, PATH developed a system that provided the content for a set of applications named the Trip Planner website, the Web Based Traveler Information website, and the Smart Phone Application, which together make up the suite of tools branded PATH2Go. As mentioned, the PATH2Go applications provide a variety of transit and parking availability information across most Bay Area transit agencies.

In order to integrate this type of information into one system, PATH worked closely with the transit agencies involved to establish a constant stream of up-to-date schedule information, route information, and changes in service. While two of the transit agencies provide open source data to the general public, the other transit agencies involved either did not provide the data to the public or did not have it available. PATH put forth a considerable effort to coordinate retrieving this data or gathering this data themselves. Some of their efforts included implementing GPS trackers on trains and buses were not available, building route shapes to identify bus routes and stations/stops, and creating algorithms to estimate real-time arrivals and departures based on

real-time and historical data. Where real-time arrival and departure times were not available, automatic vehicle locator (AVL) data was not available, or GPS trackers could not be installed, the project team used normal schedule information to feed the traveler information server. The system also offered parking lot capacity or real-time parking availability information for Park-and-Ride lots to travelers who use a local and regional train service. As a test, four such parking lots were instrumented with sensors to count the number of vehicles entering and exiting the lot in order to provide the available number of parking spots in real-time.

Lastly, the system had multi-modal trip planner capabilities, allowing users to compare cost, travel time, and environmental impact information for different mode options, including transit only, driving to transit, driving only, and bicycling trips. While the transit and mode comparison information (including estimated costs and environmental impacts) were developed specifically for the system, the PATH team leveraged the open source Google Map API to provide maps, directions, and estimated travel time information for driving and bicycling trips.

The BWI Ground Access Information System was developed by the I-95 Corridor Coalition in cooperation with BWI Airport. As mentioned, a key feature of the test was the integration of traveler information for many different travel modes into a single system.

Integrating data from numerous sources can present challenges in terms of the amount of customized software development that is required to receive the data in various formats and manipulate it to incorporate it into one system. In the case of the BWI system, many of the data sources did require the development of custom routines. For example, taxi and shuttle service cost information was obtained from BWI and the shuttle services and was loaded into the database to support the system. Custom routines were then developed to estimate the costs of trips to and from BWI. Similarly, service routes and schedules for Amtrak and MARC services had to be coded into the system databases to provide users with information about Amtrak and MARC services. What is key to a project such as this where multiple data sources must come together seamlessly is to look for opportunities to make use of any synthesized data already available from other systems. In many cases the exact data may already be available, eliminating the need to receive and manipulate raw data. Many agencies and organizations are moving toward open source data, making this an even easier feat. The BWI Ground Access Information System leveraged the following tools and data available from other systems:

- Google Maps API to display maps to users and provide turn-by-turn navigation.
- Real time delay information from travel time data that was already available to the I-95 Corridor Coalition through other projects.
- Information about Metrorail through an Application Program Interface (API) that allowed requests for rail information to be made directly to WMATA systems.

The TCC traveler information screens were developed by the Virginia Department of Transportation (VDOT) in cooperation with the Virginia Department of Rail and Public Transportation (DRPT) and other transportation partners in the Northern Virginia region. Associated with the major construction activities taking place around TCC were significant outreach activities that involved discussions between local businesses and community members concerned about the traffic impacts of the planned construction. During these discussions, VDOT and its partners developed the concept of integrating existing traveler information resources into one system specifically designed to be launched at TCC. The project partners engaged management at the shopping center and began working towards developing the system for the traveler information screens.

The next step in the development phase of the project was to clearly define a concept of operations and to identify the specific information sources that would be made available on the traveler information screens. A VDOT project partner summarized the intent for the system concept when he said, “Integrating multi-modal information in a single display was a key feature that differentiated this system from other traveler information systems available in the region.” The VDOT contractor worked closely with stakeholders to integrate the variety of content listed above in the application introduction. The traveler information screen system integrated 511 information and traffic camera video feeds available from VDOT as well as open source data from local transit agencies for transit information. The system also took advantage of an easily integrated resource from other SafeTrip-21 tests on the I-95 Test Bed to develop a traffic conditions and travel time maps for the local area.

A common theme among all three tests is that each project team developed a single system that utilized a variety of existing traveler information to provide users with multi-modal information in one location. Instead of users having to search several sources to obtain the same information, the systems developed for each test allowed users to visit a website, access a smart phone application, or view a kiosk or information screen to consider all travel options relevant to their trip or location. Because each system compiles traveler information from several different transportation sources, the applications available save users time and make considering alternative modes of transportation less of a hassle. Additionally, each test leveraged open source data from transportation agencies or existing traveler information from project partners and integrated it into the system to automatically update content when changes occur, which can cut down on development and maintenance costs of a system. Lastly, developing one system as the source for several applications like a website, smart phone application, or kiosk simplifies development.

13.2 DEPLOYMENT

While working to complete development of the NT-T/SP test, the project team began finalizing plans to launch the PATH2Go applications in order to make them available to travelers. PATH and Caltrans worked closely with the Metropolitan Transportation Commission (MTC) to formalize plans to launch the applications on MTC’s popular and high traffic volume 511 website.¹⁹ The application was officially launched in July 2010 when MTC posted a link to the “Networked Traveler” project website²⁰ developed by PATH to host the applications. The PATH2Go Smart Phone Application was also available for download from the Apple App Store and Google Android Market. From a user’s perspective, the applications were being provided by MTC, provided by UC Berkeley, or available for free download through developer-driven app markets for smart phones. The audience for the applications was any traveler in the San Francisco Bay Area.

The primary deployment activities involved maintaining the system’s data infrastructure of tracking devices, parking sensors, and source information. Additional developmental needs were also identified and addressed as use of the applications increased initially. This included introducing new versions of the smart phone application to address minor design flaws and improve functionality.

In deploying ground transportation information to airport users, the project team worked closely with BWI Airport staff to determine the best approach for delivering the applications to travelers to

¹⁹ Link to the MTC 511 website: <http://www.511.org/>

²⁰ Link to the Networked Traveler project website: <http://www.networkedtraveler.org/>

the airport. The BWI Ground Access Information System website was the first application available and first launched when it was released in October 2009. BWI Airport posted a link on the home page of their website to advertise the new information available. From the user's perspective, BWI Airport was the agency delivering the service. The audience for the information provided by the applications was any traveler to or from BWI Airport.

