National Evaluation of the SafeTrip-21 Initiative: California Connected Traveler Test Bed Final Evaluation Report: Mobile Millennium

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16. Abstract

Through the U.S. Department of Transportation's (USDOT) SafeTrip-21 initiative, the USDOT is testing a variety of technologies in a number of locations in California as well as along the I-95 corridor on the east coast. This document presents the evaluation findings, resulting primarily from in-person interviews the Evaluation Team conducted with institutional partners.

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ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
CACT	California Connected Traveler
Caltrans	California Department of Transportation
CCIT	California Center for Innovative Transportation
CITRIS	Center for Information Technology Research in the Interest of Society
DOT	Department of Transportation
DRI	Caltrans Division of Research and Innovation
GPS	Global Positioning System
I-95	Interstate 95
ITS	Intelligent Transportation Systems
MOEs	Measures of Effectiveness
NRC	Nokia Research Center
NTOC	National Transportation Operations Coalition
PATH	Partners for Advanced Transit and Highways
RTID	Real Time Intersection Delay
SAFETRIP-21	Safe and Efficient Travel through Innovation and Partnerships in the 21^{st} century
UC	University of California
USDOT	U.S. Department of Transportation
VTL	Virtual Trip Line

EXECUTIVE SUMMARY

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

PROJECT BACKGROUND

The lead partner for Mobile Millennium was Caltrans. Caltrans' interest in Mobile Millennium was 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, the capital of Finland.

Contacts made at the Helsinki workshop led to discussions regarding the potential use of mobile phone and navigation technologies to monitor real-time traffic flow, which in turn led to the launch of the Mobile Century project in February 2008. Mobile Century was intended as a proof of concept to test traffic data collection from GPS-equipped cell phones in one hundred vehicles driven on a 10-mile stretch of a highway located in the San Francisco Bay Area. The phones, which effectively served as vehicle probes, stored vehicle speed and position information every three seconds. These measurements were sent wirelessly to a server for real-time processing. The Mobile Century experiment enabled the design and development of algorithms and data collection systems to assemble traffic data from GPS-equipped mobile phones.

The Mobile Millennium project grew from Mobile Century with a strategic objective to demonstrate the potential of GPS in cell phones 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 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 USDOT 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.

Public sector funding for Mobile Millennium was targeted on the development of highway and arterial traffic models by CCIT. The Mobile Century traffic model formed the basis for the Mobile Millennium highway model. The Mobile Millennium arterial model was developed specifically for the test.

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 free download 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.

EVALUATION APPROACH

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

- Analyzed usage statistics provided by partners – discussed in Part II;
- Reviewed ground truth analysis undertaken by partners – discussed in Part III; and
- Conducted interviews with deployment and operational partners – discussed in Parts II and III.

SUMMARY OF FINDINGS

Mobile Millennium was a groundbreaking test. Not only did it push the envelope about understanding 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.[1]

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 most its 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 provided 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.

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 it 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.

Mobile Millennium contributed significantly to transportation industry's collective understanding of probe-based traffic information. The test demonstrated the potential for utilizing the vast amounts of data from using smart phones as traffic probes as a viable alternative to traditional

[1] **http://traffic.berkeley.edu/conference%20publications/virtual_trip_lines.pdf**

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 about 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 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.

PART I: INTRODUCTION

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

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

The Volpe Center made two test bed awards, one being the California Connected Traveler (CACT) Test Bed, which involved an integrated Test Bed, inclusive of three test applications (described below), in the San Francisco Bay Area. The CACT test bed hosted two additional applications[2] that were independent of the CACT test bed proposal. The lead agency for the CACT test bed was the California Department of Transportation (Caltrans).

The second test bed award was for the I-95 Corridor Test Bed, which involved a test bed along the I-95 Corridor from North Carolina to New Jersey as well as an additional independent application[3] that was deployed in North Carolina.

The California Connected Traveler Test Bed includes the following three field test applications:

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

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

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

- Networked Traveler-Transit/Smart Parking: This application involves creating a multi-modal trip planning tool for travelers in the US-101 corridor in the Bay Area. The information is available to all travelers through a website, and to registered users through a mobile website.

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

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

Part II: Mobile Application.

- **Section 1 – Background.** Provides background information on the timeline for development of Mobile Millennium, and describes the mobile application of Mobile Millennium, specifically the component of the test that focused on the user experience. This section also summarizes the evaluation approach, hypotheses, and measures of effectiveness developed previously and detailed in the Evaluation Plan.
- **Section 2 – Consumer response.** Summarizes usage statistics, and presents the results from the online user surveys conducted by Nokia.
- **Section 3 – Deployment Experience Assessment.** Details the design, deployment, and operational phases of the deployment by identifying successes, shortfalls, and significant lessons learned regarding the mobile application.

Part III: Traffic Models.

- **Section 4 – Background.** Provides background information on and a description of the highway and traffic models developed to integrate tracking information from users' smart phones, and to generate speed estimates. This section also summarizes the evaluation approach, hypotheses and measures of effectiveness developed previously and detailed in the Evaluation Plan regarding the ground-truthing of the traffic models.
- **Section 5 – Highway Model.** Presents the findings of the ground-truthing of the highway model undertaken by the project partners.
- **Section 6 – Arterial Model.** Presents the findings of the ground-truthing of the arterial model undertaken by the project partners.
- **Section 7 – Deployment Experience Assessment.** Details the design, deployment, and operational phases of the deployment by identifying successes, shortfalls, and significant lessons learned regarding the highway and traffic models.

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

Part V: Appendices

PART II: MOBILE APPLICATION

Part II of this evaluation report addresses the mobile application of Mobile Millennium.

1. BACKGROUND

1.1 MOBILE MILLENNIUM PROJECT

The lead partner for Mobile Millennium was Caltrans. Caltrans' interest in Mobile Millennium was 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),[4] the Nokia Research Center (NRC),[5] and the University of California (UC) at Berkeley. CCIT is an affiliate of the UC Berkeley Institute of Transportation Studies, with a focus on deployment and a mission to accelerate the implementation of research results. NRC's mission is to "explore technology frontiers and solve scientific challenges today, in order for Nokia to deliver irresistible personal experiences tomorrow." Since being founded in 1985 in Silicon Valley, California, NAVTEQ is focused on capturing the reality of the road network to enable dynamic turn-by-turn routing.

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[6] in Helsinki, the capital of Finland. UC was represented by the Center for Information Technology Research in the Interest of Society (CITRIS),[7] a multi-campus entity with a mission to create information technology solutions for social, environmental, and health care problems. In effect, CITRIS is a broker between academic partners and business.

Contacts made at the Helsinki workshop led to discussions regarding the potential use of mobile phone and navigation technologies to monitor real-time traffic flow, which in turn led to the launch of the Mobile Century project in February 2008.[8] Mobile Century was intended as a proof of concept to test traffic data collection from GPS-equipped cell phones in one hundred vehicles driven on a 10-mile stretch of a highway located in the San Francisco Bay Area. The phones, which effectively served as vehicle probes, stored vehicle speed and position information every three seconds. These measurements were sent wirelessly to a server for real-time processing. The Mobile Century experiment enabled the design and development of algorithms and data collection systems to assemble traffic data from GPS-equipped mobile phones.

