# EXPERIMENTAL DESIGN OF SMART PARKING APPLICATIONS FOR SAFETRIP-21 FIELD EXPERIMENTS

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1. BACKGROUND

The SafeTrip Parking project team is preparing the deployment of smart parking applications under a Networked Traveler project as sponsored under the US DOT SafeTrip-21 efforts. This document describes the premise, hypotheses, rationale, and the approach for conducting field experiments, with the goal of assessing the validity and usability of the proposed transit applications.

2. PREMISE

Taking commuter trains has become a viable alternative for commute. It is green and safe, and allows travelers to spend travel time on work, entertainment and rest as they wish rather than the driving task. Mode shift can help balance traffic and provide congestion relief. Fuel price increase in 2008 has triggered significant ridership increase. APTA Public Transit Ridership statistics (http://www.apta.com/research/stats/ridershp/index.cfm) shows that ridership remains high after fuel price drops, indicating that when travelers are attracted to the transit mode, they tend to stay with transit. Several factors have discouraged travelers from using transit to commute, including:

(1) Unfamiliarity with where, when and how to take transit prevents drivers to shift mode regardless of the fact that transit can be competitive with driving in many cases.
(2) The lack of real-time information. Waiting at the station and looking for a parking space can be very time consuming and annoying, especially when a traveler is unable to find a parking space.
(3) Not knowing actual costs for traveling with auto mode is another factor for travelers stay with the mode they are familiar with. Drivers typically think only fuel costs when it comes to auto travel, but the expenses for auto travel include amortization for owning a vehicle, maintenance, insurance and license costs.

These travelers would likely be willing to use transit as an option once they became familiar with transit use. For these travelers, dynamic parking information, together with real-time traveler information can help make commuting by train a viable option. Real-time parking information system together with comparative trip time information, presented through roadside Changeable Message Signs (CMS), pre-trip planning web site to en-route advisory application running on users’ smart phones may potentially help travelers decide on their mode-shift in a number of ways:

(1) For the travelers who are familiar with train services but have been constrained by lack of available parking at their nearest train station, providing real-time information on parking availability for nearby stations including shuttle or transit connections at these facilities will encourage them to use train service more often.
(2) If the travelers who commute on highways are provided with congestion-related information, together with real-time Caltrain trip time and parking availability information, they will likely shift their mode to trains;
Dynamic arrival time for trains and parking availability information will provide Caltrain users with better service, save travelers’ time and make transit a more viable option.

Real-time parking information in conjunction with route guidance can help reduce the time required to search for a parking space.

Information about comparative costs for available modes can likely trigger mode shift for some who are cost sensitive but not comprehend about trip costs.

Once travelers are familiar with transit travel and become trustful with real-time multimodal travel information, they likely will stay with the transit mode, as evident by recent transit ridership data. As fuel prices rose, so did transit ridership. As fuel prices declined, transit ridership did not (or did not decrease at the same rate and now remains steady at levels higher than before gas prices spiked(?)).

3. PARKING INFORMATION PROJECT APPLICATIONS

The SafeTrip-21 Parking information project will field test the following applications.

**Multi-modal pre-trip planner and information system:** As an important part of the Multi-modal traveler information system, the pre-trip planner will integrate freeway travel time along US-101, travel time (when available) along SR-82 (as known as El Camino Real), travel time by Caltrains and real-time parking space availability information at several selected Caltrain parking lots. A typical scenario will be a traveler to plan a trip from home to work, which either starts by driving or taking local buses/shuttles to the train station. Travelers that are not familiar with transit will benefit from this multi-modal planner due to its real-time contents. When travelers are attracted to the transit mode, they tend to stay with transit, and in this case this tool will help to improve the quality of traveler information system.

Also in synergy with Networked Traveler Transit applications, passengers, via their smart phones, can receive en-route information on Caltrain arrival and transfer times.

**Major test objectives:**
For this application, data will be collected for the independent evaluators to analyze and interpret how well a dynamic multi-modal trip-planner can impact travelers mode choice, improve the passengers’ perception of quality of the transit service, etc. The system functionality and performance will be measured. Details can be found in subsequent sections.

**“Mode-shift alert” for freeway drivers upon congestion:** One major objective of the parking information applications is to encourage mode shift from passenger cars to trains along the US-101 corridor. Caltrain service has not been fully utilized and parking lots have not been exclusively occupied, thus there is room for a ridership increase, thus to relieve freeway traffic and reduce emissions. This application is provided in real-time to drivers along US-101, vehicle (user) GPS locations will be constantly sent to a server at PATH, and when there is congestion / incident ahead (enabled by the Networked Traveler Safety Applications) and the current location on the freeway is close to an exit that has access to a Caltrain park & ride station with available parking spaces, then an alert is provided of “Park & Ride Info: Parking Spaces available at Millbrae station, next Baby Bullet train arrives in 15 minutes”. This application will be provided in synergy with the SafeTrip Safety application with the same smart phone platform and
extended client software.