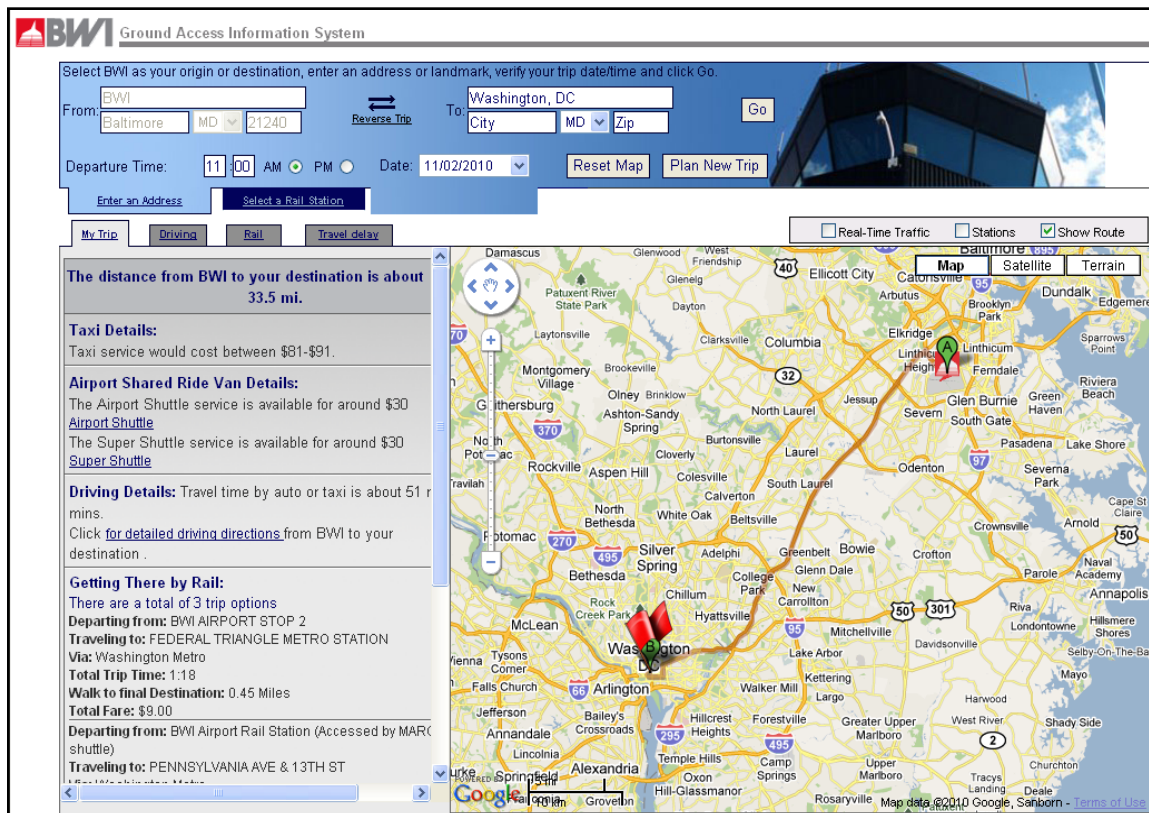


Figure 18. Example of Information Provided on BWI Ground Access Information System Website Application.

Although the mobile website and kiosk were intended to be complimentary to the website, neither was permanently launched due to a number of deployment challenges. It is important to note that the mobile website aspect of this test was re-scoped during the development phase to address U.S. DOT concerns on distracted driving. Developmental changes were introduced to discourage users from accessing the information while driving. Although the mobile website was eventually approved for launch by U.S. DOT, the mobile website was not actively marketed or well-used. The kiosk was initially deployed in April 2010, but was removed in June 2010 for a number of reasons identified by BWI Airport staff and the project team including:

- Location –The kiosk needed to be relocated to a location where more foot traffic takes place.
- Hardware – Airport staff felt that it was important that the kiosk be secured to eliminate any risk of it tipping over. Staff also desired to have the electrical plug secured to the wall such that it could not be unplugged.
- Software – Developmental changes were needed to prevent users from using the kiosk for reasons other than intended (e.g., browsing the Internet).

- Ownership – There was no agreement in place regarding which party owned the kiosk and which was responsible for maintaining the kiosk.
- Design – BWI Airport staff requested that the BWI Ground Access Information System be expanded to provide information about Maryland Transit Administration (MTA) local buses that serve Metro Subway and Light Rail stops in the Baltimore region.

In deploying public information displays, the main issue of deployment was establishing the physical location of the traveler information screens in TCC. VDOT staff noted that this was more complicated than they had anticipated because of the many restrictions on display locations that existed in the shopping center. Reaching consensus prior to the launch of the screens required many different site visits and numerous discussions with the mall management staff.

From the user's perspective, VDOT was providing the traveler information screens to shoppers in cooperation with TCC. The audience for the screens was any shopper, visitor, and employee traveling to and from the shopping center. The primary deployment activities involved observing the system to ensure operability. Several safeguards and server redundancy were built into the system design to prevent failures.

Understanding the deployment experience for each of the tests provides insight into how each agency initially launched the applications as well as requirements for maintaining the system once it was released. Each test provided information to a different audience and can help other agencies better understand how to deploy multi-modal information for a major metropolitan area, in an airport environment, or in a shopping center environment. All three tests showed that cooperation and continued dialogue among project partners from development through deployment was essential in achieving a successful deployment experience. Specific institutional issues associated with deployment are discussed later in this chapter.

13.3 MARKETING

Marketing was a key component of the deployment efforts for each test. With the launch of each application, the project teams for each test set out to spread the word about the technologies and the multi-modal information provided by each system. The three tests offer lessons learned about the effectiveness of targeted marketing efforts when deploying ITS applications for different audiences. The results of the marketing efforts provide insight into the success of methods used to reach out to potential users. Two of the tests integrated methods for understanding these results through system acceptance and performance by tracking the number of users and usage of their systems. Exploring usage of the multi-modal applications provides insight into the public need and use of the applications.

Targeted marketing efforts for the NT-T/SP test began with the release of the PATH2Go Smart Phone Application into the respective app markets and the launch of all PATH2Go applications to Bay Area travelers through the MTC 511 website in July 2010. The project team continued marketing the applications with the distribution of an August 2010 press release to local media sources as well as efforts to distribute flyers at various transit stations covered by the system in September and October 2010. PATH also coordinated an additional marketing effort using the popular social media service, Twitter. The project team posted a "tweet" to "followers of a Twitter account associated with the local/regional train service called Caltrain. After less than 4 months of availability, the NT-T/SP test enjoyed significant exposure to the PATH2Go applications as marketing efforts resulted in over 600 PATH2Go Smart Phone Application downloads and visits to the PATH2Go website applications from over 900 unique users accounting for over 1,600 total visits at an average of 1.82 visits per user. PATH developed server logs to track smart phone

application usage and utilized a free web analytics tool called Google Analytics²¹ to track usage of the website applications. Although the project team was able to track the use of the applications eventually, collection of usage information did not begin until August 2010 preventing the project team from understanding the immediate impacts of the launch. Additionally, the free analytics tool provided much greater detail for website applications usage compared to the server logs for tracking smart phone application usage.

The initial targeted marketing efforts of advertising the applications on the MTC 511 website, distributing a press release, and handing out flyers at transit stops/stations were effective in attracting users and increasing awareness of all PATH2Go applications. The most significant increase in usage of the website applications came as the result of the Twitter post. The website traffic generated by the Twitter post increased the total number of absolute unique visitors to the website by 104 percent and the total number of visits by 66 percent in the span of five days.

As mentioned before, the BWI Ground Access Information System website was first launched and marketed to airport travelers via the BWI website's home page. Additional marketing efforts from BWI Airport staff included advertising the website application to the "followers" of their popular Twitter account. With nearly 2,000 followers at the time, the BWI Airport account provided an additional opportunity to increase awareness of the system that provided multi-modal ground transportation information to airport travelers. The project team for this test also employed the free services of the Google Analytics tool to track website usage and began collecting usage information prior to the launch of the BWI Ground Access Information System website. This allowed the project team to begin analyzing the success of the targeted marketing efforts immediately after the website application launch. After 8 months of availability, the BWI Ground Access Information System website enjoyed visits from over 21,000 unique users for a total of over 23,000 total visits to the website at an average of 1.13 visits per user.

The usage analysis performed by the evaluation team provided insight into the success of the targeted marketing efforts put forth by the project team. The initial launch was effective in growing the number of users and establishing initial exposure to airport travelers. Interestingly, while there were several factors affecting website usage simultaneously, it appeared that using Twitter specifically may have been an effective marketing tool for increasing awareness of the multi-modal information available to travelers. Unlike the NT-T/SP test, which posted a single tweet on a popular local transit account, BWI Airport continued "tweeting" about the website on its account for several months. By comparing the percent different in cumulative visits per day when tweets were posted compared with other days, the usage analysis showed that the tweets increased usage in the range of 1.5 to 4 percent per day while the average for the remainder of the evaluation period came in at 1.28 percent.

As mentioned before, the TCC traveler information screens were launched on Black Friday in November 2009 in an attempt to reach out to shoppers, visitors, and employees just in time for the busiest shopping season of the year. While the screens were in place and operational, additional content was integrated into the screens in January 2010. Although the traveler information screens were live and available to the public beginning in November 2009, the project team waited to market the technology until final content was implemented. Four primary efforts were put forth to market the screens and the information that they offer:

²¹ Link to Google Analytics: <http://www.google.com/analytics/>

- A press release distributed by the VDOT Public Affairs Office;
- An update to the Tysons Corner Center Store Directory and Map by the management staff;
- Brochures distributed to all retail stores within the shopping center to advertise the screens to employees; and
- Installation of bezels around each screen and a floor graphic near each screen to draw attention to the information presented (Figure 19).