The Mobile Millennium[9] project grew from Mobile Century with a strategic objective to demonstrate the potential of GPS in cell phones 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 differed from Mobile Century in a number of respects. First, the participants were not directly recruited, but instead were

[4] **http://www.calccit.org** CCIT is a sister organization to the California Partners for Advanced Transit and Highways (PATH)

[5] **http://research.nokia.com** Nokia is a multi-national communications company headquartered in Finland.

[6] **http://www.citris-uc.org/events/CITRIS-in-Europe**

[7] **http://www.citris-uc.org**

[8] **http://www.calccit.org/index.php?page=projects&id=33**

[9] **http://www.calccit.org/index.php?page=projects&id=26**

members of the public who voluntarily registered to use Mobile Millennium. Participants 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.

Second, registered users needed to have their own GPS-enabled smart phone that could both provide location information to Mobile Millennium and receive and display traffic information sent by Mobile Millennium. (Registered users were advised to have a data plan with their mobile service provider that would allow location data to be regularly transferred from the vehicle to Mobile Millennium's data servers.) Registered users downloaded the free application software referred to as "Traffic Pilot" onto their smart phones. In exchange for participating, registered users received real time map-based traffic information on their smart phones that was not available to other travelers. A recruitment flyer for Mobile Millennium is shown in Figure 1.

Figure 1. Recruitment Flyer for Mobile Millennium

(Courtesy CCIT)

Third, the scale of participation was much greater, with the intent to achieve a level of participation measured in the thousands compared to the one hundred drivers in Mobile Century. While this would potentially increase penetration of probe vehicles, the main purposes of greater participation were to investigate how Mobile Millennium handled data collection, processing, and dissemination on a much larger scale than in Mobile Century.

Mobile Millennium was designed to accommodate up to 10,000 participants. This number reflects a design limit 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 USDOT 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.

Public sector funding for Mobile Millennium was targeted on the development of highway and arterial traffic models by CCIT. The Mobile Century traffic model formed the basis for the Mobile Millennium highway model. The Mobile Millennium arterial model was developed specifically for the test.

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.[10] The free download software continued to be available until the public participation phase ended on November 10, 2009. Several factors combined to put Mobile Millennium on a deployment fast track:

- Institutional relationships between the key public, private, and academic partners had been developing since 2006, and Mobile Millennium represents a natural progression from earlier collaborations undertaken by its primary partners;

- Freeway algorithms were developed during Mobile Century in 2008. These were updated and refined during Mobile Millennium, and are not limited to probe data. The test also addressed technical factors related to data capture, communications, and fusion; and

- Traffic data collected by Mobile Millennium did not require traditional traffic monitoring sensors or a dedicated communication system.[11] Instead it used wireless communications systems provided by telephone companies and cell phones and data service plans purchased by consumers (or provided by employers) to meet their individual voice and data wireless communication requirements.

Mobile Millennium was somewhat unusual in that it not only provided a consumer service, but also has the capability to function as a management and operational tool. Indeed the concept of collecting traffic information from traffic probe systems such as Mobile

[10] **http://traffic.berkeley.edu**

[11] The probe-based traffic data was fused with traditional sensor-based traffic data and other traffic data sources in the Bay Area to enrich the quality of the real time traffic information.

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.

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.

1.2 EVALUATION APPROACH

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

Table 1. Goals, Objectives, and Hypothesis Statements

SafeTrip-21 Goal	Evaluation Objectives	Hypothesis
Expand / accelerate research in vehicle connectivity with the wireless communications environment	Observe the consumer response to Mobile Millennium	Traffic information gathered from traffic probes will continue to grow throughout the San Francisco Bay Area
Build on ITS research	Understand the technical and institutional issues associated with gathering probe-based traffic data, and distributing traffic information to smart phone users	Lessons learned through the development of the Mobile Millennium project will build on current knowledge / understanding of the use of traffic probes for providing traffic information
Explore / validate benefits of real-time traveler information gathered from traffic probes	Measure usage of the probe-based traffic information	Usage of the probe-based traffic information will be an indication of user acceptance. Usage will increase over time.
	Measure the accuracy of the traffic information generated by the system	The system will produce traffic information that is accurate / representative of real-world conditions.

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

- Analyzed usage statistics provided by partners – discussed in Part II;
- Reviewed ground truth analysis undertaken by partners – discussed in Part III; and
- Conducted interviews with deployment and operational partners – discussed in Parts II and III.

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 2009, during a period when evaluation team activities were on hold due to USDOT'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. Highlights of the NRC user surveys are also presented later in Part II.

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:

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

Findings related to usage statistics are presented in Part II of the evaluation report (this section).

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.

Ground Truth Analysis

In order to better understand 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.

Findings related to ground truth are presented in Part III of the evaluation report.

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.

Findings related to the deployment experience are presented subsequently in Parts II and III of the evaluation report, depending on whether they relate to the mobile application or the traffic models.

2. CONSUMER RESPONSE

2.1 SURVEY APPROACH

2.1.1 Usage Statistics

When users registered for Mobile Millennium and downloaded the traffic application software from UC Berkeley's Mobile Millennium website,[12] in addition to confirming they were 18 years old or older, and agreeing to various policy statements, they were required to provide the telephone number for their mobile device, their mobile phone service carrier, the make/model of their mobile phone, and their home zip code.[13] They were also invited to provide their email address, gender, and work zip code, although this was voluntary.

Figure 2 provides a screenshot of the user registration page. In the side-bar on the left hand side of the registration page under the heading "Tested Devices" is a list of the mobile phones supported by Mobile Millennium.

Registration information was collected and stored by CCIT, and forms the basis for the analysis of usage statistics. Prior to providing usage statistics, CCIT ensured that the database did not contain personally identifiable information, and also eliminated selected software download records that were known to relate to development team members' testing activities.

[12] **http://www.traffic.berkeley.edu**

[13] While Nokia was a key partner, participation was not limited to Nokia phones. Mobile Millennium was not available to iPhone users.

