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16. ABSTRACT

This report documents the design and development of the integrated multimodal traveler information system. System architecture, database architecture, system features, communication protocols, design of mobile and web applications, and the development of multimodal transportation data collection tools and multimodal trip planning algorithm for large metropolitan area are presented in this report. Furthermore, as a means to collect real-world travel behavior data for evaluation of impacts of real-time information on travel behavior and on congestion relief, the capability of this system in collecting integrated travelers' journey data and associating travel journey data with real-time information is also included.

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Prepared by:

California PATH
University of California, Berkeley

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Executive Summary

Advanced Traveler Information Systems (ATIS) have been deemed an important tool for encouraging people to change their travel behavior and consequently have the potential to improve the overall transportation system. Examples of such behavioral changes are modal shifts from car to transit and adaptations of departure time and route choices in the event of congestion.

The effect of travel information on a traveler's decision making has been widely studied. However, most of the cited studies on the impact of real-time information are based on an analysis conducted through simulator studies and surveys. There is still a large knowledge gap between the analysis of real-world behavior and associated changes influenced by real-time information and the subsequent impact on traffic congestion. Understanding how travelers react to information (e.g., the combination of departure time, route and mode) and whether provision of (more) information is beneficial to the network conditions requires further investigation. Furthermore, current literature is lacking in understanding the longer-term effect within the context of habitual travel, in which travelers make the same trip day-to-day and are exposed to the same travel information source(s) repeatedly.

The primary goal of this project is to develop approaches to encourage and enable travelers to make choice decisions to select a mode or the time of commute in order to avoid congestion, which subsequently would help to improve traffic conditions and reduce energy use and emissions by reducing the number of single occupancy vehicles on highways. A secondary goal is to obtain high quality travel behavior data (origin, destination, and mode of travel) in order to support transportation planning and real-time traffic management decision making.

In order to achieve project goals, it is essential to develop information tools for facilitating travelers' transportation decisions (combinations of mode, route and departure time). Most of existing ATIS are unimodal, in which the information is provided for a single mode of travel (e.g., transit or driving). Seeking information about a number of modal options using unimodal ATIS can be an arduous process for the enquirer, not only requiring time-consuming consultation with a number of different sources but also prior knowledge of these sources, plus the desire to both travel by and to seek information about an alternative (non-habitual) mode. On the other hand, integrated multimodal traveler information provides information about more than one mode of travel within a particular information service. It minimizes the effort for the user in acquiring information on travel choice options (mode-route-departure time) and is able to expose the user to information on such options even if they had not intended to consider or review a modal choice decision when accessing the service. Properly presented integrated multimodal information with high quality and proper level of detail and visualization could help educate drivers to overcome the barriers to modal change. Therefore, effective tools are essential to allow travelers to intuitively interact with information and recommendations provided and record the actual trip experienced.

Under the Networked Traveler (NT) project sponsored by the USDOT and the Dynamic Passenger Information (DPI) System project sponsored by Caltrans, PATH has developed an integrated multimodal information system named Path2go to help users make trip decisions based on real-time multimodal information and to collect trip journey data for investigating the impacts of real-time multimodal traveler information on travelers' decision making and on the transportation system overall. An evaluation study conducted by an independent evaluator found that the Path2go application performed well with regard to its capability to integrate real-time, multimodal information, the accuracy and reliability of the information, its effectiveness in helping users to reduce waiting time at transit stop/station and overall travel time, and its effectiveness in encouraging travelers to consider transit as a more viable travel option. However, the limited scope of the NT field operational test (FOT), which is about four months and provided en-route information only to transit users on one corridor, limited the number of potential users (particularly choice drivers) to participate in the field tests. As a result, the influence of traveler information on decisions of time to travel was not measured and the impact on congestion relief was not measurable.

As a continuation of the NT and DPI projects, this project was conducted to further enhance the previous multimodal real-time information tools and to collect integrated multimodal transportation data and users' journey data through an extensive field operational test, such that the study of travelers' responses to information and the evaluation of the impacts of behavior changes on traffic can be performed with real-world data. The enhancement of the multimodal information tools include:

- Expended real-time data coverage to attract more users
  The targeted FOT area was moved from the U.S. 101 corridor in the San Francisco Bay area to Los Angeles County. The project team has mitigated the multimodal information system to LA County. Multimodal transportation data sources and data providers have been identified, including RIITS, NextBus and NAVTEQ. The project team has established a data sharing agreement with these data providers to collect multimodal transportation data in real-time. A set of data querying, parsing, processing and management tools have been developed and implemented for multimodal transportation data collection. Traffic and incident data being collected cover the entire LA County area, and transit real-time data being collected cover the entire fleets of LA Metro buses and trains.
- Providing more features and better real-time information to encourage model shift
  The previous information tools only provide en-route guidance and alert for transit users. In order to encourage mode shift from driving to transit, new STC (Smart Travel Choices) features, particularly designed for choice riders, are now integrated with the current tools. More specifically,

    - En-route traffic incident alert is now included for the driving mode to inform the users about dynamic changes on their driving path;
    - Text-to-speech is enabled for en-route traffic incident alert such that it won't distract the user from driving;
    - The mobile App is integrated with a Google Navigation App to provide turn-by-turn guidance, which is essential for choice riders to shift to transit in unfamiliar environments; and
    - Pre-trip alert is included to provide suggestions on commute alternatives.

  The enhanced multimodal information tools provide traveler information in both pre-trip planning and en-route guidance and updates.

- Improved the design of mobile and web interfaces
  The project team has analyzed feedback and comments received from users who participated in the NT FOT and has re-designed the mobile and web interface to improve the usability of the multimodal information tools. The improvements include 1) more graphics for users to visualizing the road conditions and comparing different travel options recommended by the multimodal trip planner, 2) the convenience for users to save their favorite trips/destinations and to enquiring real-time information or to plan a multimodal trip with the save favorites, and 3) simplified web pages and mobile phone screens to allow users to capture the information more easily.
- Improved multimodal trip planning algorithm
  In large metropolitan areas such as LA County, the complexity of the road and transit networks considerably increases the computational complexity of multimodal trip planning and thereby increasing the response speed. The previous trip planning algorithm has been modified to overcome this challenge. Algorithm improvements include 1) modeling the planning problem as time-dependent shortest path problems in order to capture the spatial and time variation nature of the transit and road networks, and 2) implementing both offline and online strategies to reduce the computational time in real-time, with the offline strategies to pre-compute the underlying road and transit networks, and the online strategies to speed-up searching for the shortest path.
- Improved integrated database
  The database structure has been modified to improve the efficiency of data sharing, and archiving integrated travelers' journey data with multimodal transportation data, which is essential for the development and calibration of behavior models, and assessment of effects of real-time information on behavior change and congestion relief.