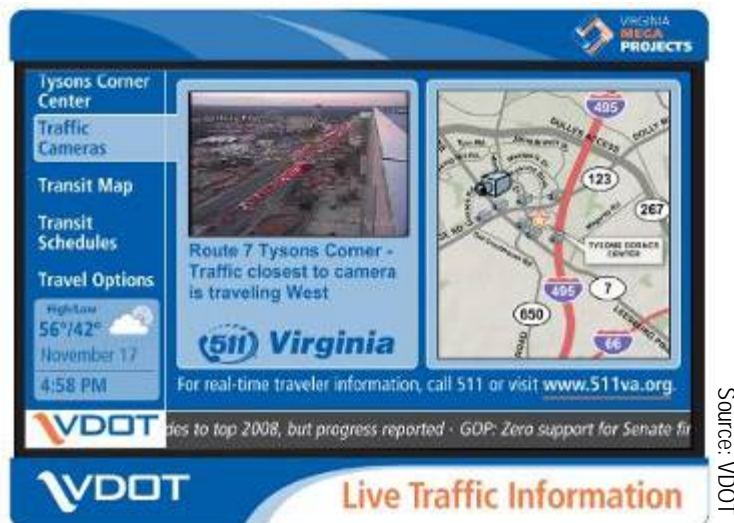


Figure 19. Bezel for the Traveler Information Screens at TCC.

The project team had no direct means for understanding usage of the traveler information screens beyond observing shopper, visitor, and employee interactions with the screens on occasion. In fact, the primary marketing efforts were the direct result of these observations by project stakeholders after observing the lack of user attention on the screens in such an information-rich environment like a retail shopping center. However, despite initial challenges, the targeted marketing efforts put forth by the project team did result in significant media exposure to the traveler information screens. Local newspapers, radio shows, and television stations covered the press release distributed by VDOT. Local travelers learned about the new traveler information screens by viewing local CBS and FOX television news reports, reading articles in newspapers like the Washington Post, or even listening to local news radio shows from NPR and WTOP. Even a popular local CBS news anchor “tweeted” about the traveler information screens to her 11,000+ followers on her personal Twitter account after noticing them at TCC.

While no quantitative usage metrics were available to better understand the effectiveness of each marketing effort, it is clear that the press release and advertisement efforts inside the shopping center increased user attention to the screens.

Each test enjoyed a successful launch and initial use of the applications that provide multi-modal information to travelers. All three tests put forth a variety of targeted marketing efforts to increase the number of users and continue exposure to the applications over time. Website marketing via project partners, press releases distributed to media sources, and use of social media websites like Twitter all proved to be effective for marketing ITS applications available via websites, mobile devices, and traveler information screens. The deployment experience for each test made it clear that a targeted marketing strategy is necessary to a user base initially. Although none of the sites developed an official strategy prior to deployment, future ITS deployments should schedule, plan, and budget for marketing efforts as they are essential to putting the technology in the hands of travelers.

The usage analysis performed by the evaluation team suggests that newer, more progressive forms of marketing like using social media websites such as Twitter can be effective for

increasing awareness of multi-modal traveler information applications. Two of the tests chose to launch applications by making them available via a project partner website. More traditional forms of marketing like preparing a press release were also used to generate additional exposure but were only effective if covered by a major media source, which the project team has no control over. Social media sites like Twitter were quite effective in significantly increasing user exposure to website applications in the short term. However, usage of the applications quickly returned to previous usage levels only a few days after the tweets. It became clear that targeted marketing efforts are essential to establishing initial user exposure to ITS applications, but the usefulness of or need for the information available from the technology generally drives consistent or return use.

All three tests showed that establishing a method for tracking usage of the applications was an important factor in understanding the effectiveness of marketing efforts. The BWI Ground Access Information System project team integrated usage tracking prior to launch and was able to observe the results of targeted marketing efforts immediately while the NT-T/SP test did not begin collecting usage information until after launch. Developing means for tracking usage prior to deployment and through launch of the technology allows the project team to better understand the results of targeted marketing efforts on an on-going basis. Through usage analysis, project teams can observe system acceptance and performance and identify opportunities to initiate additional marketing efforts if needed to reach more travelers interested in multi-modal travel information. Additionally, the evaluation team conducted a user survey for each application and asked respondents to identify how they learned or heard about the applications. The survey results provided useful insight in understanding how the majority of survey respondents were exposed to the application.

13.4 USER EXPERIENCE

Understanding the user experience associated with applications that provide multi-modal information allows the project team to improve design, identify user demographics, and deliver more useful information to travelers. Details about the multi-modal information that each test provided is important in understanding what was and was not useful to travelers. The evaluation team conducted activities to gather insight into the user experience for each test including usage analysis, user and conceptual surveys, focus groups, and interviews with the deployment partners. These data collection efforts resulted in a better understanding of user-perceived benefits and perceived accuracy and usefulness of the technologies. The user experiences associated with these three tests can help other agencies better understand the type of information offered by these systems, identify user needs, and offer lessons learned related to providing multi-modal information to travelers.

The PATH2Go Trip Planner website provides multi-modal trip planning information for travel along the US-101 corridor in the San Francisco Bay Area. Users accessing the website can plan a trip by entering an origin and destination in the form of a physical address, landmark, transit station/stop, or any other location recognizable by the system. In return, the system provides detailed information about the different transportation options available for the trip. For each trip option available, the system provides the total time required to complete the trip, the estimated total cost of the trip, and the expected carbon emissions or savings as the result of the trip; allowing travelers to make a decision based on which factor is most important to them for that trip. A trip summary is provided that allows users to consider the cost/benefit of choosing one option compared to another. For trips involving driving with a transfer to transit, the system provides the estimated cost of fuel for the driving leg of the trip, the actual cost of parking when the user will transfer to transit, and the actual fare for the transit leg of the trip. Users can even

enter their vehicle's fuel efficiency to update their itinerary with a more accurate estimate of fuel consumption. To help users consider the potential savings of considering alternate modes, the system displays a graphical representation of work/relax time versus driving time and driving emissions versus emissions saved by taking public transit for each trip option available.

The primary purpose of the PATH2Go Web-Based Traveler Information website is to provide real-time arrival and departure times for all transit routes where available as well as real-time parking availability information for several instrumented Caltrain lots along the US-101 corridor. This allows transit riders to browse transit options and plan trips across several providers versus going to each transit agency website individually. Users can view real-time information versus just schedule information, which could impact user perception of the convenience of riding transit. The parking availability information gives commuters the opportunity to consider taking an alternative mode by parking their car and riding transit for the remainder of their trip.

The PATH2Go Smart Phone Application is a multi-agency transit trip planner that provides real-time arrival and departure information and user location-based trip details for transit available in the Bay Area along the US-101 corridor. The application uses the GPS functionality of smart phones to help users identify transit options and guide them step-by-step through a planned transit trip itinerary. The primary purpose of the application is to provide real-time transit information across multiple transit agencies on-the-go. Users can also identify a trip using either website application and choose to send the trip itinerary to their smart phone in order to use the smart phone application functionality for the transit portion of the trip. With access to real-time arrival and departure times on-the-go using their smart phone, users can potentially reduce wait-time at a transit stop/station.

With the help of the project team, the evaluation team tracked application usage and conducted a web-based user survey to assess usage characteristics, perceived usefulness and accuracy, user opinions regarding functionality and usability, respondent travel behavior, and respondent demographics. Usage analysis revealed that 34 percent of the smart phone application users downloaded the app and only opened it once without returning, leaving 66 percent that used it more than once. According to a study produced by an iPhone application analytics firm called Pinch Media, it is actually common for smart phone applications to be abandoned after one use as only 20 percent of users downloading free apps and 30 percent of users downloading paid apps were using the applications the next day.²² Only 45 percent of users accessing either website application returned for at least one additional visit to the website. Frequency of use can often be an indicator of user acceptance and need for applications; however, the usage analysis did not provide a definitive way to determine what caused greater one-time use versus return or frequent use.