Major test objectives:
For this application, the test objectives are to evaluate both the subjective part of user perception and quantitative analysis of the timeliness and usefulness of the alert. A two-stage test will be carried out. The first stage will be a “driver-in-the-loop” test when drivers will only receive a “congestion ahead” (Networked Traveler Safety application) alert, and the archived GPS tracks of the freeway trip will be post-processed to learn when and where to alert the drivers about park and ride information. The second stage will be an operational test where drivers will receive real alerts and drivers’ reaction (taking the advice or not) will be extracted from the trajectories for evaluation purpose.

Changeable Message Signs For Park & Ride information: In addition to the information delivery via smart phones, several Changeable Message Signs (both fixed and mobile) will be installed along the US-101 freeway and arterials close to Caltrain Stations (e.g., Palo Alto, Redwood City, etc).

Major test objectives:
System functionality and performance will be tested. The subjective test will be based on the users perception of the timeliness of the information, accuracy of the information regarding parking space availability and train arrival time.

4. PARKING INFORMATION APPLICATIONS TEST HYPOTHESES

For each of the applications that are to be deployed for the field tests, the hypothesized outcome, expected benefits and user responses are described and listed in Table 1.

<table>
<thead>
<tr>
<th>Application</th>
<th>Applicable Situations</th>
<th>Hypothesized Outcome</th>
<th>Expected Benefits to Travelers and their Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-modal pre-trip planner</td>
<td>• For users to make the plan while at home (e.g., make a plan to work);</td>
<td>• Travelers will benefit from the integration of the real-time train arrival time,</td>
<td>• Travelers provide favorable assessment of the real-time parking availability information</td>
</tr>
<tr>
<td></td>
<td></td>
<td>parking availability information and freeway / arterial travel time. Travelers will</td>
<td>• Travelers save time on waiting at stations, failed search for non-present parking spaces;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>be less likely to miss a train, or get the train station without being able to find a</td>
<td>• Travelers use transit more often;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>parking space. Train riding could become more viable to travelers.</td>
<td></td>
</tr>
</tbody>
</table>
| Multi-modal traveler information    | • Caltrain arrival time at Train station and via smart phone  
• Get off alert and transfer information  
• Check Parking space | • Travelers will get accurate train arrival time from either the message sign at station or via smart phones;  
• Travelers will get parking space availability information | • Travelers provide favorable assessment of the dynamic traveler information;  
• Traveler choose to take Caltrain instead of |
<table>
<thead>
<tr>
<th><strong>Travelers</strong> will get “preparing to takeoff” alert on smartphone;</th>
<th><strong>Drivers</strong> get the message out of the smartphone application;</th>
<th><strong>Travelers</strong> provides favorable assessment of the “park and ride message”;</th>
<th><strong>Drivers</strong> get the message out of the smartphone application;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travels will avoid missing the destination stop and benefit from fast alighting;</td>
<td>Drivers will benefit from this “park and ride message” at the time of freeway congestion (either re-concurrent or non-re-concurrent); Freeway congestion will be relieved due to the mode shift of the drivers taking the “park and ride” alternative;</td>
<td>Traveler may save their travel time by taking Caltrain Baby Bullet service in time of congestion;</td>
<td>Travelers avoid missing the destination stop and benefit from fast alighting;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Park and Ride Message” while driving</strong></th>
<th><strong>Put Changeable Message Signs (CMS) along US-101, where close to several exits to the test sites of Caltrain Stations, showing the real-time availability of the parking lot spaces and the next train arrival time;</strong></th>
<th><strong>Drivers</strong> using US-101 will be able to benefit from the messages, not limited to the users that have downloaded our application into their smart phones.</th>
<th><strong>More commuters choose to shift mode to take Caltrain</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>availability information using a smart cell phone; and next train arrival time from their smart phones; They might decide to take transit when they see the available parking space and a feasible waiting time;</td>
<td>Drivers get the message out of the smartphone application;</td>
<td><strong>Travelers</strong> provides favorable assessment of the “park and ride message”;</td>
<td><strong>Drivers</strong> get the message out of the smartphone application;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Roadside Changeable Message Signs on Caltrain Parking Lot availability and Next Train arrival</strong></th>
<th><strong>Drivers</strong> get the message out of the smartphone application;</th>
<th><strong>Travelers</strong> provides favorable assessment of the “park and ride message”;</th>
<th><strong>Drivers</strong> get the message out of the smartphone application;</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Park and Ride Message” while driving</td>
<td><strong>Drivers</strong> get the message out of the smartphone application;</td>
<td><strong>Travelers</strong> provides favorable assessment of the “park and ride message”;</td>
<td><strong>Drivers</strong> get the message out of the smartphone application;</td>
</tr>
</tbody>
</table>

There are a multitude of common elements given in the table above. They can be reorganized into the charts below. The first chart is a diagram showing the suite of applications.
5. VALIDATION OF TEST HYPOTHESES

5.1 Parking Information Application and Expected Test Outcome

Field data as well as user experience data will be collected and analyzed to explore the user needs and preferences. Design validity and shortcomings of the parking information applications will be evaluated.