Integration of the current STC tools are being conducted under the continuation of this project, entitled 'Smart Travel Choice Field Operational Tests'. Two tests (i.e., a pilot test and a field operational test) will be conducted to collect travel behavior data, and evaluation study will be performed to assess the impacts of real-time multimodal information on travel behavior as well as on traffic. More specifically,

- Pilot testing
  A small scale field testing of the integrated STC system will be conducted with volunteers from LA Metro and Caltrans District 7 employees. The pilot testing will identify issues in the STC system in the field operational environment. Identified problems will be further debugged in the laboratory environment and corrected to prepare the system ready for the field operational test.
- Field operational test
  A 12-month FOT will be conducted after the pilot testing to collect real-world travel behavior data and associated multimodal transportation data.
- FOT evaluation
  Statistical analysis of behavior responses will be conducted using the collected real-world data. Models of travel choice making and prediction of behavior response to real-time information will be developed and calibrated to estimate the impacts of real-time information on behavior changes. Impacts of real-time information on traffic will also be evaluated.

  Focus group studies will be conducted to evaluate users' perceptions of the strengths and weaknesses of the integrated information tools and to make recommendations for improvements as the tools evolve.

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1 Introduction

California cities and metropolitan areas in the United States suffer from some of the worst traffic congestion in the country, costing travel time, fuel and money, hindering the economic development and negatively impacting the environment. INRIX's 6th Traffic Scoreboard Annual Report (INRIX 2013) revealed that traffic congestion in the U.S. increased each month for the first quarter of 2013 and is up 4 percent compared to Q1 2012. California cities, including Los Angeles, San Francisco and San Jose are among the top 10 worst cities for traffic. Drivers in these three California Cities are wasting an average of 59 hours, 49 hours and 31 hours every year in traffic.

Table 1-1 Top 10 Worst Cities for Traffic in America in 2012 (Source: INRIX 2012-2013 Traffic Scoreboard)

Rank	City	Hours Lost in 2012	% Change Q1 2013 vs. Q1 2012
1	Los Angeles	59	+6%
2	Honolulu	50	+4%
3	San Francisco	49	+3%
4	Austin, TX	38	+8%
5	New York	50	+10%
6	Bridgeport, CT	30	+16%
7	San Jose, CA	31	+13%
8	Seattle	35	-11%
9	Washington D.C.	41	-5%
10	Boston	31	+30%

On-going highway improvements and traffic management through deployment of Intelligent Transportation Systems (ITS) technologies have significantly improved the services on existing roads. However, congestion persists due to the fact that traffic demand in almost all metropolitan areas approach or exceed the available capacities of the highway systems. A report from the Census Bureau (2012) shows California is home to the most densely populated metro areas in the United States. The top 3 highest-density urban areas with more than 1 million populations are in California.

Table 1-2 Top 5 Highest-Density Urban Areas with Populations greater than 1 Million (Source: 2010 Census)

Rank	Urban Area	Land Area (square mile)	Population	Population Density (People per Square Mile)
1	Los Angeles–Long Beach–Anaheim	1,736	12,150,996	6,999
2	San Francisco–Oakland	524	3,281,212	6,266
3	San Jose	286	1,644,496	5,280
4	New York–Newark	3,450	18,351,295	5,319
5	Las Vegas–Henderson	417	1,886,011	4,525

The inability to easily and quickly add additional capacity, which would eventually fill, coupled with the growth in population, number of vehicles and the number of travelers, have led to the need for managing the travel demand to reduce congestion. Demand management and smart land use, are viewed by Caltrans as foundations for transportation management (see Figure 1-1). The key to demand management is to use various tools to encourage people to change travel behavior and to collaborate with the transportation systems to achieve congestion relief.

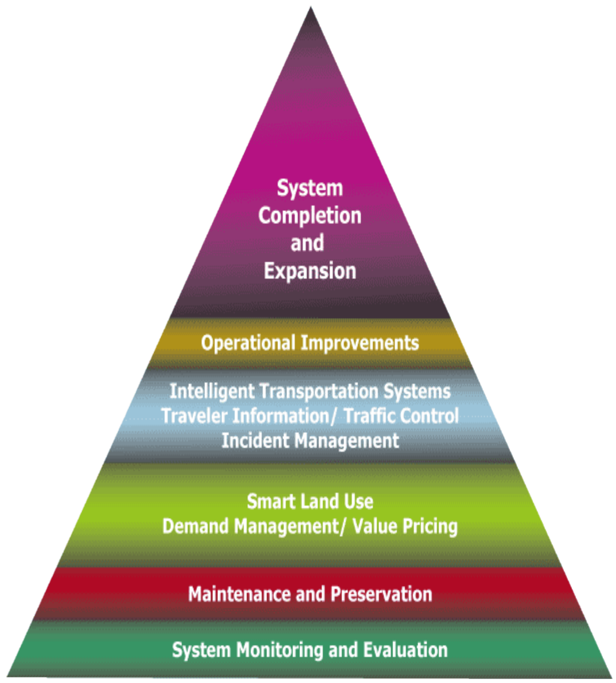

Figure 1-1 Caltrans Transportation Management Pyramid

Advanced Traveler Information Systems (ATIS) have been deemed an important tool for encouraging people to change their travel behavior and consequently have the potential to improve the overall transportation system. Examples of such behavioral changes are modal shifts from car to transit and adaptations of departure time and route choices in the event of congestion. The availability of information about transportation services and conditions has been shown to influence travel demand. Tang and Thakuriah (2012) studied the effectiveness of the Chicago Transit Authority (CTA) bus real-time information system on bus ridership and reported that the ridership in the routes with real-time information increased 2% compared with the ridership in the routes without real-time information. Yu et al. (2010) conducted an evaluation of real-time ATIS on route choice for two routes heading to Ocean City, Maryland. Predicted travel time and route switch guidance were provided to en-route travelers via a variable message sign (VMS). The authors reported that real-time ATIS yielded significantly positive effects on overall system throughput, increased 7% during the peak hours, and that real-time information led to better use of roadway capacity during congested periods. Schlaich (2010) evaluated the effects of VMS on route choice behavior in Germany by using mobile phone trajectory data. The study showed that with VMS about 30% of drivers changed their standard route and drivers do not analyze or question the reason for the route recommendation.

Several studies find out that ATIS has a positive impact on travel choices of departure times and routes. For example, Mahmassani and Liu (1999) used a multinomial probit (MNP) model framework to model and calibrate the commuter joint trip departure time and route switching behavior in response to real-time ATIS. Results collected from a laboratory interactive travel simulator study support the notion that commuters could decide to change pre-trip departure time and route decisions as well as en-route path switching decisions in response to an expectation of an improvement in trip time that exceeds a certain threshold. However, there is little evidence to suggest that the provision of information has been effective in promoting modal shift. One study reported approximately only 1.4% mode shift due to real-time information. The conclusion has often been that the information provided has not been effective technically, lacking accuracy and alternative options that prevent the driver from shifting mode. Research conducted by the University of Southampton in the United Kingdom (Kenyon and Lyons, 2003) shows that the majority of travelers do not even consider their modal alternatives for their journeys and that presentation of a number of modal options for a journey in response to a single trip inquiry could challenge previous perceptions of the utility of non-car modes, overcoming habitual and psychological barriers to consideration of alternative modes. Where the information presented incorporates comfort and convenience factors, in addition to cost and duration, it may challenge travelers' concerns about alternative modes and could persuade a modal change to occur.