The evaluation team collected a total of 121 user surveys that offered additional insight into the user experience with each of the PATH2Go applications. At least one-half of respondents

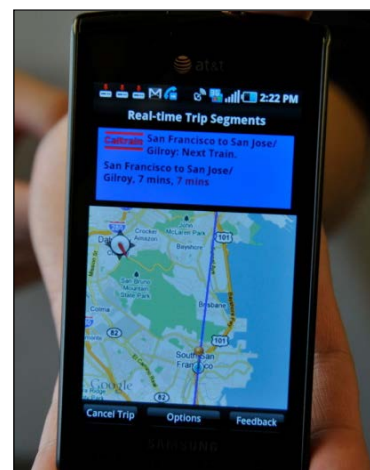


Photo courtesy of PATH

Figure 20. PATH2Go Smart Phone Application (Android platform).

²² Gonsalves, Antone. "Apple App Store Downloads Often Abandoned." InformationWeek. InformationWeek Business Technology Network. 20 Feb. 2009. Web. 6 Dec 2010. Link to article:

http://www.informationweek.com/news/personal_tech/iphone/showArticle.jhtml?articleID=214502225

reported never having used the Trip Planner or Traveler Information websites and approximately one-fourth had not used either the websites in the week before completing the survey. Use of the Smart Phone Application was slightly higher, with approximately one-half of respondents reporting they had never used it or had not used it in the past week. Fifty percent of respondents reported using the applications to plan transit trips for regular trips (e.g., commuting to work or school). When considering the attributes and value of all three PATH2Go applications, users were generally pleased with them, although there were areas where the applications could be improved. There was strong agreement that the ability to access multiple transit services and having reliable real-time arrival and departure information was important. Finally, most respondents reported that having the transit information available to them made them more confident about using transit, though there was not significant evidence that having this information would lead them to choose an alternative mode for their usual transportation. Lastly, almost half of respondents offered suggestions when asked how to make the applications better. Ideas for improvement mainly concerned performance and design and seemed to focus on the ability to get the needed information efficiently, especially concerning routine (daily commute) information.

The BWI Airport Ground Transportation website serves as a pre-trip planner to travelers looking for information about the various modes of ground transportation available to and from BWI Airport. Travelers can visit the website and enter their starting location for travel to the airport or end location for travel from the airport in order to assess the options available. Users have the option to enter any physical address or landmark or choose from a list of transit stations that serve the Baltimore and Washington, D.C. areas; another example of an ITS application that combines information from multiple agencies and sources. For each trip planned the following information is provided on the My Trip tab if available for that trip:

- The total distance to or from BWI from the origin or destination entered;
- The estimated cost of taxi service for the trip;
- The estimated cost for an Airport Shared Ride Van (including services by Airport Shuttle and Super Shuttle);
- A summary of the trip for driving by vehicle or taxi including estimated time and a link to detailed driving directions; and
- A summary of the available transit options for the trip (based on schedule information) including begin stop/station, end stop/station, transit agency, total trip time, walking distance to final destination, and total fare if available for each option.

The system also provides more detailed information related to driving trips and transit trips. Users can access detailed turn-by-turn driving directions for the trip or a detailed step-by-step itinerary for each of the transit options available for the trip; as many as three transit options may be provided. The detailed information provided for each of the trip options allows travelers to compare total trip time, total fare, departure time, and arrival time across all options and make a decision based on which factor is most important to them. Additionally, users can also access a real-time estimate of delay that may occur along roadways near BWI Airport related to the trip planned if a user decides to drive or take a taxi or shuttle.

The BWI Ground Access Information System mobile website was developed to serve as an on-the-go trip planner for travelers who are looking for information about ground transportation options to and from BWI Airport using a mobile device. As mentioned previously, the mobile website accesses information from the BWI Ground Access Information System just as the website does, but presents it in a slightly different manner. Figure 21 shows the home page of

the mobile website as it appears on an Apple iPhone.²³ The final piece of the BWI Ground Access Information System is the kiosk application which was intended to provide ground transportation options to travelers inside BWI Airport, specifically in the ground transportation area of the baggage claim terminal. For convenience, the kiosk had a built-in printer which allowed users to print the detailed itinerary provided after a trip was planned and take it with them.

Because the website was the only application officially launched, the evaluation team both conducted a web-based user survey specific to the information available via the BWI Ground Access Information System website and tracked usage. Usage analysis showed that nearly 90 percent of users only visited the website one time, resulting in very few regular or return users of the website. Visit frequency can be an indicator of perceived usefulness of the site, but in this case, the low number of return visits may be an indicator that air travelers do not need this type of information very often or more than once. Furthermore, it could be argued that the website provides the most value to those who travel less often and who are therefore not as familiar with the airport and the various travel options there. This is further supported by the results of the 132 user surveys collected by the evaluation team. There was only one respondent that indicated that he/she travels through BWI once or twice a week and would have a need for the type of information provided by the website more frequently.



Figure 21. BWI Ground Access Information System Mobile Website.

Despite the low frequency of visits, respondents seemed to be satisfied with the website and the information it provided overall. The large majority of respondents agreed that the information provided on the website was very valuable information to have prior to traveling to/from BWI airport and that other major airports across the country should provide this type of ground transportation information (74 and 80 percent, respectively). About half of respondents agreed that the information made them aware of a travel option that could make their trip to/from BWI less stressful, that the information made them aware of a travel option that could save them time getting to/from BWI airport, and that having this information has increased their satisfaction with travel to/from BWI airport. Nearly half of respondents (46 percent) felt that they were very likely to use a travel option that they learned about from the website. Seventy (70) percent of respondents indicated that they were likely or very likely to visit the website again or recommend the website to someone else, but very few (15 percent) felt that they would be very likely to start using the website on a regular basis; again suggested that user frequency was an indicator of how often the information was needed, not acceptance. Respondents also provided suggestions for how to improve the website. The most common request involved the ability to enter the desired arrival time to their destination versus only having the option to enter desired departure time from their origin location. Respondents also requested that the website provide even more information including more public transit options, more specific directions, and expand the coverage area.

²³ An iPhone Simulator was used in Figure 21 to clearly display mobile website content: <http://www.testiphone.com/>.

The five display screens installed at Tysons Corner Center provided shoppers, visitors, and employees with a wide variety of multi-modal traveler information. Because the TCC screens were developed to prepare for the potential impacts of major construction in the surrounding area, the content is centered on local travel. Traveler information provided on the screens at TCC included:

- Real-time freeway conditions via a color-coded map and corresponding estimated freeway travel times to selected locations in Metro DC;
- Traffic camera views covering roadways in the immediate vicinity of TCC;
- Transit map, bus route schedules, and other public transportation information for the surrounding area;
- Information about traffic incidents and construction activities on roadways in the immediate vicinity of TCC based on 511 Virginia updates;
- Information on Virginia Megaprojects including the HOT Lanes and the Dulles Corridor Metrorail Projects;
- TCC information and advertisements about commuter programs; and
- Local time, news, and weather information.

As envisioned by the project stakeholders, the content is integrated into a single system. Each screen within the shopping center runs on the same system and provides the same information at each location simultaneously. The system is run continuously on each of the screens and uses a structured loop, or playlist, to rotate through the different types of information available and users don't have the ability to query specific information from the screens at any given time. Because such a wide variety of information is provided, the content layout on the screens includes a Coming Features section to show what will be shown next on the screen. Current news from a local news source is provided in a scrolling News Feed section while the current weather, temperature, time, and date are provided in a rotating Weather section of the screen to entertain users while they wait. These features were implemented to prevent users from growing impatient while waiting to see the information that is relevant to them. A total of fifteen different types of information are available on the screens, which can generally be categorized into Travel Tools Information and Awareness Information. With the traveler information screens, shoppers, visitors, or employees at TCC had the opportunity to access a wide variety of multi-modal information via a single source while inside the shopping center. Users could make decisions about the best time to leave or identify the best route to take based on multiple factors – traffic conditions on the surrounding roadways, freeway travel times to primary destinations in the region, or the arrival of the next or last transit bus (Figure 22).