The goal of providing the parking information, including the multi-modal pre-trip planner and the real-time parking availability information and Caltrain arrival time information, is to make the alternative of driving - taking Caltrain - a more viable choice. The idea is to help drivers make more informed choices potentially shifting their mode to transit, thereby helping to reduce congestion on the freeway and contribute to emission reduction. The test will focus on how well drivers respond to the different ways of delivering the real-time multi-modal transit information, including how parking availability could influence the traveler’s decision-making process and help them decide to shift mode. The experimental design of the tests should focus on the observation and analysis of user responses, both qualitatively and quantitatively.

We note that the user response data will be collected in different ways for different information delivery methods.

- For the roadside CMS, we will conduct a survey to a group of freeway commuters to study their responses to the messages.
- For the recruited testers that are using our smart phone applications, their consent of collecting the GPS tracks (detached with personal identity) will be obtained and then the GPS tracks together with the archived data about when, where and what messages have been delivered to the users. By analyzing the GPS tracks, we will be able to determine if the driver followed the advice to shift mode or not. And the effectiveness of the real-time

![Figure 2 Hypothesized Expected Outcomes of Parking Information Applications](image-url)
“park and ride” message will be measured. The recruited testers will also be given a
survey to review the usefulness and timeliness of the messages.

- For the users that are using the multi-modal pre-trip planning applications, the user
  responses on their preferences and needs will be collected. Two forms of data collection
  will be made. First is to collect the user browsing history data, that includes when and
  how the users used the application, the frequency of usage, etc. Another form is the
  collection of user preference by asking users to take an on-line survey.

Through analysis the collected data for the different methods of information delivery, the
quantitative and qualitative part of the system performance can be measured.

5.2 Functional Processes and Operating Constraints

Before discussing further the necessary data collection and the availability of observable data to
validate the test outcome, it is critical to point out the constraints of the data acquisition process
within the context of the planned field tests.

5.2.1 Functional Process of Parking Information Applications

- For multi-modal pre-trip planning, information could be delivered to the travelers either
  when they are at home, or they are already on the road. The planning application does
  not require a continuous wireless link, so any form of internet connectivity will work,
  including the wireless mobile network, wired network, on any terminals, ranging from
  smart phones to desktop computers. This application will be web-based. The procedure
  will be easier compared to the former one.

- The Parking information applications are part of the Networked Traveler Program of
  projects, which largely relies on consumer wireless communication devices, especially
  the GPS enabled smart phones and PDAs to deliver real-time traveler information. The
  GPS technology used in the smart phones are essential for the project in order to collect
  the GPS tracks of the travelers to know their location in real-time to push to them up-to-
  date, location-based information: the “park and ride available” alert. We also need a
  continuous wireless link with full coverage of the test sites, which could be either a 3G
  network or the legacy GPRS system. For these users, they will need to register with the
  PATH test server, download software and then start using the application. Detailed
  procedures will be described later.

- While for the roadside message signs, CCIT and PATH will work together with Caltrans
  District 4 to explore the possibility of using either (1) the existing dynamic signs along
  US-101; or (2) place mobile signs as a temporary solution at desirable locations, along
  US -101 and along major arterials in test sites close to the stations.

The three major applications have different constraints on data collection process. To improve
the quality of the collected data, test participants will be recruited in conjunction with the
Network Travelers FOT. Based on our “parking lot selection” analysis, the participants of each
of the applications features different characteristics in terms of their origin and destination and their most frequently used commuting mode. The candidate participants for different applications are listed in Table 2.

<table>
<thead>
<tr>
<th>Application</th>
<th>Candidate Participants</th>
<th>Origin-Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-modal Pre-trip Planning</td>
<td>Travelers that frequently use transit to commute (to San Francisco) (riding Caltrain)</td>
<td>Origin: Millbrae, Burlingame, Redwood City, San Carlos, Menlo Park, E. Palo Alto, Palo Alto, Destination: San Francisco</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Will identify participants from the listed origin cities</td>
</tr>
<tr>
<td>“Park and Ride alert”</td>
<td>Travelers that drive-(alone) to San Francisco</td>
<td>Origin: Mainly from Millbrae, Burlingame, Redwood City. (Other candidate cities are not as desirable since the freeway is further away from Caltrain station, thus difficult to divert, and also fewer travelers)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Will identify participants from the listed origin cities</td>
</tr>
<tr>
<td>Parking and Caltrain arrival time information Signs</td>
<td>All travelers using north bound US-101 to commute from San Mateo County to San Francisco</td>
<td>We will use the same group of participants as the “Park and Ride alert” application. Will send the participants survey forms to collect their opinions on the usefulness and data quality of the messages.</td>
</tr>
</tbody>
</table>

For the transit oriented group of participants who take the Multi-modal pre-trip planning application, the following procedure will be needed to collect experimental data:

1. Users register for the service (User will need to register only once, after which users will only need to login with their user name);
2. Users enter origin and destination for the intended trip (User can save the trip origin and destination as “home”, “work”, etc. for later usage. So the same user does not have to input the address of origin and destination each time).
3. Upon each use, the user origin and destination will be sent to the server (and archived for later analysis).
4. User preferences for the routes include: Minimum travel time; minimum number of transfers; minimum driving distance to transit hub; minimum fare (with gas mileage in consideration), etc. User preferences will also be stored for analysis purposes;
5. PATH server will generate routes according to the user preferences, based on real-time
freeway travel time along US-101, real-time arrival times of the Caltrain trains, SamTrans and VTA buses and other static information including the schedule of BART;

(6) User confirms one choice, or cancels the planning and the action will be sent to the server and stored;

(7) System server receives AVL data from Samtrans and VTA for buses running along El Camino Real and Caltrain trains. Train and bus arrival time will be estimated in real-time by a PATH server and stored in the database; Server receives real-time freeway travel time data from MTC server (one minute updating rate);

(8) The time of usage, the origin and destination, the user preferences and the user decision (the confirmed choice or void) will all be archived.

For the driving oriented group of participants who take the “Park and ride alert” application (and will see the roadside changeable message signs as well), the following procedure will be needed to collect the experimental data:

(1) User needs to register for the service (same process as “multi-modal pre-trip planning”);

(2) User enters origin and destination; (same process as “multi-modal pre-trip planning”);

(3) User confirms that the GPS data (with personal identity detached) will be sent to a PATH server for research purposes only (this step will need to be done only once);

(4) User activates the application and drives toward specified destination (desirably San Francisco) along US-101;

(5) The GPS data will be sent to the PATH server every 30 seconds or less;

(6) Server will check if the driver is approaching the test sites; Test sites include the Caltrain stations where we have real-time parking availability information available (to be more specific: three or four stations among Millbrae, Broadway, Redwood City, Menlo Park, Palo Alto) and the freeway exits that have access to these stations;

(7) If the driver is approaching the test sites, the server will calculate the travel time to the destination based on real-time freeway data (updates from MTC every minute); will compare the remaining travel time to the alternative “park-and-ride” travel time, including the time to park, waiting for the train and train travel time (which is estimated based on Caltrain AVL system); when certain conditions are met (freeway travel time is high, Parking is available, Caltrain waiting time is low, next train is Baby Bullet train or express train), a “Park and ride alert” will be given, which literally will include freeway travel time, Caltrain arrival time, parking availability, and Caltrain travel time.

(8) GPS track will be continuously recorded so that after post-processing of the data, we intend to learn whether or not the driver has taken the advice to divert or not; that being said, the driver does not have to press a button or answer a question to respond, thus will keep the driving safe.

(9) The actual travel time on the freeway (if the driver did not divert), or the actual arrival time of the Caltrain and actual trip time of the Caltrain (if the driver diverted) will be obtained by post-processing the archived AVL data and the result will be used as basis for data accuracy verifications;

(10) After the installation of the roadside Message, the drivers will be given several surveys regarding their opinions on the usefulness and accuracy of the information provided by the CMS.
5.2.2 Constraints in Data Acquisitions

The following constraints in both quality and quantity of data acquisition should be noted:

(1) There are accuracy constraints for the various real-time data sources, which will in turn limit the accuracy and availability of test data collection:
   a. Parking data is subject to sensing errors, such that the parking space availability information may or may not be accurate. Therefore, the availability of parking spaces will be encoded in a conservative way before being delivered to the travelers. Details will be discussed in the next section;
   b. Freeway travel time from MTC has a one-minute sample period, plus the link speed info from the MTC data is also subject to errors as have been observed during the feasibility study. The error will result in inaccurate traveler information (such as false alert of “park and ride message” when freeway travel time is excessively overestimated); Error statistics will be obtained during the field test to build an alerting algorithm with error tolerance;
   c. AVL data are only available for partial routes of SamTrans and VTA at the test sites; Whenever AVL data is not available, bus arrival time will be based on schedule only, which is subject to larger errors than real-time data;

(2) Constraints on obtaining user generated system data (including the user choices, user GPS track, user preferences, etc):
   a. Subscribed users may or may not be using the applications during the test period. During the user recruiting, we will make every effort to recruit relevant users, that is commuters that fit into the mode of our application and who use the route frequently enough. Of course the quality of the application itself will greatly affect the frequency of its usage by the users, which is also an MOE of the system: An application that is frequently used by the travelers should be considered as much more positively viewed;
   b. GPS tracks of the subscribed user will only be collected upon consent of the user, and the user could stop sending the GPS data at any time during the test; The GPS track during the user commute, especially the trajectories before and after the user gets the “park and ride” alert are essential to know the action the user has taken; For safety concerns, we would rather not distract the driver by asking driver questions or let the driver press a button;
   c. Accuracy of the GPS trajectories highly depends on quality of the built-in GPS unit in the user’s smart phone, which may be subject to outliers from time to time;
   d. Users may or may not travel between the prescribed origin and destination;

(3) Constraints on obtaining the user feedbacks
   a. User may or may not provide final confirmation of the choices provided by the multi-modal pre-trip planner. Void of user confirmation will be treated as negative feedback, which will lead to conservative estimation of the user’s opinion;

5.3 Measures of Effectiveness
The planned field tests of the parking information applications is also on a limited scale, and considered a pilot test as it is to be carried out within a limited period of performance (for the year of 2009) and scope. However, it is still important to establish the framework and methodology to conduct the system assessment toward the end of the pilot test so that effectiveness and usefulness of parking information applications can be properly measured. The following table illustrates how a matrix of measures of effectiveness can be constructed.