1.1 Research Needs and Project Goals

Predicting behavior is critical for travel demand management, system design, and operations. Predicting behavior is also challenging as travelers have varying preferences, motivations, experiences, and decision-making processes. Models for predicting behavior must incorporate important explanatory variables such as environmental factors, social influences, and heterogeneous attitudes and values. If such factors are not taken into account, it will appear that people are making irrational transport choices and modeling will fail to guide public policy to the best possible outcomes (Walker, 2011).

1.1.1 Needs for Further Understanding of Traveler Response to Real-Time Travel Information

The effect of travel information on a traveler's decision making has been widely studied. However, understanding how travelers react to information (e.g., the combination of departure time, route and mode) and whether provision of (more) information is beneficial to the network conditions requires further investigation.

Most research papers on the topic have been concerned with a particular type of information, a particular travel mode and a particular travel context and situation. For example, the majority of studies consider the effect of travel time information on car-drivers' in-trip adaptation of route-choices (Chorus et al. 2006). Furthermore, the research and experiments are limited to 1) stated preference (SP) survey in which travelers are asked which route to choose given a specific context and type of information, 2) interactive route choice experiments in simulation environments in which travelers make consecutive route choices and their behavior towards risk and different types and quality of information is investigated, and 3) revealed preference (RP) survey in which travelers report their past route choices which, however, are often hardly related to an actual network in terms of alternatives and traffic conditions. Although this type of methods and experiments provide flexibility to focus and test particular hypotheses and scenarios, it has the drawbacks of external validity and for the assessment of behavioral changes over time (Ramos et al. 2012).

Travel choice decision-making is complex and influenced by a number of factors. Travel time and cost have been the two dominated factors in behavioral models. However, there are other factors that also influence travelers' decision-making, such as the environmental impact of their choices and feedback regarding the comparison between actual travel time experienced and predicted (Walker, 2011), and the ability to productively use their time on transit vehicles (Rubin 2011). These factors need to also be included in behavioral models in order to provide generic, integrative knowledge concerning the potential response to information among travelers.

A deeper behavioral understanding of traveler response to information is necessary for an increase in insight into policy issues such as the provision of travel information as a travel demand management tool.

1.1.2 Needs for Conducting Field Operation Tests (FOT) to Validate the Research Hypothesis and to Assess the Impacts of Trip Recommendations by Real-Time Information on Modal Shift

Due to modeling and data limitations of existing studies the effect of heterogeneity and dynamics in user decisions under real-time information have not been effectively addressed. As a result travel choice dynamics under real-time information and the associated complex dynamic behavioral processes are not yet well-understood.

Most of the cited studies on the impact of real-time information are based on an analysis conducted through simulator studies and surveys. There is still a large knowledge gap between the analysis of real-world behavior and associated changes influenced by real-time information and the subsequent impact on traffic congestion. Current literature is lacking in understanding of the longer-term effect within the context of habitual travel, in which travelers make the same trip day-to-day and are exposed to the same travel information source repeatedly. Field operational tests (FOT) will allow the calibration of behavioral models with real-world data to reduce the prediction bias. More importantly, richer data collected from FOT enable the assessment of learning effect (or the evolution of decision-making over time) on behavioral change, which could eventually lead to attitude change, for example, willingness to shift mode from car to transit.

1.1.3 Project Goals

The primary goal of the project is to develop approaches to encourage and enable travelers to make choice decisions to select a mode or the time of commute in order to avoid congestion, which subsequently would help to improve traffic condition and reduce energy use and emissions by reducing the number of single occupancy vehicles on highways.

A secondary goal is to obtain high quality travel behavior data (origin, destination, and mode of travel) in order to support transportation planning and real-time traffic management decision making.

In order to achieve project goals, it is essential to develop information tools for facilitating travelers' transportation decisions (combinations of mode, route and departure time). Most of existing ATIS are unimodal, in which the information is provided for a single mode of travel (e.g., transit or driving). Seeking information about a number of modal options using unimodal ATIS can be an arduous process for the enquirer, not only requiring time-consuming consultation with a number of different sources but also prior knowledge of these sources, plus the desire to both travel by and to seek information about an alternative (non-habitual) mode. On the other hand, integrated multimodal traveler information (IMTI) provides information about more than one mode of travel within a particular information service. It minimizes the effort for the user in acquiring information on travel choice options (mode-route-departure time) and is able to expose the user to information on such options even if they had not intended to consider or review a modal choice decision when accessing the service. Properly presented integrated multi-modal information with high quality and proper level of detail and visualization could help educate drivers to overcome the barriers to modal change. Therefore, effective tools are essential to allow travelers to intuitively interact with information and recommendations provided and record the actual trip experienced.

1.2 Overview of Networked Traveler and Smart Parking Project

An integrated multimodal information system has been considered as an addition to ATIS not only as a tool for travelers for making informed travel decisions but also as a congestion relief tool.

Under the Networked Traveler project sponsored by the USDOT, a suite of applications named Path2go has been developed based on real-time highway, transit and parking information along the US-101 Corridor in the San Francisco Bay Area. Path2go is one of the first attempts to integrate a suite of both web-based and mobile-phone-based applications to provide travelers with integrated traffic, transit, multimodal real-time information. The web-based trip planner allows users to plan and compare trip options involving a combination of driving and/or taking transit. Users can also compare trips using different modes of travel based on real-time travel time, cost and the carbon footprint. Once a trip has been planned, it can then be sent to the user's smart phone to receive real-time updates on the bus / train arrival times and even audio alerts when the next bus is arriving.

Field testing of Path2Go was conducted between July and November, 2010. Over 750+ registered mobile phone users and 1000+ web users were recruited. Trip planning and execution data were collected and analyzed to assess the effectiveness of real-time multimodal information on travel behavior. Users were invited to take a detailed survey. Survey results were analyzed by an independent evaluator (SAIC). The independent evaluation results (Hector-Hsu et al. 2011) showed the Networked Traveler Path2go application performed well with regard to its capability to integrate real-time, multimodal information, the accuracy and reliability of the information, its effectiveness in helping users to reduce waiting time and overall travel time, and its effectiveness in encouraging travelers to consider transit as a more viable choice.