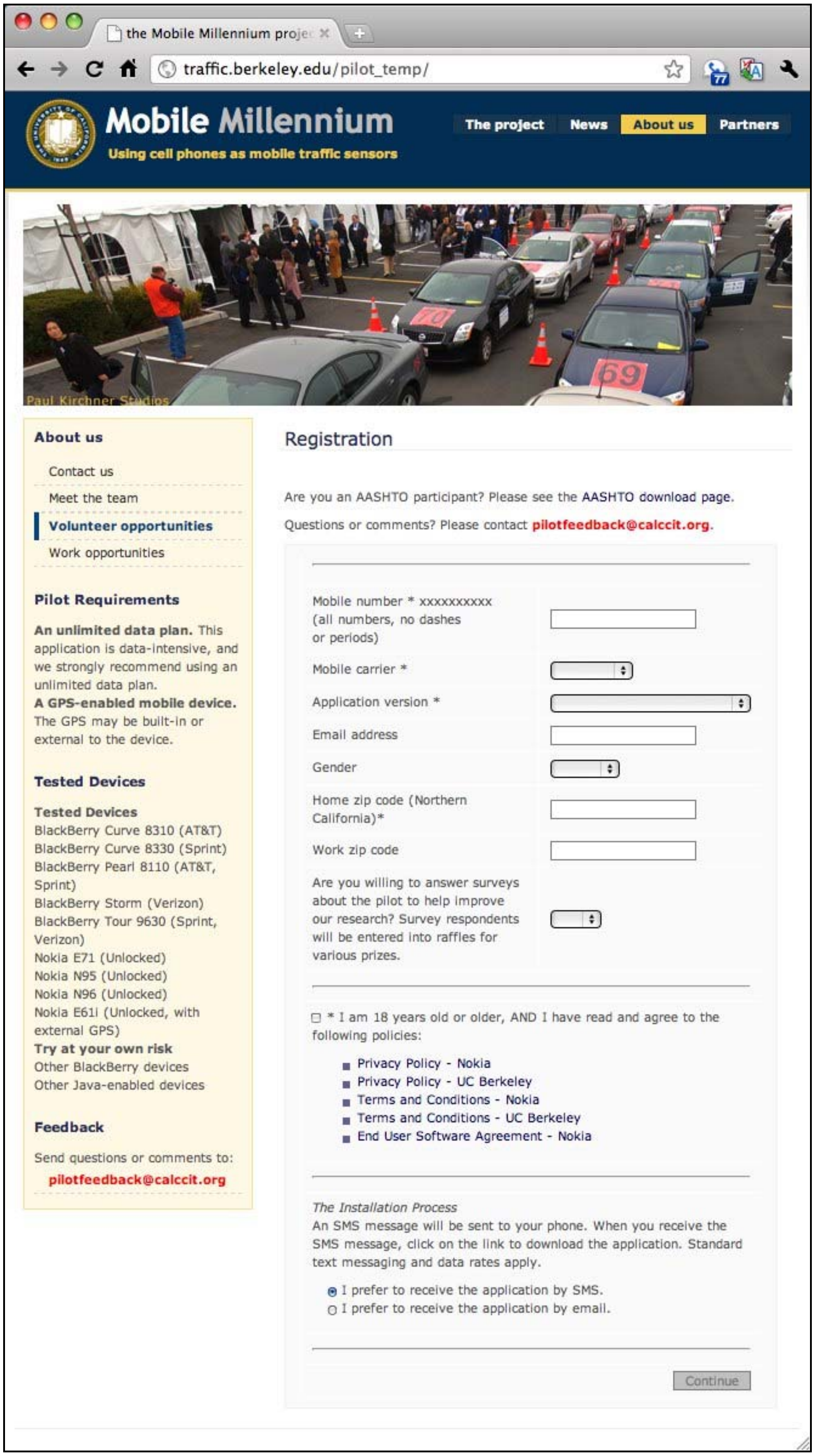

Figure 2. Screenshot of Mobile Millennium User Registration website

(Courtesy CCIT)

2.1.2 NRC Web-based Survey

As part of the registration process, users were invited to volunteer to participate in future user surveys regarding the system.14 As an incentive to participate, NRC offered the opportunity to win prizes from a drawing, such as a free phone. If users chose to participate in surveys, they were required to provide an email address.

Users who ‘opted-in’ to participate in surveys were invited to respond to two user surveys, in January and June 2009, through an email sent to their registered email address. The email contained a link to the website hosting each survey, which was then taken online. The user surveys were developed and analyzed by NRC. As mentioned previously, these surveys were undertaken to support NRC’s internal development activities and do not directly support the evaluation objectives. As such, the findings of the surveys cannot be considered to be independent, although they do provide some insights regarding user perceptions.

2.2 FINDINGS

2.2.1 Usage Statistics

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 monthly distribution of downloads is provided in Table 2. This analysis ignores additional downloads in early November 2008, prior to the official launch. It is understood that these downloads were by members of the development team, or by others affiliated with the partners.

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 eleven 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.

Table 2. Monthly Downloads of Mobile Millennium Application Software

Month	Days Per Month in which Downloads were Available	Number of Downloads Per Month*	Cumulative Downloads (percent)	Average Downloads (per day)
November 2008	21	1,498	66.8	71.3
December 2008	31	276	79.2	8.9
January 2009	31	114	84.2	3.7
February 2009	28	58	86.8	2.1
March 2009	31	40	88.6	1.3
April 2009	30	58	91.2	1.9
May 2009	31	46	93.3	1.5
June 2009	30	43	95.2	1.4

[14] More than 1,500 users expressed an interest to participate in user surveys

Month	Days Per Month in which Downloads were Available	Number of Downloads Per Month*	Cumulative Downloads (percent)	Average Downloads (per day)
July 2009	31	38	96.9	1.2
August 2009	31	20	97.8	0.6
September 2009	30	20	98.7	0.7
October 2009	31	25	99.8	0.8
November 2009	10	5	100.0	0.5
Total	366	2,241		6.1

* Refers to the total number of mobile phones to which the application software was downloaded, i.e. ignores duplicate downloads to any given mobile phone number.

Source: CCIT

Home zip code was a required field when users registered for the application software. The vast majority of downloads were by users who declared their home zip code to be in a range from 936xx to 959xx (see Figure 3). This corresponds to the Bay Area/Sacramento region. In addition, there were a small number of downloads from further afield, mostly in California, but with a few out of state. Downloads are spread across more than 400 zip codes, with the greatest concentration around the immediate Bay Area.

Work zip code was an optional field when users registered for the application software, and were not provided for 400 of the application software downloads. Work zip codes were more concentrated than home zip codes, with the greatest concentration around the immediate Bay Area, notably in the San Jose area (see Figure 4). Interestingly, downloads are spread across more than 485 zip codes, which is more than for home zip codes. Work zip codes associated with more than 160 downloads were for locations outside of the Bay Area/Sacramento region, i.e. not in the zip code range from 936xx to 959xx. Many of these were for out of state locations.

High numbers of downloads are associated with Palo Alto, Berkeley, and Sacramento, where NRC, CCIT and Caltrans are located. Whether this highlights increased awareness of Mobile Millennium or possible distortion in the usage statistics related to development team activity cannot be determined by the Evaluation Team without gaining access to personally identifiable information.