<table>
<thead>
<tr>
<th>Expected Test Outcome and Traveler Responses</th>
<th>Measures of Effectiveness (MOE)</th>
<th>Parameters and Variables to Assess MOE</th>
</tr>
</thead>
</table>
| Public awareness of parking information applications | • Spectrum of project partnerships | • List of partners in project  
| | • Scope of community participation | • Scope of participation by partners  
| | | • List of participating organizations outside of project team  
| | | • Number of participating users  
| | | • Number of data samples collected in field tests  
| | | • Percentage of positive feedback by users  
| | | • Outreach efforts  
| | | • Sessions of activity reports held in public forums and conferences  
| | | • Technical papers presented  
| | | • Reports of media events  
| Favorable user experience and positive user feedback to the multi-modal pre-trip planner | • Willingness to participate and to maintain continual use of the application | • Number of participating users  
| | | • Periods of active usage  
| | | • Continuity and frequency in activating applications  
| | | • Percentage of positive feedback by users  
| | | • User feedback to surveys and questionnaire on  
| | | - Functional usefulness  
| | | - Functional acceptability  
| | | - User interface friendliness  
| | | • User answers in surveys and questionnaires (to be detailed and designed later)  

<table>
<thead>
<tr>
<th>Mode shift actions by users: “Park and ride” alert and CMS information</th>
<th>User Mode shift actions</th>
<th>Frequency of user activating the application of “Park and Ride” alert; Percentage of samples when a mode shift is seen after “Park and Ride” alert is given to the traveler; Percentage of users (based on survey data) ever shifted / or would shift mode upon seeing each CMS information ; Time saving preferences to switch mode (from user perspective)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>User feedback to the information; Timeliness of alert; User interface friendliness; Information accuracy; User feedback on CMS message content</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User provides favorable feedback to the information: User thinks the information provided by “Park and Ride” alert and CMS information are useful to travelers to make mode shift decisions;</td>
</tr>
<tr>
<td>Objective Parking Availability information accuracy</td>
<td>Accuracy of the encoded parking space availability information</td>
<td>Presented encoded parking lot availability information as compared to the ground truth (can only be done for several days when ground truth data is available (will have surveyors to count the parking lot occupancies));</td>
</tr>
</tbody>
</table>

### 6. DATA COLLECTION AND ANALYSIS

#### 6.1 Application Field Test Schedule

Table 4 provides a list of milestones and targeted applications for this phase of Safe Trip 21 field deployment tests.
### Table 4 ST-21 Parking Information Field Test Initial Milestones

<table>
<thead>
<tr>
<th>Milestone Date</th>
<th>Rollout Functionality</th>
<th>Precipitating Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 30&lt;sup&gt;th&lt;/sup&gt; 2009</td>
<td>Caltrain parking space availability information; <strong>Driver-in-the-loop</strong> simulation of the park-and-ride alert</td>
<td>SamTrans approval of instrumentation of Caltrain parking lots; Trajectories available from the subscribed drivers for safety applications of Networked Traveler</td>
</tr>
<tr>
<td>June 30&lt;sup&gt;th&lt;/sup&gt; 2009</td>
<td>Multi-modal pre-trip planner; “Park and Ride” alert; Changeable message signs;</td>
<td>(1) Integration with Networked Traveler Safety applications in driver interface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2) MTC provides transit information and real-time freeway travel time;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3) SamTrans provides access to AVL/C system;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4) Caltrans D4 approves interfacing to the Changeable message signs;</td>
</tr>
<tr>
<td>Nov 30&lt;sup&gt;th&lt;/sup&gt;, 2009</td>
<td>Field testing</td>
<td>CPHS approval Drivers co-recruited with Networked Traveler Safety applications–</td>
</tr>
<tr>
<td>Dec 31&lt;sup&gt;st&lt;/sup&gt; 2009</td>
<td>Dataset and report</td>
<td></td>
</tr>
</tbody>
</table>

### 6.2 User Recruiting

We will recruit users in three phases, several hundred per phase (early Spring, late Spring, early Summer), by working with management from the following organizations:
- SF Transportation Management Association
- Metropolitan Transportation Commission
- AAA (Northern California Automobile Association) and
- Samtrans
- Santa Clara Valley Transportation Authority
- Stanford Commuter Club (given in order of priority in recruitment)

Each user will be required to have a cell phone and an unlimited data plan.