In addition to the survey conducted by the independent evaluator, the project team also conducted a survey to get users' feedback on the use of the application. Two-thirds of survey respondents considered the Path2go applications satisfactory, while 27.5% had no opinion and 6% gave the applications poor ratings. In general, well above half of the respondents indicated that the information provided was useful, accurate and helpful for them to reduce waiting time. They stated that the information had influenced them to consider transit as a more viable choice. However, the dissatisfaction rate for the mobile application was high (29%), particularly on the mobile user interface. Key feedback and suggestions received from users are summarized as follows

- Add en-route incident information for driving
- More user-friendly screens (mobile)
- Add map and overlay with current location of recommended transit vehicle (mobile)
- Add favorite trips for easier enquiring (mobile)
- More user-friendly pages (web, too much information to process)

The first suggestion of adding en-route incident information for driving is due to the limited scope of the field test under Networked Traveler, in which en-route information updates were only provided to transit trips. As a result, the influence of real-time information on decisions of departure time and actual mode taken was not measured and the impact on congestion relief is not measurable. The limited scope of FOT also limited the number of potential users (particularly choice drivers) to participate the field tests. Users' feedback from the Networked

Traveler FOT suggested the needs for enhancement of previous multimodal real-time information tools, in order to support the study travelers' response to information and evaluate the impacts of behavior changes on traffic.

1.3 Needs for Enhancement of Multimodal Information Tools

The ideal way to study traveler decision making under real-time information is through direct observation of actual decisions in real-world systems while measuring all relevant factors. Although the integrated multimodal information tools developed under Networked Traveler achieved a high acceptance rate among the users, there are needs to improve and enhance the previous tools to 1) deliver proper information to meet the interests of majority travelers, 2) to improve the data quality in order to enhance the reliability of provided information, and 3) to attract more users with improved mode coverage and better real-time information. More specifically,

- Need for expending real-time data coverage to attract more users
  The Networked Traveler FOT was conducted along the US-101 corridor between San Francisco and San Jose consisting of US 101 (freeway) and State Route 82 (El Camino Real), with public transit services including Caltrain, BART, VTA in San Jose, Muni in San Francisco, and SamTrans, which provides connections between San Francisco and San Jose. Per project scope of focusing more on travelers who favorite transit, the US-101 corridor proved to be an ideal FOT site as it covers multi transit (agency) services and transit modes. However, it has limitations for general travelers to use. The corridor does not include an alternative highway route to US 101. Commuters seem to have a strong habit on mode of travel, probably due to transit accessibility at either the home or the work place. It is necessary to expand the real-time data coverage to include corridors that are suitable for choice drivers, who usually drive but see transit as an option for their travel. Data coverage expanding will lead to attract more users, particularly the choice drivers. As a result, the targeted FOT area for this project was chosen to be the entire County of Los Angeles.
- Need for providing better real-time information and usability for choice drivers to encourage modal shift
  Under Networked Traveler, the multimodal information aspect was presented in pre-trip planning, in which a traveler is provided with multimodal travel options with side-by-side comparison of travel time, cost, and the carbon footprint. En-route information was only provided to transit users. Despite the transit en-route navigation feature, which guides the travelers through their transit trips with dynamic information updates regarding transit vehicle's arrival time at their alighting stop/station, travel time to the departure stop/station, and transit connection information (when transfer), was highly appreciated by the users, users' feedback suggested to also include real-time information on en-route driving, particularly the incident information.

- Need for improving the design for information delivery
  Need for improving interface design (both mobile phone and web) and communication protocol (mobile phone) is in two parts. Users' feedback from Networked Traveler FOT suggested to improve the mobile phone and web interface design so that the information regarding recommended travel options and en-route updates can be easily captured with less human interaction. The improvements could include more graphics for users to visualize the road conditions and different travel options.
- Need for enhancing the capability of travelers' journey data collection
  As the primary goal of the project is to encourage and enable travelers to make smart travel choices, it is essential that the STC system is designed in the way to effectively collect travelers' journey data. This type of data, combined with traffic and transit data, will enable the development and calibration of behavior models, and assessment of effects of real-time information on behavior change and congestion relief.

1.4 Project Objective and Approaches

The objectives of this research are to develop and field test an integrated multimodal real-time information system and to study the benefits and deployment issues of such integrated multimodal real-time information tools.

1.4.1 Use Real-Time Multimodal Traveler Information for Congestion Relief

Previous studies show that the effectiveness of real-time traveler information on changing travelers' behavior relies on a number of factors, including whether the information has adequate content for travelers to make well-informed decisions, the reliability of the information, and how the information is presented to the travelers. The ability to use the information to change behavior obviously depends as well upon the extent to which alternative choices are made available by the transportation network itself.

Reaching the congestion relief goal requires informed participation of a large number of travelers. Commuters account for a large percentage of travelers in metropolitan regions, particularly during congested peak periods. While commuters' chief interest is to get to their destination quickly, many of them potentially have other interests, including fuel/cost savings, comfort and convenience, efficient use of travel time for productivity, improved safety or reduced chance of accidents, and more recently, emission reduction for a sustainable environment. An effective real-time information system, while aiming at congestion relief will be most effective if it is tailored to the travelers' interests.

1.4.1.1 Utilizing Existing Regional ITS Infrastructures and Communication

The reliability and data coverage of real-time information are significant factors that influences travelers' transportation choices both pre-trip and en-route. Realizing the greater potential of centralized integrated multimodal transportation data in transportation management, many regions have deployed regional ITS infrastructure and communication to collect multimodal transportation data, and make the data available to public or to transportation management and research centers. The 511 system in the San Francisco Bay Area, Regional Integration of Intelligent Transportation Systems (RIITS) in the Los Angeles Area, and Intermodal Transportation Management System (IMTMS) in the San Diego Area are such examples. Utilizing the capability of existing regional data management systems allows the real-time information technology to be easily transferred and deployed in other regions where the multimodal transportation data capability is in place.

1.4.1.2 Integrating Multimodal Travel Recommendations into the Design of Real-Time Information Delivery

On the information delivery side, we integrated travel option recommendations into system design so travelers do not need to search alternative travel options. In addition, in order to encourage habit or choice drivers switching to transit, transit option for their travel will always be provided, which could lead to change of their previous perceptions of transit and change of travel behavior.

1.4.1.3 Centralized Integrated Database and Data Processing

A server-side centralized data processing and archiving was deployed, in which travelers' information enquiring (plan a trip from an origin to a destination, check transit information, get en-route update, etc.) and journey data (which trip the traveler is actually taken) will communicate with the server and stored into the server database. Centralized data processing and archiving will enable the tools 1) to provide personalized information for travelers' particular trip (both pre-trip and en-route) and 2) to associate travelers' information enquiring and actual trip taken with the information provided for behavior analysis.