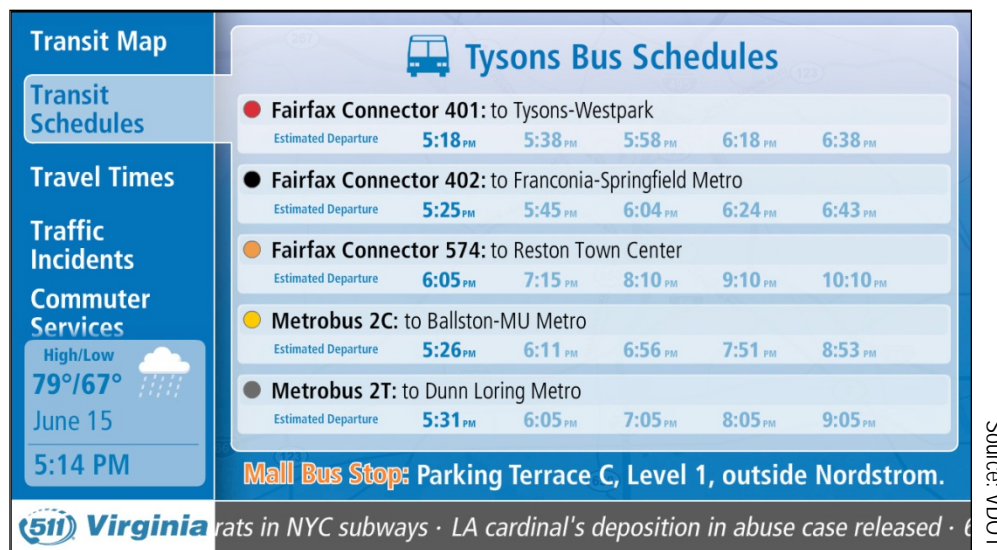


Figure 22. Transit Schedules Content on the Traveler Information Screens at Tysons Corner Center

Due to the sheer amount of content provided on the screens and difficulty identifying users of the information, the evaluation team conducted a conceptual survey of any passerby willing to stop and answer questions. In order to capture the user perspective of both shoppers and employees, the evaluation team also conducted focus groups with shoppers and employees at TCC. Although no information about usage of the screens was available, a total of 385 surveys were collected from shoppers and employees inside the shopping center. Overall, respondents reported that the traveler information screens provided some type of information that was either important to have before leaving TCC or interesting to view one of the screens. The Travel Tools information that gives insight into current roadway conditions (i.e., Travel Times, Traffic Incidents, and Traffic Cameras content) was rated the most important information for visitors to obtain before leaving TCC. The survey findings indicate that, although there were few, public transportation users rated the Transit Map and Transit Schedules content very important to obtain before leaving TCC. Not all information on the screens was seen as being particularly useful or a benefit to travelers. Focus group participants felt that the travel time information, transit maps and bus schedules, and the traffic camera screens were most useful. Perhaps in the future, those screens could be shown more frequently. On the subject of waiting to see need information, most participants said they would wait “a minute at most” or “a few minutes” to see the screens they felt were most useful. One suggestion made was to make the screens interactive so that travelers could get to the information they needed when they needed it.

While the three tests offered different functionality, each put multi-modal information into the hands of travelers and helped them make travel decisions based on what was most important to them. The common theme among the three applications in terms of user experience was that each combined multi-modal traveler information from a wide variety of sources and made it available through a single source.

Overall, survey and focus group results indicated that users found the multi-modal information provided by the various test applications useful and valuable but had suggestions for how the applications could be improved. While the frequency of use was low for the NT-T/SP test applications and the BWI Ground Access Information System applications, it was clear that a low return rate was not necessarily an indicator of user acceptance but more a sign of how often

users need the multi-modal information provided, especially in the case of the latter. When viewing multi-modal information available in a public place like a shopping center, information about roadway conditions was most important to users to obtain before leaving. For some of the tests, users indicated that the multi-modal information provided made them feel more confident about using transit or made them aware of alternative options where they could save time and reduce stress, and they would consider trying these new options. In the case of providing multi-modal information about ground transportation options at an airport, users reported that the trip planning website increased their satisfaction with and perception of the airport.

One additional common message voiced by each project team was the necessity to establish a means for identifying user needs before developing or deploying applications. Preliminary user needs assessments, beta testing, and forums for on-going user feedback are all popular methods for improving application design, identifying system bugs, and achieving better overall system performance and usefulness. For the majority of these tests, schedule and budget prevented the project team from thoroughly exploring user needs prior to system design or formally establishing means for gathering user feedback.

13.5 PRIVACY

No major issues associated with privacy were raised as part of providing multi-modal travel information to travelers.

13.6 INSTITUTIONAL ISSUES

Lastly, institutional issues experienced during each phase of the project life cycle provide valuable insight into the challenges that the project teams faced related to categories presented above (i.e., development, deployment, marketing, and user experience). The evaluation team conducted interviews with all project partners involved for each test to better understand what challenges or setbacks a project team might face as well as identify successes and best practices when providing multi-modal information to travelers.

The NT-T/SP test resulted in significant insight into the understanding of distributing real-time transit information. The test demonstrated the ability to integrate transit, traffic, and parking information across multiple agencies in real time. The test highlighted the potential for distributing personalized information via the internet and smart phones.

The development, deployment, and operation of the NT-T/SP test required extensive cooperation from local transit agencies. This activity was critical to the test, as PATH needed to install various forms of tracking devices on trains and buses. Previous working relationships facilitated this process, although supporting the NT-T/SP test was, understandably not the highest priority for the transit agencies given the many demands on their limited staff resources. The PATH project team was therefore very respectful of the requirements of the transit agencies, and the availability of their key staff. For example, when PATH installed the tracking devices on one agency's locomotives, this was done on weekends over several weeks to avoid any possible disruption to rail services.

No formal process was followed with regard to determining user needs. The project schedule did not allow for sufficient time to conduct a comprehensive user requirements analysis. Consequently, the development of the PATH2Go applications was mostly influenced by the need to establish a database of transit services, including real time status from multiple transit agencies, address the development requirements of three different smart phone platforms, integrate the three PATH2Go applications, and ensure the highest possible quality for the user

interface and overall user experience. These issues were addressed through regular coordination between team members responsible for these respective areas. User interface and application design issues were identified and addressed by members of the project team during these coordination efforts.

From an institutional perspective, much can be learned from this pioneering effort to deploy a multi-modal traveler information system that includes deploying a kiosk in an airport environment. When deploying equipment in an environment like an airport, there can be challenges not encountered when deploying ITS technologies in other environments. For example, the stakeholders who need to be involved to deploy a piece of technology in an airport can be quite diverse. Not all players may be obvious at first and all are not likely to have a background or interest in transportation. As a result it is important to work with the airport staff early on to identify all potential stakeholders and to have a formal written agreement or memorandum of understanding among all involved parties, including those who will maintain the unit. Involving all stakeholders early can allow them to voice opinions up front for inclusion in the system requirements.

A final key institutional lesson is to look for opportunities to make use of any synthesized data already available from another agency or organization. This is especially important when pulling diverse data sets from multiple organizations, as is the case with a multi-modal traveler information system. As more and more agencies and organizations move toward open source data, there will be increasing opportunities for this type of cost savings in the future.

One developmental challenge with the TCC traveler information screens involved determining how much real estate should be allotted to each piece of content. Public agencies and private companies may not always have the same goals in terms of content for this type of information. The shopping center management wanted the screens to include entertainment content while VDOT wanted the focus of the system to be the traveler information. A compromise was reached in which a portion of the screen was reserved for weather and news feeds, with the majority of the screen space reserved for the traveler information.