#### 6.2.1 Targeted Users

There are two groups of users that we targeted to recruit for the applications:
- Commuters that frequently take transit (Caltrain) to San Francisco from San Mateo County and Santa Clara County;
- Commuters that frequently drive(-alone) to San Francisco from San Mateo and Santa Clara County;
Table 5 User Recruiting Cities and Population Size

<table>
<thead>
<tr>
<th>Commuter group</th>
<th>Commuters that frequently ride trains</th>
<th>Commuters that drive-alone</th>
</tr>
</thead>
<tbody>
<tr>
<td>User applications</td>
<td>Multi-modal Pre-trip planner</td>
<td>“Park and ride” alert and CMS information</td>
</tr>
<tr>
<td>destination of the commute</td>
<td>San Francisco</td>
<td>San Francisco</td>
</tr>
<tr>
<td>Will recruit users from these cities:</td>
<td>Redwood City, Menlo Park, East Palo Alto and Palo Alto</td>
<td>Millbrae, San Mateo, Redwood City</td>
</tr>
<tr>
<td>Number of the population of users that match the condition in the candidate cities:</td>
<td>Millbrae-Burlingame ~300</td>
<td>Millbrae-Burlingame ~6000</td>
</tr>
<tr>
<td></td>
<td>Redwood City San Carlos ~500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Menlo Park East Palo Alto ~200</td>
<td>San Mateo-Coastside ~4600</td>
</tr>
<tr>
<td></td>
<td>Palo Alto ~ 500</td>
<td>Redwood City San Carlos ~3600</td>
</tr>
</tbody>
</table>

In Table 5, we listed the population size of the users that we targeted to recruit. The calculation is based on the year 2000 San Francisco Bay Area Census data and also the year 2008 Caltrain annual report. Note that the Caltrain report does not have destination included, so the number of train riders are North Bound only, not necessarily to be destined to San Francisco, though most of them are assumed to be. The selection of the users based on their origins and destinations, as well as their commuting mode, should significantly increase the quality of collected data.

6.2.2 Definition of Samples for Parking Information Applications

A sample is defined here as basically one usage of the applications of one occurrence of the alert. For different tests, the sample size requirement would be different. Also there are two dimensions for the sample size, one is the number of participants in the test, the other is the number of repeated experiments per participant. Focus on which dimension depends on the application.

Table 6 Sample Definition for Applications

<table>
<thead>
<tr>
<th>Test</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-modal Pre-trip Planner: User Feedback</td>
<td>A sample is one set of yes / no feedbacks from one user, to the survey questions such as usefulness, interface friendliness, data accuracy (about predicted parking space availability, train arrival time, etc).</td>
</tr>
<tr>
<td>“Park and Ride” Alert: User Mode Shift Actions</td>
<td>A sample is one trip trajectory data, including the GPS track, the time when the alert message is given to the driver, and the post-processed result of whether or not the driver followed the advice;</td>
</tr>
</tbody>
</table>
“Park and Ride” Alert: User feedback  
A sample is one set of yes/no feedbacks from a user to the survey questions about the usefulness and user friendliness of the presented information;

CMS information: User feedback  
A sample is one set of yes/no and multiple choice feedbacks from a user to the survey questions about the usefulness and accuracy of the presented information;

Objective accuracy of parking space availability information  
Will be continuous data records on the parking space availability; Test will be based on data collection period of time instead of sample size;

Objective accuracy test of “Park and Ride” alert  
The accuracy in terms of the triggering condition when predicted freeway travel time is competitive to the Caltrain riding time will be evaluated;

6.2.3 Sample Size Estimation

The required sample size for the experimental tests are calculated based on the type of the survey, margin of error, confidence level and the candidate population size, if applicable.

<table>
<thead>
<tr>
<th>Expected Traveler Response</th>
<th>Assumptions</th>
<th>Sample Size</th>
</tr>
</thead>
</table>
| 1. Traveler provides favorable feedback to “Multi-modal Pre-trip Planner” | 1. Dichotomous (Yes/No) Outcome  
2. Margin of error =5%  
3. Confidence level =95%  
4. Population size= ~1,500  
5. Response distribution=50% (50% is the worst case which requires the most samples) | 306  
(or with sample size as low as 100, the margin of error would be 9.5%) |
| 2. “Park and Ride” Alert: User Mode Shift Actions | 1. Dichotomous (Yes/No) Outcome  
2. Margin of error =5%  
3. Confidence level =95%  
4. Population size= ~14,000  
5. Response distribution=10% (We are expecting this percentage to be quite low) | 137  
(or at a sample size of 100, the margin of error would be 5.86%) |
| 3. “Park and Ride” Alert: User feedback positively | 1. Dichotomous (Yes/No) Outcome  
2. Margin of error =5%  
3. Confidence level =95%  
4. Population size= ~14,000 | 374  
(or at a sample size of |
6.3 Data Collection

As outlined in the application rollout schedule and milestones above, the parking information applications will be made available in June. Corresponding to this schedule, the data collection will be implemented in several stages:

6.3.1 Quantitative Data

(1) Collection of user data in response to parking information applications

After the initial validation period, the data collection will continue as long as the user opts to activate the functions in his/her commutes. If a user signs up in the early stage of the field test, the data collection period can continue for 5-6 months before the conclusion of the field tests.