1.4.2 Conduct Extensive Field Operational Test to Evaluate the Impacts of Integrated Traveler Information Tools on Travel Behavior Changes and Congestion Relief

Realistic assessment of impacts of multimodal travel information on travel behavior change and congestion relief should be performed using real-world data rather than pre-described and assumed scenarios used in laboratory experimental environments. It takes time for travelers to familiar with the information tools and to learn their alternative travel options (particularly transit option) which could lead to change their previous perceptions and habit to overcome the barriers to modal change. Therefore, we planned to conduct an extensive field operational test to assess the longer-term effects of information on travel choices, and the outcomes can be practicable for travel demand management for congestion relief.

2 Overview of STC System and Features

This section presents an overview of the integrated multimodal traveler information system, in terms of its system architecture, features, multimodal traffic and transit data sources, and centralized database architecture.

2.1 System Architecture

Figure 2-1 illustrates the service-orientated system architecture for the integrated multimodal information system. The system consists of the following key components:

- Data interface for gathering multimodal traffic and transit data in real-time;
- User interface with mobile and web applications (e.g., pre-trip planning and en-route information update);
- Central processor with a set of software modules to aggregate the data, predict travel time by mode, generate personalized information related user's travel and optimize the routes for multimodal trip planning; and
- Database system to archive multimodal traffic and transit data, generated traveler information data, and travelers' journey data.

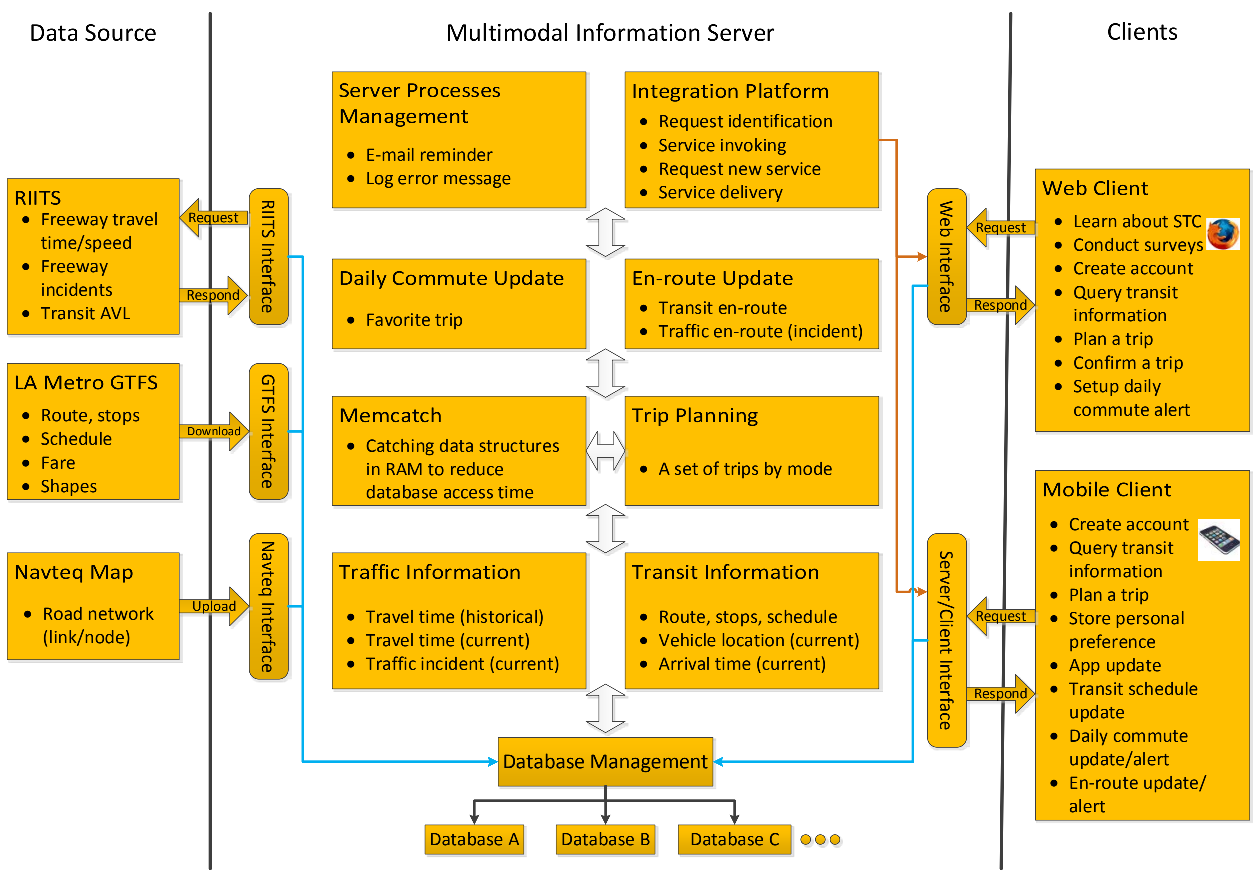

Figure 2-1 System Architecture

The database architecture is illustrated in Figure 2-2, which includes the database repository, the reusable modules for accessing the database. The data can be retrieved or stored through an SQL interface, which is for the real time data exchange with data server programs, and a JDBC interface for data exchange with web services and many reusable modules for offline data retrieving.

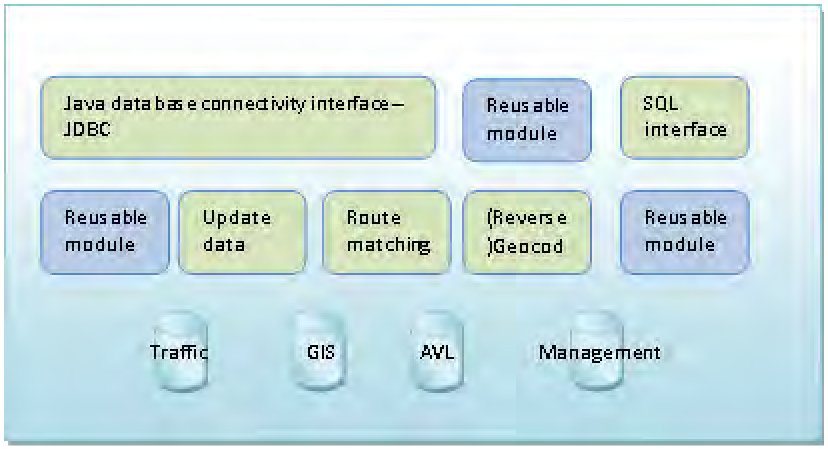

Figure 2-2 Database Architecture

The central processor is comprised of the following modules:

- Multimodal trip planning engine using real-time and historical transit and traffic data to provide optimal trips by mode (driving, park-and-ride, transit) and calculate attributes (travel time, cost, carbon footprint) associated with each trip. The trip planning engine can be accessed from both the mobile phone and web.
- Traffic and transit travel time prediction using real-time multimodal data and historical statistics
- Map matching of traffic incident locations
- En-route information generation (driving, walking and on transit). The objective of this application is to build highly accurate and timely en-route information for the user based on their location and itinerary. The location of the user traveling via a multimodal trip is tracked and projected to the itinerary, and is associated with relevant traffic incidents that could cause delay. Information content is generated for a certain user for any stage of a trip, either before the trip, driving to destination or park-and-ride, waiting at a transit stop/station, and riding on a transit bus or train. Information include alert of "traffic incident down the road" while driving, "update travel time" while driving or riding a transit vehicle, and alerts of "your bus/train is coming" while waiting at a station/stop and "approaching the destination stop" while riding transit.