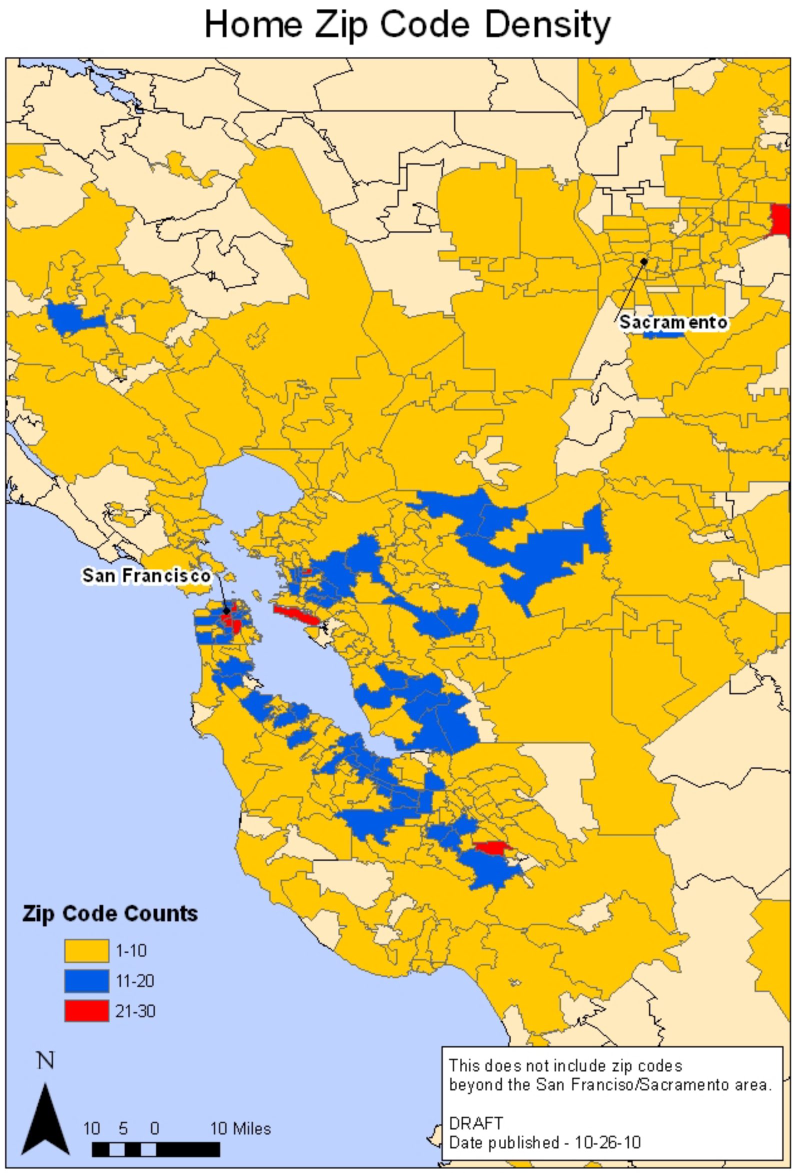

Figure 3. Number of Registered Users for Each Home Zip Code

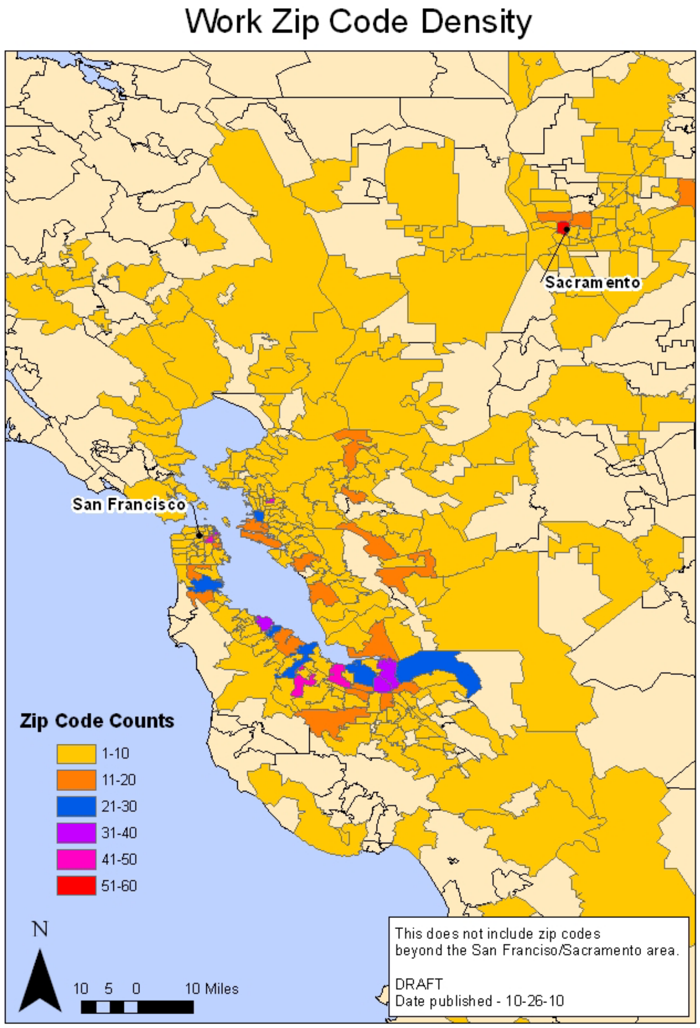

Figure 4. Number of Registered Users for Each Work Zip Code

2.2.2 User Surveys

The usage statistics provide a quantitative insight to the adoption of Mobile Millennium. However this is an incomplete picture because it reveals nothing about the characteristics of users or the actual pattern of use of the system. The user surveys conducted by NRC goes some way towards providing insights to who the users are, how they use Mobile Millennium, and they perceptions about using the system and perhaps how it can be improved. The user surveys were intended to support NRC's product development process related to traffic information services. NRC received no federal or state funding related to its participation in Mobile Millennium. Indeed NRC invested its own resources and expertise to the test, and these surveys would normally be considered proprietary. However NRC provided the survey results to the Evaluation Team (hard copy) and has graciously agreed to allow the findings to be summarized in this evaluation report.

The surveys were conducted in the first half of January 2009 and through most of June 2009, two and seven months respectively after the launch of Mobile Millennium. As mentioned previously, participation was optional, and approximately three quarters of users agreed to participate in future surveys at the time of registration. An email was sent to the email address of users who 'opted-in' to participate in surveys prior to each survey. The email invited users to participate in one or both user surveys (depending on when they registered) and contained a link to the website hosting each survey, which was then taken online. The user surveys were developed and analyzed by NRC.

Almost 80% of all Mobile Millennium users had registered by the time of the January 2009 user survey. More than 90 percent of all Mobile Millennium users had registered by the time of the June 2009 user survey. The survey instruments are summarized in Appendix A.

The surveys mostly asked different questions, so there is limited scope for any trend analysis. Table 3 provides an overview of response rates for each survey, and participant characteristics for the June 2009 survey.

Table 3. User Survey Response Rates

	January 2009	June 2009
Survey Dates	January 6 to January 16	June 2 to June 26
Registered Users	1,774 (by end December 2008)	2,090 (by end May 2009)
Responses (Invitations)	370 (1,300)	286 (1,550)
Response Rate	28.5%	18.5%
Male / Female	n/a	86% / 14%
Age	n/a	18-25 5% 26-35 24% 36-45 34% 46-55 22% 56+ 15%

Source: NRC

One similar question area in both surveys related to frequency of use – see Table 4. In both surveys it was apparent that the majority of users were infrequent users. The minority of users that used Mobile Millennium daily declined from 33% in January 2009 to 11% (6 or more uses in the past 7 days) in June 2009.