Overall, system deployment went smoothly with few challenges. In fact, several stakeholders suggested that they believed, in retrospect, that drawing shoppers' attention to the displays was one of the key challenges in this project. Stores and advertisers spend considerable effort to attract the attention of shoppers to their stores and displays making it difficult for the traveler information screens to stand out in such an information-rich environment like a retail shopping center.

Some other challenges included: implementing the additional content initial deployment of the screens; selecting satisfactory screen locations that both provided information at convenient locations within the shopping center and did not violate lease agreements with tenants; and working with a wide variety of partners with unique perspectives and goals. However, one of the primary reasons for success was that a clear agreement was laid out with all partners at the outset of the project and that a detailed concept of operations was created early on with the involvement of all parties. Frequent communication between the various stakeholders was key to the success of the project.

Institutional issues often provide the basis for building on and improving technology to make it more useful and valuable to travelers today as well as not repeating previous mistakes. The three tests related to providing multi-modal information to travelers offer tips for successful deployment, key lessons learned, and important factors to consider when developing multi-modal ITS applications.

A common challenge among all three tests involved integrating a wide variety of information from different sources into a single system. The project teams faced unique challenges along the way when identifying and compiling multi-modal information. Identifying essential stakeholders and ensuring clear and consistent as well as written agreements stood out as a necessity for deploying successful applications. Establishing a concept of operations and leveraging existing information or open source data proved to be key element in project development.

Lastly, incorporating a formal process for identifying user needs can result in greater initial user satisfaction/attention and less developmental changes after initial launch. A comprehensive approach to user requirements analysis should be a part of the initial project schedule and budget discussions.

13.7 CONCLUSIONS

The tests involving multi-modal travel information described in this chapter offer valuable insight into issues across all aspects of a project. These three tests also helped identify areas for future research related to multi-modal traveler information. In fact, the NT-T/SP received will remain operational through 2011 with new Caltrans funding. The BWI Ground Access Information System efforts to install a kiosk at BWI Airport are on-going and in the process of expanding the application to include additional bus routes that serve BWI Airport. While these tests will provide the opportunity to continue building on valuable lessons learned, additional research needs were identified throughout the evaluation lifecycle that are larger in scope and focus than the continued efforts by the on-going project teams.

During deployment interviews for the NT-T/SP test, PATH developers identified the need for a national standard format for transit operations data. Companies like Google, which offer transit information via their Google Maps website, have established a good starting point for a standardized data format. If transit agencies provide open source data meeting their standards, Google will incorporate the transit services offered into the information provided to travelers via Google Maps. However, Google transit standards are more focused towards users and application development. Transit agencies should consider what standards are necessary for transit operations in addition to user information and application development when defining a national standard. This would allow for data-driven best practices collaboration across transit agencies regarding transit operations techniques. If a standard were achieved and put into practice by transit agencies across the nation, the next step would be for the same agencies to provide the data collected in open source. The need for applications that provide real-time transit information could be met by developers instead of transit agencies. With open source data, real users with development knowledge can design applications to meet known user needs at no cost to the transit agency.

However, major challenges exist regarding data ownership when attempting to gather transit operations data from multiple transit agencies. Many agencies have contracted out data collection and management to private companies that provide data in return but own rights to the database, creating sole source issues when trying to gather data. Another challenge involves the ITS systems that many transit agencies use to collect real-time transit operations data. Systems for equipment like GPS and signal priority are not integrated and may have been contracted from several different vendors, which can overly complicate data integration. Often times, there are certain vendor limitations or the two systems do not have the ability to communicate with each other to allow for a single data source.

Despite these hurdles, a national standard is needed to provide travelers with the real-time information needed to make choosing transit more appealing as a primary mode of transportation.

There is also a need for continuing research to identify contributing factors and the cost-benefit balance required to induce mode-shift. This area of future research needs was realized in discussions related to the NT-T/SP test with the Metropolitan Transportation Commission of the San Francisco Bay Area. Project stakeholders working for the well-known transportation planning, coordinating, and financing agency expressed a need for understanding the factors that encourage mode shift.

Without a clear understanding of what causes travelers to consider and ultimately choose an alternative mode to driving alone, transportation agencies and stakeholders have a difficult time providing the right type of multi-modal information needed to induce mode-shift. Research that can clearly identify the various benefits of choosing transit or other alternative modes is essential for transportation agencies to understand. If an agency knows what motivates its travelers to consider their services, they can leverage that knowledge to make their operation more appealing to users. While a long list of factors like cost, time, environmental impact, oil dependence, convenience, and many others are known considerations, little is known about the relationship between these factors and the proper balance required to change travel behavior.

An understanding of the delicate balance between the cost incurred and benefit achieved when choosing an alternative mode is essential to increasing rates of mode-shift. Exploring traveler perceptions vis-à-vis personal choices—such as whether it's worth it to spend more to achieve a shorter trip, whether a longer trip is justified because it reduces stress and provides more exercise, and whether to put up with additional inconvenience to reduce one's carbon footprint—is key to formulating a plan and making changes that will make alternative modes more attractive to travelers. Once this is achieved, the next step will be to establish performance measures for assessing the mode-shift across several transportation options, providers, and industries. ITS technologies like those used in these three tests are providing the data needed for traffic and transit operations agencies to collaborate and better understand mode shift and travel demands across modes.

14 PROVIDING IN-VEHICLE SAFETY ALERTS IN END-OF-QUEUE SITUATIONS

Advanced Driver Assistance Systems (ADAS) are being developed and deployed to assist drivers with a number of driving tasks. These encompass systems to warn drivers when they are departing the roadway; detect possible collisions with adjacent vehicles; and 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 studied in this test.

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, nor is this data applicable to critical and time-sensitive decision-making.

One of the SafeTrip-21 Initiative tests focused on this important need, the **Networked Traveler – Foresighted Driving (NT-FD)** test. The 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, instrumented vehicle, field test design. 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; where 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.

The lessons learned are organized and presented according to the following processes:

- Design and Development
- Deployment
- Marketing
- User Experience
- Privacy
- Institutional Issues

14.1 DESIGN AND DEVELOPMENT

Development of the necessary equipment, systems, and the test protocol evolved over time and included a number of modifications that were necessitated due to policy changes and re-scheduling. The following section summarizes the activities conducted to develop the test's equipment and design.

The experimental design developed by PATH (which was completely separate from the evaluation) focused on developing the necessary equipment and systems to assess whether or not providing the test participants with safety alerts would influence driver behaviors. The test was also conducted to determine if the alerts might have the potential

to reduce the number of crashes or the probability of a crash at the end of queue or curve locations.

To reach these goals, the development of the necessary hardware systems and the software underwent a number of changes that were due to the re-scoping of the NT-FD test to minimize the likelihood of test participants being distracted while driving. This test was re-scoped towards the end of 2009 to reflect U.S. DOT'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, some are of the opinion that the algorithms could not be refined enough to help minimize the false alarms. The re-scoping of the project meant that PATH staff needed to respond to changing requirements that necessitated re-estimating the levels of effort associated with meeting the considerable time constraints to develop equipment specifications and then procure, install, test, and de-bug the vehicle subsystems for the this test.

The project involved the installation of the alert device in four instrumented vehicles, each of which had 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; and
- Do all the above with minimal distraction to the driver.

While PATH had use of four vehicles (two Nissans and two Audis, such as that in Figure 23) for the test, none of these vehicles were equipped with the instrumentation required to conduct the test. 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



Photo courtesy SAIC

Figure 23. Audi Vehicle Used in the Test

was compounded by the fact that two different makes of vehicle were involved. (Data stored on each vehicle's on-board computer were required as part of PATH's proposed analysis.)

It should be noted that one aspect of the NT-FD test beyond the control of PATH was 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 when including 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,²⁴ and 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 provided results of 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."²⁵

Indeed, for ground truth speeds greater than 55 mph, 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 percent, i.e. the SpeedInfo speed was nearly double the ground truth speed.