2.2 System Features

The information tools include the following major features:

- User preference setting and synchronization
  Users can set their preference of travel through mobile phone and/or web, including desired mode of travel, maximum walking distance and number of transfers, favorite trips (e.g., home to work), day-of-week, time-of-day and threshold for receiving pre-trip alerts. When User's preference will be synchronized between the mobile phones and the central server through web APIs.
- Pre-trip alerts to avoid congestion
  Once a user turned on the pre-trip alert (in preference setting), the system will compare the real-time travel time with the historical statistics, and if the difference in travel time exceeds user preset threshold (say 20% longer than usual), a text alert will be sent to user's mobile phone to inform the user. The user could either change the departure time or plan a new trip for alternative travel options.
- Multimodal pre-trip planning
  A user can plan their trip from an origin to a destination or use their stored favorite trips through either web or mobile phone. A set of recommended multimodal trips will then be presented to the user depending on his/her preset preference of mode of travel. A transit trip will be provided if the user is only interested in a transit option, otherwise 3 trips (respectively, for transit, driving and park-and-ride) will be provided. This way a user who does not see transit as a travel option can be informed that there is a transit option for his/her particular trip. Multimodal trips will be presented to the user with side-by-side comparison of trip start and end times, trip time, cost and carbon footprint such that the user can evaluate the trip recommendations in one glance. Detailed trip information by mode will also be available (with graphic map view) if the user wishes to explore trip details. A user can confirm a recommended trip for receiving en-route updates and alerts. If the user planned and confirmed a trip with the web, the trip itinerary will be automatically synchronized with his/her mobile phone to allow the user to receive en-route information on his/her phone.
- En-route update and alters
  The server will track the location of the user (location is obtained from mobile phone GPS) and project the location to the itinerary, which is a combination of driving, walking and riding transit segments. En-route updates and alerts will be provided to users on a segment-by-segment manner.
  - On the driving segment, incident locations will be processed to determine where the incidents are relevant and could have delay impact to user's driving segment. The relevant incident alert such as "construction near XXX location and expect delay" will be provide to the user via text-to-speech.
  - On the walking segment (going to ride or transfer to a transit bus/train, or waiting at a stop/station), the alert of "your bus/train is coming" will be provided to the

user when the transit vehicle is within certain time window to arrive at the stop/station.
    - On the transit segment (riding on a bus/train), the alert of “your departure stop/station is approaching” will be provided to the user when the transit vehicle is within a certain time window to arrive at user’s departure stop/station.

  The text-to-speech feature will always be on for the driving segments (hands-free), and the user can turn it on or off as wish.

  It would be desirable if the information tools can provide alternative options when providing en-route alerts for the driving segments. However, the current incident data feeds do not contain enough information to allow the prediction of the impact of an incident on travel time. Although it is technically feasible (i.e., server central processor calls the trip planning engine and returns the recommended alternative options), this feature will not be included.

  For transit segments, if the user missed the connection with the planned bus/train, the information tools will automatically update the connection information with the next bus/train and the user can continue to receive en-route update/alerts without interruption.

- Enquiring transit arrival information
  This feature is designed particularly for park-and-ride and transit users, who want to have a quick access of information, either on-the-go (with mobile phone) or with a computer (web), for planning their arrival time in order to catch a bus/train, without trip planning.
- Reducing mobile phone’s battery consumption
  Continue querying GPS location and communicating with the server could drain the phone battery quickly and reduce the usability of the information tools. Users will be advised to charge the phone while driving and using the information tools (like when using Google Navigation). For transit segments, once user location has been matched with bus/train AVL data, the information tools will lower the rate for GPS querying and communication with the server such that the use of the information tools will not consume a lot of battery power.
- Collection of travel behavior data
  The uniqueness of the STC information tools is that they 1) provide integrated multimodal travel options with a single enquiry to encourage modal shift, 2) provide comparison of recommended travel options in terms of travel time, costs and environmental impacts (i.e., emission savings), which allows travelers to evaluate their travel options at a glance and to select the best option for their travel, and 3) collect travelers’ behavior data in response to travel recommendations.

  Collected behavior data will include 1) how the information was enquired, 2) what is the traffic and transit condition at the time of information enquiring, 3) what are the recommended travel options provided to the user, 4) how the user actually gets to his or her destination, and 5) what is the travel time difference between planned and actually experienced trip.

2.3 Data Sources

Table 2-1 lists the data category, data source and updating rate for collecting multimodal traffic and transit data. The objective is to utilize and integrate existing multimodal data sources and data providers to support STC system features as described in Section 2.2, and the goal is to provide traffic and transit data that cover the entire Los Angeles County region.

Table 2-1 Summary of Data Sources and Updating Frequency

Category	Description	Information Type	Data Source	Updating Rate
Road Network	Spatial topology of road network (node-link representative, road attributes, i.e., one-way/bi-direction, turn restrictions, speed limits, etc.)	Static	NAVTEQ Digital Map	Quarterly
Transit Network	Configuration of transit routes, stops, schedules, connections and fares	Static	GTFS	Quarterly
Transit Parking	Parking garages/lot along transit rail, location, capacity and filing-up rate	Static	LA Metro	Yearly
Transit Bus AVL	Real-time transit bus locationing and expected time-to-arrival	Real-Time	RIITS	Every 2-minutes
Transit Rail AVL	Real-time transit rail locationing and expected time-to-arrival	Real-Time	NextBus open API	Every 1 minute
Traffic Detector	Configuration of loop detectors, location, route, direction, etc.	Static	RIITS	Daily at midnight
Traffic Detection	Traffic volume, occupancy, and speed	Real-Time	RIITS	Every 1 minute
Traffic Event	Lane closure, traffic accident attributes, etc.	Real-Time	NAVTEQ Traffic Incident API	Every 1 minute

2.3.1 Road Network Representative

Digital maps are an essential part for any travel information systems for trip planning and guidance, and for visually presenting travelers with their travel choices. NAVTEQ digital maps are used as the geographic information systems (GIS) data source. Node-link representatives of road network and road attributes, such as road type (one-way vs. bi-directional, arterial vs.

freeway), speed limits, etc., were extracted from NAVTEQ digital maps to form a node-link representation of the road network in Los Angeles County.