Table 4. Frequency of Use

	January 2009	June 2009
Use on a daily basis? (Yes / No)	33% / 67%	
How many uses in the past 7 days?		0 40% 1-2 30% 3-5 19% 6-10 7% 11+ 4%

Source: NRC

In the January 2009 survey, 9% of respondents indicated that they had not actually used Mobile Millennium, mostly because "my phone is not supported'. In the June 2009 survey, "It does not work on my phone" remained the top reason for never using the system.

For the January 2009 survey, 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:

- Better user experience (16 comments)
- More accurate travel data (10 comments)
- Higher quality traffic incident data (10 comments)
- Traffic data on more roads (8 comments)
- Personalized traffic information for the routes I drive(7 comments)
- Driving directions (7 comments)

For the June 2009 survey, the focus was more on how respondents use the system. For example, nearly half of users opened the application to view traffic information prior to getting in their car (24% in a building, 23% on their way to the car), one third (34%) of users opened the application when they were "in my car as I started driving,"[15] and 19% opened the application "while I was driving, when I encountered (or became concerned about) traffic." Frequent users of Mobile Millennium were least likely to open the application while driving. (It is noted that Mobile Millennium blanked the mobile phone screen as a power saving feature after a short period of time. This prevented users from viewing the application unless they altered default phone settings or requested a screen refresh.)

One behavior that emerged from the June 2009 survey 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.

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.

2.3 SUMMARY

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 BlackBerrys, 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.

[15] The duration implied by the statement "in my car as I started driving" is unknown

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.[16] 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.

As mentioned previously, these findings are based on data that was not collected by the Evaluation Team for the purpose of supporting the independent evaluation. Nonetheless, 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 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 a key factor driving governing the number of users is outreach and promotion.

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.

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

[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.

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.

Due to the lack of opportunity for the Evaluation team to conduct its own evaluation, it was not possible to support an objective that comprehensively addressed user perceptions, particularly with respect to accuracy, timeliness, usefulness, and privacy. However the NTC surveys indicated that only 7 percent of respondents did not trust the system to protect the privacy of their travel data. Among the small number of respondents who had decided not to use the system in the future improvements that would convince them to try the system again included a better user experience, more accurate travel data, higher quality traffic incident data, traffic data on more roads, personalized traffic information, and driving directions.

3. DEPLOYMENT EXPERIENCE ASSESSMENT (MOBILE APPLICATION)

This section focuses on the deployment experience with regard to consumer response, such as how consumers interacted with the mobile application and the quality of customer service. The information in this section is mostly based on interviews conducted with representatives of NRC and NAVTEQ. (Section 7 addresses deployment experiences related to traffic models.) These interviews were conducted on the basis that the findings would be published. In the interest of protecting proprietary information, interviewees declined to discuss matters related to future business strategies and related topics.

3.1 FINDINGS

Mobile Millennium was somewhat unusual in that it effectively provided a consumer service, rather than a management or operations tool. However 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. It is not unreasonable to assume, therefore, that users would have their own expectations for mobile services and electronic consumer products based on similar commercially available products and services.

3.1.1 Background

Nokia is shifting its corporate focus to include mobile services, rather than just device sales, e.g. Nokia acquired NAVTEQ (for approximately $8.1 billion[17]) to enable navigational services to be offered.[18] This reflects Nokia's direction to satisfy the consumer experience, which is expected to lead to more device sales.[19] Prior to SafeTrip-21 and the development of Mobile Millennium, Nokia had already engaged UC-Berkeley's capabilities in traffic engineering. Nokia was funding UC-Berkeley to support Nokia's research into business opportunities in the transportation market. Nokia considers the rate of technology innovation with UC-Berkeley was excellent – "an unusually collaborative partnership."

When Caltrans became aware of the details of this relationship it became part of the three-way collaboration that led to Mobile Millennium. Nokia learned about how Caltrans collaborated with the public, the California Highway Patrol, and others and recognized Caltrans' desire to connect with users. Thus all three parties had a mutual interest in developing and operating systems that recognized and responded to individual needs. Nokia would not have done the project if they had "to sell" UC-Berkeley on it; UC-Berkeley "got it" and understood that information consumers had to be interactive and involved in the process.

Nokia considers the biggest legacy of Mobile Millennium is how the mindsets of the UC-Berkeley students were changed on the subject of how technology can radically change transportation, and how, as a result, seeds are being sewn as these students take up their own faculty jobs.

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[17] **http://corporate.navteq.com/webapps/NewsUserServlet?action=NewsDetail&newsId=645&lang=en&englishonly=false**

[18] **http://www.nokia.com/press/press-releases/showpressrelease?newsid=1235107**

[19] See statement by Nokia President and CEO at the 2010 Nokia Annual General Meeting, in May 2010: **http://www.nokia.com/NOKIA_COM_1/Microsites/AGM_new/2010/en/materials/olli_pekka_kallasvuo_agm_speech_en.pdf**

3.1.2 NRC Goals

Nokia had two primary goals and one ancillary goal for its involvement with Mobile Millennium:

Primary

- To get a better understanding of what is possible regarding the quality of traffic data (accurate and precise data.) Accuracy is a function of the probe penetration, Nokia conducted “sub-experiments” involving 100-150 participants who were put on a road network to simulate the system.
- To understand the trade-off between users’ perspectives on privacy and users contributing data about their travel behavior.

Ancillary

- To understand how users want to use traffic information. Nokia found that consumer expectations were not what they expected. Pre-conceived notions (based on previous experience with other systems/applications/mobile devices) colored their reactions and acceptance to the data and its presentation.
    - User perceptions were different and that impacted how the consumer navigation roadmaps were developed; changed existing services and that information translated into other service and device plans; though they did not elaborate on the specific changes/developments since these are proprietary project development plans
    - The experience affected the development process and created a “wide footprint” for “transportation consumerism” and impacted Nokia’s understanding of the user experience (i.e., what the people expect from their electronic devices)

Nokia met these goals and declared its involvement with Mobile Millennium to be beneficial and “extremely positive.” Mobile Millennium has affected how Nokia looks at its business – they’re not just selling phones – they are selling phones and services. By including services in their plans (and while still a very small portion of their overall revenues) they realize that services and a consumer oriented relationship (with services support and interaction with consumers) is an important function since “consumers will buy devices based on their experiences (services and applications) with them.

In fact, much of the emphasis on the results and lessons learned from Mobile Millennium was this “discovery” of consumer experiences and the project helped them define what factors they should be exploring. Furthermore, the concept and definition of consumer experience is being defined, “even as we speak”; the U.S., in their opinion, is still lagging behind Europe but “we are catching up.”

3.1.3 Deployment and operational costs

Seven full time NRC researchers (Ph.D.s and staff scientists) were dedicated to Mobile Millennium. In part this reflects NRC’s recognition that any application must be constantly updated and enhanced to make it interesting to users – consumers expect new features continually. In addition, several system administrators were responsible to keeping the system operational 24/7 (as part of their regular work duties.) However, with sufficient computing power, maintaining the system was easy.