(2) Collection of parking availability data
Parking availability data is an important data source to the smart parking project. It feeds data for all the three applications: the multi-modal planner, the CMS information and the “Park and Ride” alert. So the accuracy of the parking space availability information is vitally important to the success of the project.

The experimental test of the parking availability information will be based on a manual survey of parking space occupancy, which will be used as ground truth data for verification of the vehicle sensing and parking space prediction algorithm output.

- **Data collection sites**
  - (To-be) Instrumented Caltrain stations, to include Millbrae, Redwood City, Menlo Park, Palo Alto and Hillsdale.
- **Data collection period of time**
  - One week
- **Data**
  - Record the time up to seconds of each vehicle leaving and entering a given parking lot. Each surveyor will do only one parking lot of a station per day.
  - Record each entering or leaving vehicle, including its time. If multiple vehicles enter or leave at almost the same time and it is difficult to distinguish the time separately, record them as a group.
  - Note WHEN the parking lot gets filled up.
  - The processed parking space occupancy data for the given parking lot (if instrumented);
  - The encoded parking space availability information based on the detection algorithm (The encoding procedure will map the number of available spaces to a discrete state indicating likelihood of getting a parking space);

(3) Collection of driver trajectories for mode-shift actions of “Park and Ride” alert application

The “park and ride” alert will be a smart phone based application that is downloadable by users. As has been discussed before, recruited users are expected to be commuters driving alone North Bound to San Francisco, using US-101.

- **Data collection sites**
  - Along the US-101, North Bound, where “park and ride” alerts could be given to the driver;
  - To give the driver a “park and ride” alert, several conditions must be met:
    - Predicted Highway travel time is high, and competitive to that of riding Caltrain (include the waiting time at train station);
    - Current location close to Caltrain station with Parking availability information and Baby Bullet or limited train service;
  - Based on these conditions, the major sites for this test would be:
    - North Bound US-101 before the exit to Millbrae Station (E Millbrae Ave. Exit, or Exit 420). It will take only less than 3 minutes to divert from US-101 to the Millbrae Station;
    - North Bound US-101 before the exit to Broadway Station (Exit 419B). It will take at most 3 minutes to divert from US-101 to the Broadway Station; this exit can also serves as a divert point to ride at Millbrae when the freeway between Broadway and Millbrae is congested.
North Bound US-101, exit 409 (Whipple Ave.) to Redwood City Station, driving time about 5 minutes;

Other locations are also possible, but only in extreme conditions, such as lane-closure, when driving long distances along local streets or taking a local train is acceptable (travel time competitive to freeway driving).

- Data collection period of time
  - During the 5 to 6 months of the experimental test;
  - Sample size defined in Table 7.
- Data
  - Driver’s origin and destination of the trip;
  - Driver’s GPS trajectory of the trip (including timestamp);
  - Predicted Caltrain arrival time, predicted freeway travel time;
  - When and where “Park and Ride” alert is given to the user;
  - The trajectory of the user after being given the alert;
  - By post-processing the trajectory data to get the driver decision: whether or not has the driver shifted the mode;

(4) Collection of “driver-in-the-loop” simulation data for the “Park and Ride” alert application
The data collection sites are the same with the real alert application. The collection period will be one to two months, before starting the real alert application test. The collected data will not include the time and location of the alert given (since we are not giving the alert). The actual arrival time of the train and the actual travel time along freeway (the drivers are not supposed to shift mode, since there are no such alert given to them) will also be included in the test.

(5) Collection of CMS travel time log data.
The log data show how often the CMS signs display that riding the Baby Bullet has a time advantage over driving along US-101. The data can be correlated with the survey results to evaluate the CMS system performance.

6.3.2 User Survey and Questionnaire

User survey forms will be provided to the two groups of travelers.

(1) User information at registration
All users are required to register when they sign up for the application services. In this registration process, certain questions about the users will be posed. Answers to some questions are required, and others are optional. For example, to assess the coverage of user base, the driving distance and zip codes for origins and destinations of regular routes will be useful information to have in this registration process. The detailed form of questions will be provided later.

(2) On-Line Feedback
Users will be given the option of providing anytime feedback on problems encountered in the use of the applications as well as desired changes or suggestions on the applications that are offered.

(3) Mid-term Survey
Three months into the initial use of the field tests, each user will be required to go through a web-based survey. This survey will be an initial assessment of user experience on the safety applications.

(4) Final Survey
One month before the project is concluded, users will be asked to go through another survey. This will be another milestone to assess the user experience as well as to observe any noticeable changes in user experience after exposure to the applications for an extended period. After the final survey, unless the user opts to discontinue the service, data will continue to be collected, which may be valuable for later evaluation of the field tests.