2.3.2 Regional Integration of Intelligent Transportation Systems (RIITS) and Other Data Sources

The Regional Integration of Intelligent Transportation Systems (RIITS) is a communication network that supports the real-time exchange of information to help manage the regional transportation system, with its coverage primarily focused on Los Angeles County (RIITS 2013). RIITS' central mission is to support the core business needs of public agencies by creating a 'one-stop shop' for real-time data about the complete transportation system. The RIITS network combines real-time transportation data from Intelligent Transportation Systems and agencies across Los Angeles County, and in return provides value-added information on the operation of multimodal transportation systems (including freeway, arterial, and transit systems) to partner agencies and to the general public (RIITS 2010). The RIITS system currently obtains baseline data from:

- 2000 freeway loop detectors (Caltrans)
- 100 freeway video surveillance systems (Caltrans)
- Arterial loop detectors at 3500 arterial traffic signals (LADOT)
- 2800 buses (LA Metro)
- Two rails (LA Metro trains, Green and Red Lines)
- Incident reports (CHP)
- Freeway closures (Caltrans)

Figure 2-3 graphically shows the locations of RIITS' freeway loop detectors (red dots), which cover 8 Interstate Highways and 14 California State Routes, as listed in Table 2-2.

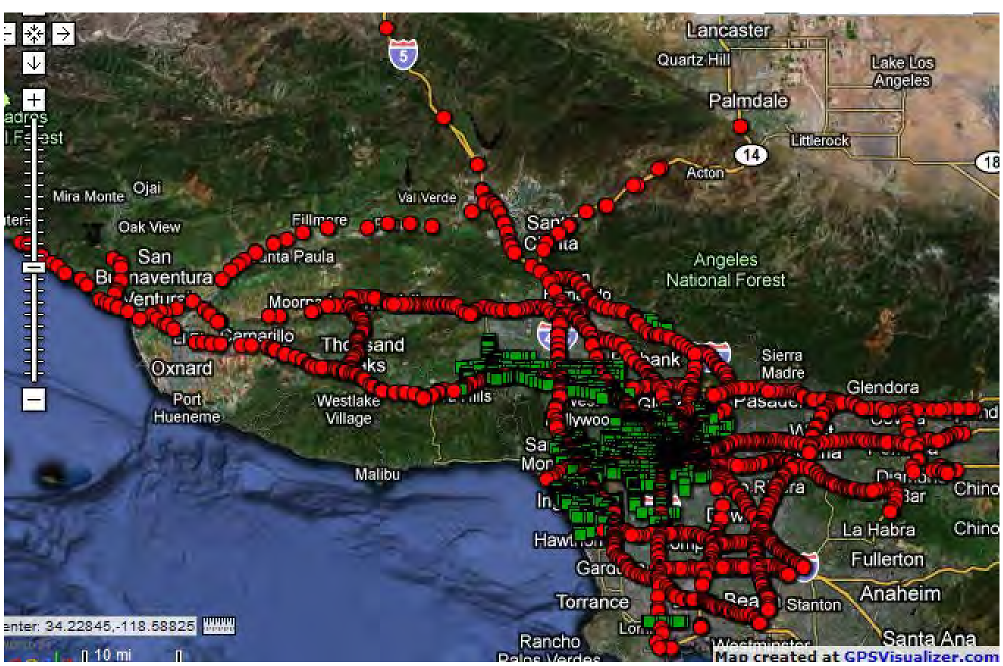

Figure 2-3 RIITS Freeway Loop Detectors (Red Dots)

Table 2-2 Lists of Highways with Traffic Data Provided by RIITS

Category	Number of Highways	List of Highways
Interstate Highways	8	I-5, I-10, I-105, I-110, I-210, I-405, I-605, I-710
State Routes (SR)	14	SR-2, SR-14, SR-23, SR-33, SR-47, SR-57, SR-60, SR-71, SR-91, SR-101, SR-118, SR-126, SR-134, SR-170

Figure 2-4 illustrates the locations of arterial loop detectors (green dots) in Los Angeles County (about 4,500 detectors).

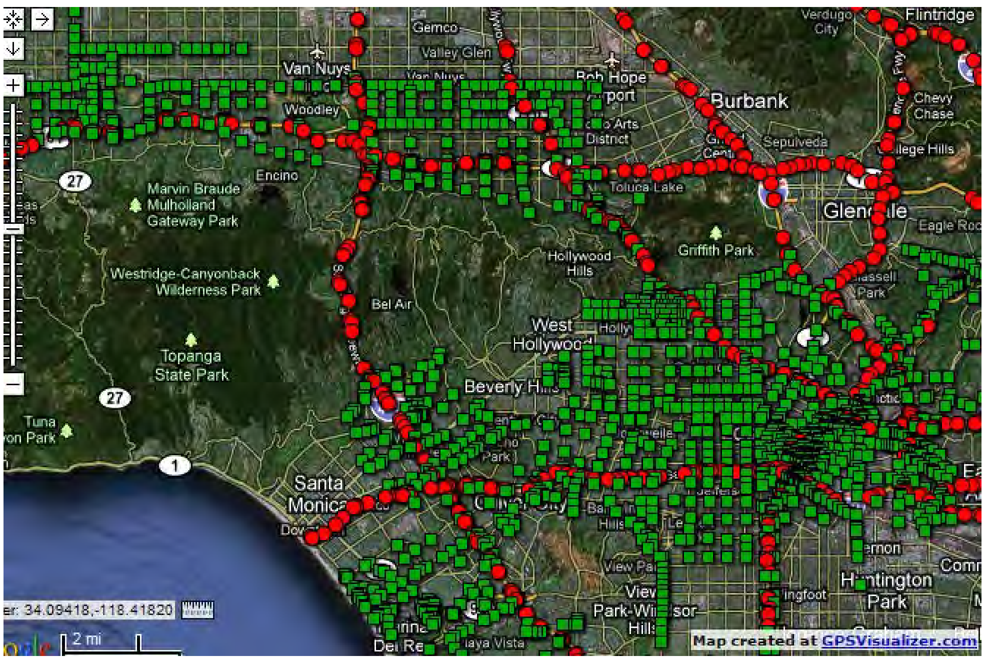

Figure 2-4 RIITS Arterial Loop Detectors (Green Dots)

Los Angeles County Metropolitan Transportation Authority (Metro) is the major transit service provider in Los Angeles County. The RIITS system obtains real-time transit vehicle location data from the entire Metro bus fleet (2,228 buses and 170 bus routes) and two out of 6 Metro rail lines (4 light rail and 2 subway). Figure 2-5 shows the system map for the LA Metro Bus and Rail System, and Figure 2-6 illustrates a snapshot of real-time Metro bus location data obtained from RIITS, with each red pin representing one bus.