3.1.4 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.

The Mobile Millennium approach provides an alternative to using traditional sensor technologies and infrastructure for gathering traffic information. This is consistent with a desire to not install and maintain infrastructure for the purposes of gathering data and providing consumer information. Mobile Millennium also provides an ability to supplement traditional traffic data sources with probe data.

3.1.5 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 they were over 18 years old and had 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.

Nokia considers the contributor/recipient consumer is more complicated, in the sense that it is difficult to anticipate all their needs. Two characteristics that Nokia identified are that they crave to provide feedback and they want customization. Such consumers will try to report problems, and they want to know more.

Indeed, some users did not want Mobile Millennium to end. However, it was an experiment and it had to end. Nokia did not want to maintain a service that it could not provide to a high standard. It also did not want consumers to feel that "there was no one at the other end."

3.1.6 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 was 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.

Working with the government did have some impediments; primarily structures and processes that had to do with funding streams and cycles and general budget issues – funds can suddenly be cut without warning; also, some of the processes, such as public notices and/or press releases could take a long time (e.g., getting all reviews and approvals for a press release took 2 weeks, which, according to Caltrans was "a record" – it usually takes much longer; while in Nokia's experience they have to be nimble and need to turn things around very quickly. From Caltrans' perspective, delays were primarily caused by checks and balances within its processes.

Nokia was very complementary about how Caltrans is concerned to provide the best service to users. In what it described as an "eco-system" Nokia also sees an additional role for government – to get more participation from consumers by enabling them to provide information about their own behaviors so has to provide better services in return. 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."

Nokia had to accommodate Caltrans' timescale challenges that were created by funding availability issues. It is difficult when Caltrans' funding can be switched on and off, although this was in part related to unplanned funding interruptions resulting from the ongoing California fiscal crisis and therefore beyond Caltrans' immediate control.

In the private sector, you have to be immediately responsive to situations, such as when a competitor makes an announcement. That said, Caltrans went to extraordinary lengths to expedite its internal processes, e.g. by physically handing documentation to recipients rather than waiting for normal delivery mechanisms.

In the private sector, a risk for governments is that a company can go out of business.

3.1.7 Approaches for managing anonymity and privacy

Nokia's stance on privacy is that it is a customer 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:

- 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.

- 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 wrapping yourself 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 upfront issue for Nokia. It can be difficult to regain trust and credibility should a breach of privacy occur.

As mentioned previously, NRC and CCIT developed a feature called virtual trip lines (VTLs) which was a technical approach to minimize the potential for individuals' travel patterns to be tracked near the start and end of each trip. Smart phones transmitted their location information only when they crossed a VTL. NRC set the location of VTLs at intervals along highways and arterials, such that they were slightly distant from residential areas.

PART III: TRAFFIC MODELS

4. BACKGROUND

Part II of this evaluation report addressed the consumer response to Mobile Millennium. Part III addresses the other major component of Mobile Millennium, namely the processing of probe and other data to generate traffic information. While consumer response relates to how individual users interact with, and respond to, Mobile Millennium through their smart phones, the traffic models represent the 'back office' of Mobile Millennium. The traffic models are intentionally hidden from the view of consumers, but are nonetheless critical to the seamless operation of Mobile Millennium.

4.1 OVERVIEW OF TRAFFIC MODELS

Two traffic models have been developed for Mobile Millennium, one for highways and one for arterials. The highway model was developed for the earlier Mobile Century project and 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. This processed traffic information from each model is then merged with mapping information, using color coding 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.

4.2 EVALUATION APPROACH

The overall evaluation approach for Mobile Millennium has been previously described in section 1.2. The evaluation focus for traffic models is to support the SafeTrip-21 goal to explore/validate the benefits of real-time traveler information gathered from traffic probes. Specifically the evaluation objective is to measure the accuracy of the traffic information generated by Mobile Millennium, with a hypothesis that the system will produce traffic information that is accurate and representative of real-world conditions. A fuller description of each traffic model is provided in the relevant sections below.

Model validation is a process to assess the accuracy of a model and fitness for its purpose. Typically, model validation compares a model's key output parameters to actual measurements of the same parameters at an equivalent time of day. These parameters usually include traffic volume on specific segments (or groups of segments) in a given direction during a commute period. The actual measurements should be independent of any inputs on which the model is based, to avoid the possibility of spurious accuracy whereby the model predicts parameter values that are the same or similar to the model's input parameter values. Put simply, if a model has been developed based on traffic volumes for segments A, B, and C, the model validation process should consider model accuracy for segments X, Y, and Z.

If the model outputs and actual measurements for the selected parameters are in close agreement, the model can be considered validated, and subsequently used as a basis for assessing the operational impacts of specific transportation improvements. (Even when validated, the model should only be used within the limitations of its inputs parameters, e.g. within a specific geographical area, or for a specific time of day.) If the model outputs and actual measurements are not in close agreement, the model cannot be considered validated, leading to potentially unreliable results when the model is used for operational analysis. This can occur because the model is flawed and needs to be refined. Alternatively, this may be because the actual measurements were atypical or inaccurate, and therefore not an acceptable basis for comparison in the model validation process. In this case, additional or higher quality measurements of actual conditions may need to be collected.

More complex models require a more comprehensive model validation process. Typically, smaller models with limited numbers of segments, entry/exit points, intersections, and routing options tend to be more straightforward to validate than larger models covering major metropolitan areas with multiple segments, entry/exit points, traffic signal controlled intersections, and routing options. The Mobile Millennium highway model is somewhat analogous to the small model characterized above, while the arterial model is somewhat analogous to the more complex model.

However, the Mobile Millennium traffic models have a layer of complexity not normally associated with validation of traditional traffic models. This is because the key model output parameter is not segment traffic volume but real time segment travel time. This adds three layers of complexity to the validation of each model:

- Compared to traditional validation of traffic models focused on a peak period, the Mobile Millennium models generate multiple outputs continuously, in short time segments. Consequently, more measurements of actual conditions are required to validate the models around the clock to match the way that the models are used.

- Traffic conditions are often dynamic and non-recurring, such as traffic incidents, weather, visibility, the behaviors of other drivers, and the influence of nearby non-traffic events, e.g. house fires. These conditions are frequently unpredictable, can occur almost anywhere at any time, and can be resolved without ever knowing what happened.

- The key output of the Mobile Millennium models, and the basis for model validation, is travel time not traffic volume. Actual measurements of travel times are inherently more difficult to collect than traffic volumes, because each measurement requires two observations – time at start of segment and time at end of segment. Travel times typically need more resources to measure than traffic volumes.

The process of validating the accuracy of the Mobile Millennium traffic models is referred to as ground truthing. The project partners are best placed to undertake the ground truthing of the Mobile Millennium traffic models, as they have the greatest understanding of the traffic models as well as unrestricted access to all the required data. CCIT has responsibility for this effort, as it developed and hosts the traffic models. The role of the Evaluation Team has been to review the findings of the ground truth activities undertaken by CCIT, which are explained in greater detail in the relevant sections below.