PATH staff were keenly aware of the schedule and functionality challenges entailed by the re-scoping of the project. Due to these challenges they were required, often in a very short timeframe, to identify staff with additional skill sets to install, test, and develop the equipment and software needed. While the staff was able to design the system to meet all functional requirements they were also cognizant that the systems were not as "elegant" or "efficient" as they could have been. However, the re-scoping required equipment not originally anticipated, therefore, additional computers to receive and compile information were acquired and added. In addition, the scope change and the tight deadlines precluded the staff from conducting structured usability testing on the "soft alerts" that were installed in the vehicles. Participants were supportive and positive with the auditory displays and the design, however, and this is a testament to the insights the PATH project team had in regards to these issues, especially while on the tight deadlines.

Finally, the team gained a greater appreciation for the variability of the different on board computer data access from the two vehicle manufactures. 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

²⁴ Link to the San Francisco Bay area 511 Traffic and Driving Times page:
<http://traffic.511.org/default.asp?refresh=5>

²⁵ Report provided by MTC – Caltrans. ITS Pilot Project Demonstration: SPEEDINFO Evaluation. June 2006.

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.

14.2 DEPLOYMENT

The test focused on how drivers reacted to the information provided by the in-vehicle alert system. 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.) Deployment of the system relied on the installation and integration of the on-board computer systems, the video data collection system, and ensuring the processes for recruiting and assessing the participants' perceptions were completed.

The process for conducting the test was carefully designed to meet the experimental requirements of PATH and to address the evaluation objectives of the Evaluation Team. 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; 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 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.

One primary focus of the test was the collection of participant perception data to understand their experiences with the system. This information was 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 each participant created a user ID and password that 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 conducting the test, each participant was assigned one of the four test vehicles which they used for their daily driving for a two week period. For the first week they drove without the alert; it became operational the second week. Participants picked up the vehicles at the PATH Richmond facility and underwent a briefing on the vehicle's and alert system performance. When they returned two weeks later, the data from the on-board systems were downloaded and the participants completed the debrief interview with the Evaluation team staff. 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.

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.

As with most (if not all) field experiments, there is a great deal of coordination that must be accomplished between all members of the project team, ranging from participant recruitment, supporting the participants while they are involved in the program, and ensuring the feedback mechanisms (surveys), and onboard data collection processes are reliable. Due to PATH's experience in conducting field experiments, the processes in place proved to be successful. Participants who did experience problems or issues were able to reach PATH staff to resolve the issues.

14.3 MARKETING

As discussed earlier, this test represented the fielding of the safety alert system as a "beta" system, i.e. a pre-mass market application with a small number of screened volunteer participants. Therefore, marketing was not a primary factor, though data were gathered regarding participants' views on the design and possible marketability of the system.

- *Willingness to Pay.* As part of the debriefing, participants were asked if, and how much, they would be willing to pay for an alert system, like they had just used. Initially, approximately one-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. Further probing, however, showed that they considered the alert system would be much more helpful for trips where they did not know the traffic patterns as well as they did on as they did on their daily commutes. Some participants 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. Drivers who participated in the study did perceive the utility of the system, though felt it could be improved if it were coupled with other driving aids, such as a GPS system that might also offer information on real-time traffic. When considering the design and possible marketing of an alert system, these opinions, as well as emphasizing the utility of the alerts on non-routine routes, should add to its attractiveness.

14.4 USER EXPERIENCE

The primary focus of the evaluation was to assess how participants viewed the alert system on a number of different dimensions. The results of this assessment are presented below.

Both sources of information – the online survey and the debrief results – were used to assess the users' experience with the system. There were a number of factors that were assessed and are briefly noted below.

- *Loudness.* The overwhelming majority of participants indicated the sound level was “just right” though, 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.
- *Timing of the Alerts.* Few 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” and were related to participant observations that at times they received the alerts but could not immediately see the slower traffic. For those who felt the alerts “were late,” participants indicated they would have liked to have heard them earlier so they could have had more time to decide to change their routes; the alerts typically occurred as they approached decision points (such as highway interchanges or exits).
- *Annoyance.* Over half reported the alerts were not annoying and when they did report they were “a little” or “slightly annoying” this was due to the alerts sometimes cutting off the sound system. But most reported they, “got used to the alerts and they weren’t a big deal.”
- *Usefulness.* Overall usefulness of the alerts showed a wide distribution of responses; just over one-half “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. Participants reported that they found the alerts made them more aware of traffic when they came on. However, due to their routine commuter patterns, participants also reported they were “pretty aware” of 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.
- *Distraction.* The alerts were designed to orient the participants to the slowed traffic ahead, and therefore, make them more attentive to the driving environment. Participants’ reactions to the alerts indicated that 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, becoming more focused on traffic without being distracted.

- *Accuracy/Correctness.* None of the participants rated the alerts as “very accurate” or “very inaccurate” while almost three-fourths of them rated them as “slightly accurate” or “somewhat accurate.” 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.
- *Sense of feeling safer.* Participants’ ratings of the alerts’ effect on safety showed they felt the alerts made them feel safer. 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.
- *Behavior Changes.* While not measured directly for this part of the evaluation (driver behavior and performance will be analyzed by PATH), respondents reported the alerts made them more aware of the traffic conditions and 40 percent reported that they did reduce their speed when they received the alerts. 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.

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 unclear whether these are functionally adequate for this purpose. It is also unclear what the respective roles of the public and private sectors would be in the development, operation, and maintenance of a more widely available system. Regardless, the NT-FD test has much to contribute to the ongoing evolution of the traffic information services sector.

14.5 PRIVACY

PATH took stringent steps to protect the privacy of the test participants, and was transparent about what information was collected and why. This included the data collected from the on-board data collection systems as well as the online survey and the debrief.

Test participants needed to supply a large amount of data to PATH to participate in the test. This included a background check on their driving history as well as other personal information. 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. In addition, participants were informed that the on-board system would be recording their location for the duration of the test, but were assured that when the analysis was completed, all data would be destroyed.

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.

Based on the surveys conducted with the test participants, there were no 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 their two week stint.

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 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 tracking purposes 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.

14.6 INSTITUTIONAL ISSUES

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 driver. In this way, the level of distraction to the driver would be substantially reduced (compared to the original concept using smart phones). 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.

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 (see below), 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.

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 to fully instrument 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 cushion 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 that 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.

14.7 CONCLUSIONS

While it is only one application within the SafeTrip-21 Initiative, NT-FD provided a very detailed look into providing safety alerts to drivers. One of the primary areas of interest, indeed, the factor that led to the re-scoping of the project revolved around the alert's possible distraction to drivers. It will be critically important for ITS professionals to develop procedures that consider distraction into all levels of their deployment planning. Doing so may advance research to support

innovative and non-distracting interfaces, thereby improving safety and enhancing marketability of the technologies.

15 CONCLUSIONS AND LESSONS LEARNED

The evaluation findings indicate that the SafeTrip-21 Initiative has advanced its goals of expanding research related to vehicle connectivity in the wireless communications environment; advancing ITS applications; and exploring benefits of deployment-ready applications that provide enhanced safety, real-time information, and navigation assistance.

The evaluation findings suggested that the SafeTrip-21 Initiative has advanced its goals of expanding research related to vehicle connectivity in the wireless communications environment; advancing ITS applications; and exploring benefits of deployment-ready applications that provide enhanced safety, real-time information, and navigation assistance. The main elements of the Initiative considered how to:

- Transition ITS research into real-world use;
- Accelerate acceptance and adoption of ITS;
- Generate widespread awareness about the potential of deployment-ready ITS technologies to provide transportation benefits to travelers, public agencies, and commercial vehicle operators;
- Test and evaluate multiple ITS applications in an integrated, multi-modal operational test setting relative to prospective benefits in terms of safety, mobility, commercial vehicle safety and operations, and e-payment services; and
- Identify environmental and energy benefits of ITS.