Qualitative data to assess user subjective experience of the applications will be collected through surveys and online feedback. The types of data that can potentially be collected include the following, but the exact form and questions of the survey will be developed later:

- Overall impression of applications
  - Usefulness
  - Interface friendliness
  - Reliability
  - Issues or problems in using applications
  - Preferences

- Traveler background information
  - Age
  - Gender
  - Familiarity or experience with smart phones
  - Origin-destination

- Traveler experience with specific applications
  - How often traveler uses the application (or sees the message sign) daily or weekly
  - How frequent traveler receives the information
  - Which information is most useful (or the traveler think may be useful to other drivers in general);
  - Specific problems encountered with individual applications
  - Recommended changes

6.4 Data Analysis
The purpose of data collection and analysis is several-fold:
(1) to assess the effects of intended applications on users;
(2) to provide supporting evidence in determining the extent of success in project objectives; and
(3) to explore the weaknesses and shortcomings of implemented functions for future improvements
6.4.1 Multi-modal pre-trip planning application

Some options will be provided to users, including the trip time option (specifying the departure time or arrival time), walking option (e.g., what is the longest acceptable walking distance), transferring option (e.g., what is the maximum acceptable number for transferring), and fare options. User inputs will be stored in the database for examining the usage of the options. If some options are rarely used, we will consider revising them. In addition, we will collect feedback and comments from users on the planner. The information collected will be used to revise the planner design.

6.4.2 "Park and Ride" alert application

In order to verify the statistical significance of data representation, several critical data elements must first be scrutinized.

(1) Validity of using GPS data for monitoring user trajectory for the scenarios
Since the GPS data is based on user smart phone data, the trajectories do not necessarily reflect the scenario of commuting between the specified origin and destination. A route matching algorithm based on GPS trajectories will be used to detect the driving scenario. The algorithm will also be used to monitor the status of the user. Interesting scenarios include:
- The user is driving along US-101 (and which direction);
- The user has arrived at the destination (trip finished);
- The user is off freeway and driving along local route;
- The user is taking Caltrain; (to know if the user is actually taking the train, we need to have a sufficiently long segment of GPS track which matches with the GPS on one of the Caltrain trains);
- The user is not driving (based on speed and current location);

(2) Real-time freeway travel time prediction and freeway actual travel time
U.S. 101 link speed data received from MTC as well as the predicted freeway point-to-point travel time will be archived. Users’ GPS track data will be archived and processed to obtain the actual freeway point-to-point travel time, using the route matching algorithm. The observed actual freeway travel time will be compared to the predicted travel time, and to revise the freeway travel time prediction.

(3) Caltrain arrival time prediction and actual arrival time calculation
AVL/GPS data for Caltrain locomotives as well as Caltrain Dispatch data will be archived. The predicted Caltrain arrival times and actual arrival times at stations will be archived. The actual arrival time at station will be determined by matching Caltrain locomotive’s real-time GPS location with station locations. If both the distance to a station and locomotive’s GPS speed are less than predetermined thresholds, the actual arrival time at the station is then observed.

(4) Use GPS coordinate to determine how the information is being utilized:
Using the route match algorithm, the user GPS track will be matched to different scenarios. The driver decision will be interpreted based on the combination of the scenarios, or when
eligible, driver’s input (for example, when the driver is off the road, and is not driving).

<table>
<thead>
<tr>
<th>Combination of scenarios</th>
<th>Interpretation how the information is utilized</th>
<th>Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>User driving along US-101 + (User get alert) + User arrived at destination</td>
<td>Alert rejected</td>
<td>Automatic matching based on GPS trajectories</td>
</tr>
<tr>
<td>User driving along US-101 + (User get alert) + User driving on local road + user taking Caltrain</td>
<td>Alert accepted</td>
<td>Automatic matching based on GPS trajectories</td>
</tr>
<tr>
<td>User driving along US-101 + (User get alert) + User driving on local road + application closed</td>
<td>Alert accepted / rejected</td>
<td>Depends on which road the driver goes, May need manual review of the data to determine;</td>
</tr>
<tr>
<td>User driving along US-101 + (User get alert) + User driving on local road + user confirms that the alert is accepted</td>
<td>Alert accepted</td>
<td>User confirmation</td>
</tr>
</tbody>
</table>

6.4.3 Changeable Message Sign Information
The data from this application will be survey data collected from the recruited drivers. Survey results will be analyzed to get the qualitative test results on the application.
## APPENDIX A

This section contains the candidate sites currently being considered for Transit Application.

### Table A.1 Candidate Sites for Field Tests of Transit Application

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Site Location</th>
<th>Site Characteristics</th>
<th>Type of Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>US-101 North Bound</td>
<td>● Freeway</td>
<td>● Park and Ride alert and CMS information</td>
</tr>
<tr>
<td></td>
<td>Specific locations for the message signs:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Millbrae Exit (North Bound)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Redwood City Exit (North Bound)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Caltrain stations: Millbrae, Broadway, Redwood City, Menlo Park, Palo Alto</td>
<td>● Caltrain stations</td>
<td>● Caltrain parking space availability information</td>
</tr>
<tr>
<td>3</td>
<td>San Mateo County</td>
<td>● Residence area</td>
<td>● Multi-modal pre-trip planner</td>
</tr>
</tbody>
</table>