It is noted that the ground truthing activities assess the accuracy of the traffic information generated by the traffic models. The accuracy of the traffic maps or the visualization of the traffic information on the traffic maps is not part of these ground truthing efforts.

5. HIGHWAY MODEL

The Mobile Millennium highway model was originally developed for the Mobile Century project, and the algorithms on which it is based have not fundamentally changed during this time. However there has been some minor tuning of model/network parameters and enhancement to the model software over the intervening years by CCIT under the auspices of UC Berkeley.

5.1 GROUND TRUTH METHODOLOGY

Ground truthing of the highway model used historical data collected as part of the Mobile Century project. No new data were collected, but the highway model has been updated since the Mobile Century project. Mobile Century culminated in an 8 hour event on February 8, 2008, along northbound Highway I-880 near Union City in the Bay Area. CCIT used two types of data for ground truthing:

- General traffic conditions were simulated using 77 instrumented vehicles driven as probes by recruited students.[20] The vehicles were driven as probes in general traffic, following pre-determined loops throughout the day. The loops represented a series of segments in the highway model. The vehicle probe locations were continuously tracked using the VTL technique and their location data was used as an input to the highway model. Using these data, the highway model estimated the travel times along the segments, and regularly updated these estimates in real time during the 8 hour period of Mobile Century.

- Independent observations of general traffic conditions were made by video-taping vehicles driving on I-880 at key locations, and subsequently reviewing the video tapes to manually transcribe and timestamp vehicle license plate data. License plates were then matched at adjacent locations, and the difference in their timestamps gave the travel times between the camera locations. These independently measured travel times were then compared to the corresponding output of the highway model.

5.2 FINDINGS

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. (Arterial travel times are addressed in the next section.)

[20] Although it was planned to use 100 vehicles, only 77 vehicles provided usable data

6. ARTERIAL MODEL

Unlike the Mobile Millennium highway model, which was based on the Mobile Century highway model, the Mobile Millennium arterial model was developed specifically for the test. The Mobile Century project was focused on a section of I-880, and did not require the development of an arterial model. In practice, seven arterial models have been developed for Mobile Millennium. A brief overview of the development of each is described in the following section.

6.1 DEVELOPMENT OF THE ARTERIAL MODEL

- **April through December 2008 – Model #1.** Most of the work done in this period was focused on the demonstration for the official launch in November 2008. CCIT developed a relatively simple model for estimating arterial travel times from VTL data. (The model was not based on a standard transportation model and was more of a time-series based model.) The working assumption was that VTL data would be the primary source of data for arterial estimation. The model developed at that time worked well at relatively high penetration rates, but was not very robust when the penetration rate was insufficient. In effect, the model was not designed for large city-wide estimation of arterial travel times.

- **January through August 2009 – Models #2 and #3.** CCIT took a more statistical approach, and developed new models that were both variants of regression models that are common in other fields.[21] CCIT researched how to use these regression techniques in a traffic setting, focusing on learning the spatial-temporal relationships among the different links of the network. CCIT conducted its research using some micro-simulation data as well as the data from the set of experiments in New York for the ITS World Congress. Both of these data sets lacked the spatial-temporal coverage needed for a larger metropolitan area. While the models worked well, they needed a relatively high penetration rate (5% to 10%) to be effective. The working assumption continued to be that VTL data would be the primary source of data for arterial travel time estimation. However not only were penetration rates too low to make reliable travel times estimates, it became clear during 2009 that the number of registered users would not grow much higher than the months immediately following the November 2008 launch. Consequently Mobile Millennium users received very little traffic information regarding arterial travel times.

- **August through December 2009 – Models #4 and #5.** In August 2009, CCIT began to seriously consider how to use data from the Cabspotting project.[22] While the penetration rate was not high, it appeared that there was enough historical data to be able to infer traffic patterns. CCIT decided to investigate models which first learned the general traffic patterns through a city and then use sparse real-time data to identify the deviations from the patterns. Models #4 and #5 were two different approaches that were developed somewhat independently by different members of the CCIT team. Both have the same general description as for Models #2 and #3, but they were different in their technical details. Model #4 is still being developed and has the advantage that it learned the traffic patterns well, but the disadvantages were that it required massive amounts of computing power and ultimately did not perform well in real-time. Model #5 had the advantage that it ran quite fast and worked well in real-time, but the disadvantage was that it was less robust to noise in the data.[23] Models #4 and #5 were not based on traditional transportation models, although both

[21] **http://www.ce.berkeley.edu/~bayen/conferences/trb10a.pdf**

[22] Cabspotting tracks taxis as they move through the San Francisco Bay Area: **http://cabspotting.org**

[23] **http://www.ce.berkeley.edu/~bayen/conferences/itsc10.pdf**

were capable of using travel time distribution forms inspired by transportation theory. The models were actually very general and it was possible to use any travel time distribution form. With these models CCIT's focus shifted away from VTL data to using the type of data received from Cabspotting (one GPS measurement per minute).

- **January through June 2010 – Model #6.** (This model was used for the arterial ground truth experiments.) CCIT begins working on deriving the specific form of link travel time distributions, and went through several iterations on how to best solve the optimization problem that arises when trying to learn the distribution parameters. While this had been settled in May 2010, before the arterial ground truth experiments, CCIT continued to refine some of the global parameters of the model that needed to be specified, such as what time intervals to break the day down into, and how to weight old data. CCIT did not change any parameters in response to seeing ground truth data, but did adjust parameters just based on the raw data that was received. The advantage of this model was that it was based on traffic flow theory and it was capable of learning the link distribution parameters with smaller amounts of data than previous models. The disadvantage was that it occasionally overfit the data (if insufficient data had been received) and produced unreliable outputs. This could possibly be corrected if sufficient time was spent tuning the global model parameters, but this has not yet been attempted.

- **June 2010 through the present – Model #7.** CCIT combines the ideas of models #5 and #6, along with some other ideas from transportation theory about flow conservation (a concept used in the highway model) into model #7. CCIT only has very preliminary results so far on this model, but is more encouraged by progress to date than with any of the preceding models. CCIT considers that this model combined with higher volumes of data (even just 1%-2% penetration rate is estimated to be sufficient) may lead to conclusive results. However, in order to validate that assessment, CCIT would need to run a much larger arterial ground truth experiment than those conducted for Mobile Millennium, with roughly 200 vehicles covering a large portion of a city and collecting video data on a large number of roads.

Although models #1, #2, and #3 were the most current models during the operational phase of Mobile Millennium, none of these models were ground truthed. Model #6 was used for arterial ground truth experiments, but was not developed until after the operational phase had concluded.

6.2 GROUND TRUTH METHODOLOGY

Ground truthing of the arterial model required new data collection, as the arterial model has been developed since the Mobile Century project. Given the greater range of arterial traffic conditions in a large metropolitan area such as the San Francisco Bay Area, CCIT chose to conduct ground truthing activities in two separate locations during separate time periods:

- San Pablo Avenue, an arterial running parallel to I-80 through the East Bay cities of Berkeley, Albany, and El Cerrito. Ground truthing activities occurred during April 27-29, 2010, for 3 hours each afternoon.