Several applications successfully transitioned previous ITS research/deployments into real-world use for everyday travelers and practitioners. All of the I-95 and CACT Test Bed applications leveraged existing data sources such as private traffic data providers, public transit agency information, and/or existing data infrastructure to develop systems/applications that put traveler information directly in the hands of the public, allowing them to make more informed decisions about travel and operations. All eight SafeTrip-21 applications helped accelerate the understanding of the factors that help promote acceptance and adoption of ITS technologies by both users and operators. Two of the I-95 Test Bed applications provided real-time traffic information to travelers across various mediums including a website and at high-volume locations for long-distance and local travel (e.g., rest areas and shopping centers) which gave practitioners insights to better understand where real-time traffic information is most useful.

An application on the CACT Test Bed accelerated the understanding of vehicle connectivity concepts by using existing DSRC infrastructure to provide in-vehicle safety alerts to drivers via Vehicle to Infrastructure communication and explored the benefits of providing enhanced safety and real-time information. Development of another CACT Test Bed application involved close collaboration with transit agencies in a metropolitan area to collect real-time transit information across all major transit providers and deliver it directly to users via the web and smart phones.

By fully deploying these applications, many of the SafeTrip-21 tests generated greater public awareness around the types of travel information ITS technology can offer. The evaluation resulted in valuable feedback and a better understanding of the perceived benefits of ITS technologies to travelers and public agencies. Several SafeTrip-21 tests also showed that ITS technology is capable of collecting the data needed by traffic and transit operations agencies to collaborate and better understand mode shift and travel demands across modes. Several

applications resulted in the opportunity to test and evaluate methods for providing integrated, multi-modal information to travelers, including the ability to compare travel modes using factors such as cost, time, and environmental impact using ITS to help users realize the environmental and energy benefits of choosing alternate modes.

In evaluating these objectives, the Evaluation Team has identified several sets of key messages regarding the risks associated with ITS deployments and the success factors that might mitigate these risks, as well as possible avenues for future research. What follows is a list of these lessons identified in the evaluation findings that were presented the preceding sections.

The SafeTrip-21 Initiative identified risks related to large-scale collaboration and mitigating factors to promote effective partnerships.

The SafeTrip-21 Initiative involved stakeholders across multiple organizations in existing and new partnerships crossing public, private, and academic boundaries. The evaluation of the SafeTrip-21 technologies provided insight as to how these delicate relationships are best negotiated and how long-established relationships facilitated deployment of technologies. The SafeTrip-21 Initiative highlighted how successful partnerships can leverage the respective capabilities of public, private, and academic partners in pursuit of a shared vision.

- **Established and respectful working relationships facilitate a shared team vision and a sense of ownership, which serve as a solid foundation for a successful deployment.**
- **Documenting the vision through a concept of operations is one way to keep stakeholders on the same page.**
- **It is not sufficient to find consensus at the concept formation stage; sustaining regular communications among partners is needed.**
- **Conflicts in collaborative relationships can carry directly into the technology.**
- **Formal agreements are necessary to establish working relationships and communication protocols.**
- **Interactions between commercial and non-commercial entities require unique understanding and planning.**
- **Transportation professionals and system engineers need to develop a shared understanding and language.**

The SafeTrip-21 Initiative demonstrated the feasibility of alternative approaches to collecting and using traffic data.

One aspect of this evaluation was an exploration of alternative approaches to collecting and using traffic condition data. In some cases, applications demonstrated new sources of traffic condition data. In other cases, applications made use of traditional data in new ways. The SafeTrip-21 Initiative highlighted how the mass-market availability of GPS-enabled smart phones complements traditional fixed sensors as a new data source, as well as offers the potential to deliver personalized travel information.

- **Traffic model development can benefit from integrating traffic probe data with other sources for both freeways and arterials.**
- **There is potential for using traditional traffic data in new and innovative ways.**
- **The ability to deploy a traveler information concept is only as successful as the availability, timeliness, and accuracy of its data sources.**
- **ITS technology provides the means for remote monitoring and maintenance of traffic signal plans.**
- **Practical concerns of transportation professionals governed their acceptance of traffic data devices.**

The SafeTrip-21 Initiative identified aspects of information delivery and design which appeals to users and improves the user experience.

When presenting travel information to travelers, the user experience is critical to success. The SafeTrip-21 Initiative highlighted the importance of adopting a customer-oriented approach to travel information and recognized that customers had varying needs.

- **Stakeholder relationships will not necessarily be transparent to users.**
- **The importance of assessing user needs early and often should not be underestimated.**
- **Users expect an efficient and usable interface for receiving travel information.**

The SafeTrip-21 Initiative developed new approaches to address distracted driving.

Organizations and individuals are becoming increasingly aware of the dangers associated with distracted driving. The U.S. DOT is a leader in terms of delivering this message to citizens and shaping the research which will advance techniques for mitigating distracted driving. In fact, several SafeTrip-21 tests were re-scoped during this evaluation to better address distracted driving concerns. As a result, the SafeTrip-21 Initiative advanced knowledge and technological solutions to distracted driving.

- **“Geofencing” is a promising approach to limiting driver distraction.**

The SafeTrip-21 Initiative explored issues of privacy related to user acceptance.

Concerns over relinquishing privacy can be a potential pitfall for many ITS related technologies. The evaluation considered the ways in which the SafeTrip-21 partners addressed this and identified potential factors for success.

- **Creative privacy protection procedures can be reassuring to users of personal devices providing probe data.**
- **Reciprocity and transparency related to the collection of personal information are potential success factor for ensuring acceptance by travelers.**

The SafeTrip-21 Initiative indicated success factors related to effective development and meaningful deployment.

Several factors related to the applications and the process of deploying the applications can optimize the chance for success. These factors are usually reflected by the types of trade-offs and decisions made by partners during the development and deployment process.

- **Existing open-source data is becoming an important component of efficient system development.**
- **Keeping solutions simple enables progress and optimizes chances for success.**
- **Redundancy in system design and monitoring minimizes failure risks.**
- **It is challenging to develop ITS applications as an aftermarket addition to consumer products due to design variations in the absence of an industry standard.**
- **Performance monitoring during deployment facilitates technical improvements.**
- **Frequency of use is not always an indicator of value.**
- **When considering how to proceed following a test deployment, it is important to clarify the roles of the private and public sector.**

The SafeTrip-21 Initiative highlighted the increasing role of traditional and innovative marketing in transportation systems.

Marketing related to the SafeTrip-21 deployments turned out to be a more significant issue than anticipated. Marketing entails a variety of techniques for making users aware of opportunities to access a particular application, including traditional press releases, advertisements, or direct invitations for participation. Marketing of travel information systems was critical to success regardless of the method by which the information is accessed by the public.

- **Providing travel information in public places necessitates creativity to make potential users aware of the service.**
- **Social media is an increasingly powerful tool, especially in promoting mobile applications.**
- **Traditional press releases are still effective in reaching large media outlets.**
- **Marketing efforts should not only be directed at consumers but at transportation professionals' networks.**

The SafeTrip-21 Initiative explored ways to support users in making cross-mode travel decisions.

Promoting transit alternatives is a continuing transportation need. The SafeTrip-21 Initiative focused on trying to make travelers aware of their options and make it easy for them to plan trips than minimize the use of a personal vehicle.

- **Travelers place value on being able to compare real-time choices from a single source in part because it increased their confidence in their decisions.**
- **It is difficult to assess mode shift.**

The SafeTrip-21 Initiative suggests future research opportunities.

Several topics were identified in the evaluation that would benefit from future investigation and research.

- **Arterial model development is a complicated issue that would benefit from continuing research and the development of new techniques.**
- **Transportation agencies will have to address the need for new procurement methods to acquire data and information services.**
- **To maximize the potential of using transit data, there is a need for a national standard.**
- **Continuing research is needed to identify contributing factors and the cost-benefit balance required to induce mode-shift.**
- **Further innovation is needed to provide timely and useful travel information at the fingertips of travelers while keeping drivers from being distracted.**
- **The potential impact of social networking related to travel and transportation is not well-understood.**

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