- Van Ness Avenue, an arterial in the City of San Francisco's downtown area. Ground truthing activities occurred during June 29-July 1, 2010, for 3 hours each afternoon.

As with the highway model, CCIT used two types of data for ground truthing the arterial model:

- General traffic conditions were simulated using up to 20 instrumented vehicles driven as probes by recruited students. The vehicles were driven as probes in general traffic, following pre-determined loops throughout the day. The loops represented a series of segments in the arterial model. Data from the probe vehicles probe locations were continuously gathered using the VTL technique as an input to the arterial model. Using these data, the arterial model estimated the travel times along the segments for various time intervals during the data collection period.

- Independent observations of general traffic conditions were made by installing six temporary blue tooth readers on existing street furniture along the two arterials. Blue tooth data was continuously collected from passing vehicles that contained activated blue tooth devices such as mobile phone headsets. Through a process of filtering, the 'signatures' of individual blue tooth devices were time-stamped at each reader they passed, and the difference in timestamps between adjacent readers used to estimate actual travel times of general traffic. These independently measured travel times were then compared to the corresponding output of the arterial model.

6.3 FINDINGS

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 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 of drivers in anticipating the best lane to be driving in. The only way to address this is to collect considerable amounts of data.

- The blue tooth 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, e.g. San Pablo Avenue, 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, e.g. Van Ness Avenue in downtown San Francisco, 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.

7. DEPLOYMENT EXPERIENCE ASSESSMENT (TRAFFIC MODELS)

This section focuses on the deployment experience with regard to the Mobile Millennium traffic models. The information in this section is mostly based on interviews conducted with representatives of CCIT. The findings herein represent the observations and opinions collected in those interviews.

7.1 FINDINGS

As stated previously, Mobile Millennium was unusual in that it effectively provided a consumer service, rather than a management or operations tool. While consumer response relates to how individual users interact with, and respond to Mobile Millennium through their smart phones, the traffic models represent the 'back office' of Mobile Millennium. The traffic models are intentionally hidden from the view of consumers, but are nonetheless critical to the seamless operation of Mobile Millennium. Because Mobile Millennium provides a 24/7 service, having the traffic models offline can potentially lead to a loss in consumer confidence.

7.1.1 Background

Prior to SafeTrip-21, Caltrans and the other partners had already recognized that traditional infrastructure-based approaches to collecting traffic data presented inherent challenges on multiple fronts including deployment, maintenance, and cost. Following the completion of Mobile Century in 2008, the (then) recent onset of smart phone technologies and their future potential to generate vast quantities of traffic probe data, combined with the scarcity of consumer orientated traffic applications represented a logical next step for the Mobile Century concept.

Mobile Millennium was a natural progression for Caltrans, CCIT, UC Berkeley and NRC from the earlier Mobile Century project. The Mobile Century highway model formed the basis for the Mobile Millennium highway model, but the arterial model had to be developed from new.

7.1.2 Partner Goals

Collectively, the Mobile Millennium partners had a strategic objective to demonstrate the potential of GPS in cell phones to alter the way traffic data is collected, by leveraging the existing cell phone infrastructure to collect data and transmit it directly back to drivers. From the perspective of Caltrans, CCIT, and UC-Berkeley, this meant developing traffic models that could process continuous large volumes of traffic data from multiple sources, especially traffic probes, and convert that into actionable traffic information for NRC to send to users' smart phones. The performance of the traffic models therefore became a critical element of the overall Mobile Millennium test for the partners.

7.1.3 Implementation challenges and how they were overcome

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 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 to not 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 economic situation where California is dealing with staff furloughs on a regular basis. The Caltrans procurement process underwent major change 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 things had to be implemented.

7.1.4 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.

PART IV: SUMMARY AND CONCLUSIONS

8. SUMMARY AND CONCLUSIONS

8.1 SUMMARY

Mobile Millennium was a groundbreaking test. Not only did it push the envelope about understanding 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 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, CCIT, NRC, and UC 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 VTLs, 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 most its 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 provided 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.

8.2 CONCLUSIONS

The conclusions that follow are grouped according to the evaluation objectives for Mobile Millennium.

8.2.1 Observe the consumer response to Mobile Millennium

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. This 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 it 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 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 a key factor driving governing the number of users is outreach and promotion.

8.2.2 Understand the technical and institutional issues associated with gathering probe-based traffic data, and distributing traffic information to smart phone users

Mobile Millennium contributed significantly to transportation industry's collective understanding of probe-based traffic information. The test demonstrated the potential for utilizing the vast amounts of data from using smart phones as traffic probes as 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.[24] 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 extensive use of automated tracking implicit with using smart phones as vehicle probes, the partners considered that privacy was an issued about which transparency was the best approach. The great majority of users indication that they trusted that Mobile Millennium protected their travel information.

8.2.3 Measure usage of the probe-based traffic 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

[24] From a mathematical perspective, the fixed data is a special case of the mobile data in which the measurements are obtained at a location which does not move.

operation of cell phones while driving, or by other electronic devices typically used in vehicles, e.g. navigation systems, was not studied.

8.2.4 Measure the accuracy of the traffic information generated by the system

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.

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PART V: APPENDICES

APPENDIX A: NRC MOBILE MILLENNIUM SURVEYS

Question	Question Type	January 2009 Nokia Survey	June 2009 Nokia Survey
Gender			√
Age range			√
Who is your mobile service provider?		√	√
What kind of mobile device do you intend to use with the Traffic Pilot?		√	√
Did you register to receive an SMS or email link for the Traffic Pilot download?		√	
--Did you receive the SMS or email?		√	
Did you successfully download and install the Traffic Pilot onto your mobile device?		√	
--Why was the download and/or installation of the Traffic Pilot unsuccessful?		√	
For how many trips have you used the Traffic Pilot?	Frequency of use	√	
Will you use the Traffic Pilot again in the future?		√	
--Why have you decided not to use the Traffic Pilot in the future?		√	
--What would convince you to use the Traffic Pilot again?		√	
Do you use the Traffic Pilot on a daily basis?	Frequency of use	√	
How could we improve the Traffic Pilot? What would make it more useful to you?		√	
In the last 7 days how many times did you use the Traffic Pilot	Frequency of use		√
Think back to the last time you used the Traffic Pilot. When did you open the application?	How used (first point)		√
--I never used the Traffic Pilot because…			√
Did you trust the Traffic Pilot to protect the privacy of your travel data?	Privacy		√
In general, for how long do you keep the application open?	How used (how long)		√
When do you use the Traffic Pilot?	How used (when)		√
Why do you use the Traffic Pilot?	Why used (shows perceived benefits)		√
In your opinion, how useful are the following types of traffic information?	Usefulness (general)		√
In your opinion, how accurate are the following types of traffic information?	Accuracy (general)		√
How do you feel about the following form factors for receiving traffic information?			√