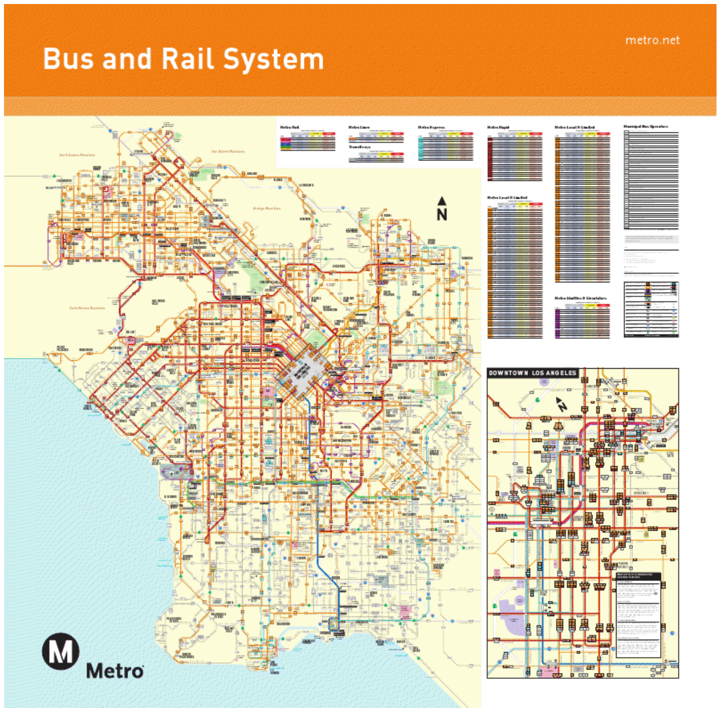

Figure 2-5 Los Angeles Metro System Map

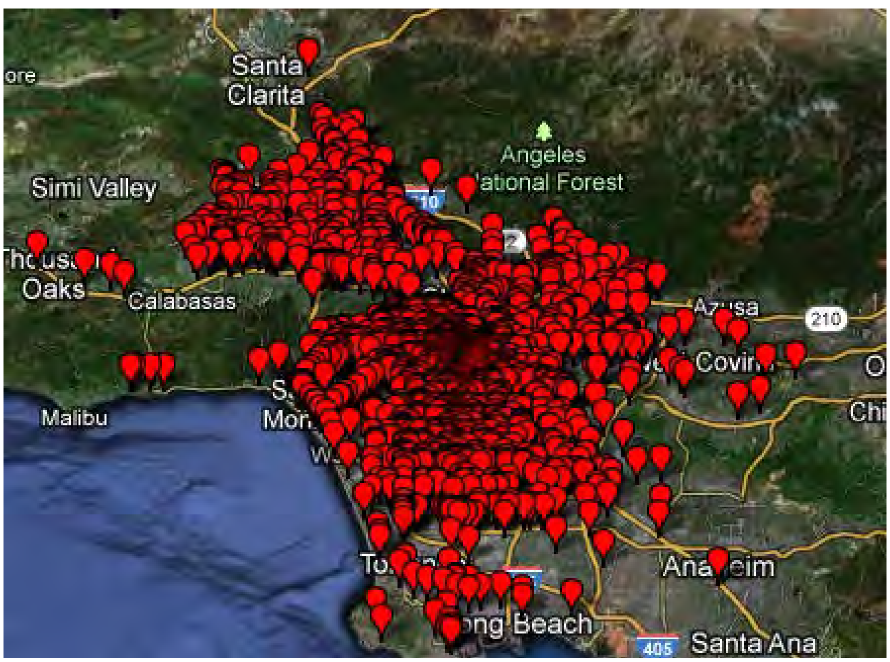

Figure 2-6 Snapshot of Real-Time Metro Bus Location (Each Red Pin Represents one Bus)

Since the RIITS already provides a 'one-stop shop' for real-time traffic and transit data in Los Angeles County, it naturally becomes the primary multimodal data source for supporting the STC system. The project team conducted an assessment of data quality on multimodal transportation data provided through the RIITS network, and has identified the data gaps described below with alternative data sources to fill the data gaps.

- Transit static configuration data such as transit routes, stops, shapes, schedules and fares.

Transit static configuration data provided through the RIITS network only include route name and a description of the route. Fortunately, as Google Transit Feed Specification (GTFS) has become a popular common format for public transportation schedules and associated geographic information, and has been adopted by many transit agencies (GTFS 2013a and 2013b), GTFS data published by LA Metro was selected to fill the data gaps on the configuration of LA Metro's transit network.

- Transit real-time rail location data
  LA Metro provides 6 rail services, including 4 light rail – Metro Blue Line, Red Line, Green Line, Gold Line, and 2 subway lines– Metro Purple Line and Expo Line. However, real-time rail data provided through the RIITS network only includes the Red and Green Lines. Compared with transit bus service, commuting on rail usually is faster and is considered as a viable and more competing travel option for mode shift from driving to transit than bus services. Fortunately, near the end of this project, LA Metro has made the entire real-time rail data available to the public through NextBus public APIs. The project team has therefore integrated NextBus data feeds for LA Metro's real-time rail data.
- Real-time traffic incident data
  Real-time traffic incident data (i.e., accident) are obtained from CHP (California Highway Patrol) report, which includes location attributes (i.e., latitude and longitude) associated with the incident. One of the STC features, i.e., en-route alerts while driving, requires map matching the incident location and associate the relevant incidents with the en-route trip. The accuracy of incident location is important for this purpose. It was discovered that, although about 90% of incidents can be correctly map matched with NQVTEQ digital maps, there are situations, which require a manual review to identify the matching, mainly due to the noise from the GPS latitude and longitude measurements. Through another PATH project, the project team has established agreement with NAVTEQ for getting real-time incident data from Los Angeles County. Compared with RIITS traffic incident data feeds, incident data feeds from NAVTEQ have two major advantages, 1) the location of the incident has already been map matched with digital maps and is provided in terms of linkID in NAVTEQ map format and 2) the severity of the incident has a better categorization. Due to these considerations, real-time traffic incident data feeds from NAVTEQ is also included as one of the multimodal data sources for the STC system.
- Parking garage/lot data for Park-and-Ride travel option
  The RIITS network does not currently include parking information. The project team has obtained parking information for public parking owned by LA Metro and along Metro's 6 rail lines. The parking information includes the location of public parking, capacity, and surveyed filling-up rate for each of the parking facilities. Note that because there is no real-time available parking space data in these public parking facilities, the historical surveyed parking fill-up rates will be used to support the Park-and-Ride travel option.

2.4 Database Structure

Archiving and managing the large set of data efficiently is very challenging since there are many different types of transportation data, including traffic data, transit data, underlying road network data, detector data, user data, and application data. The data from these different sources are strongly related to each other. Moreover, the amount of multimodal and user data are substantial.

Hence, our goal is to design an integrated, scalable and efficient ITS database.

2.4.1 Layered Database Structure

In order to improve flexibility and reduce complexity, we decomposed the data management into several layers, as Figure 2-7. The lowest layer is the underlying road network. The second layer is designed for the static multimodal and user data, while dynamic multimodal data is handled by the third layer. The fourth layer is designed for applications, such as multimodal trip planning, en-route alert and pre-trip alert, etc.

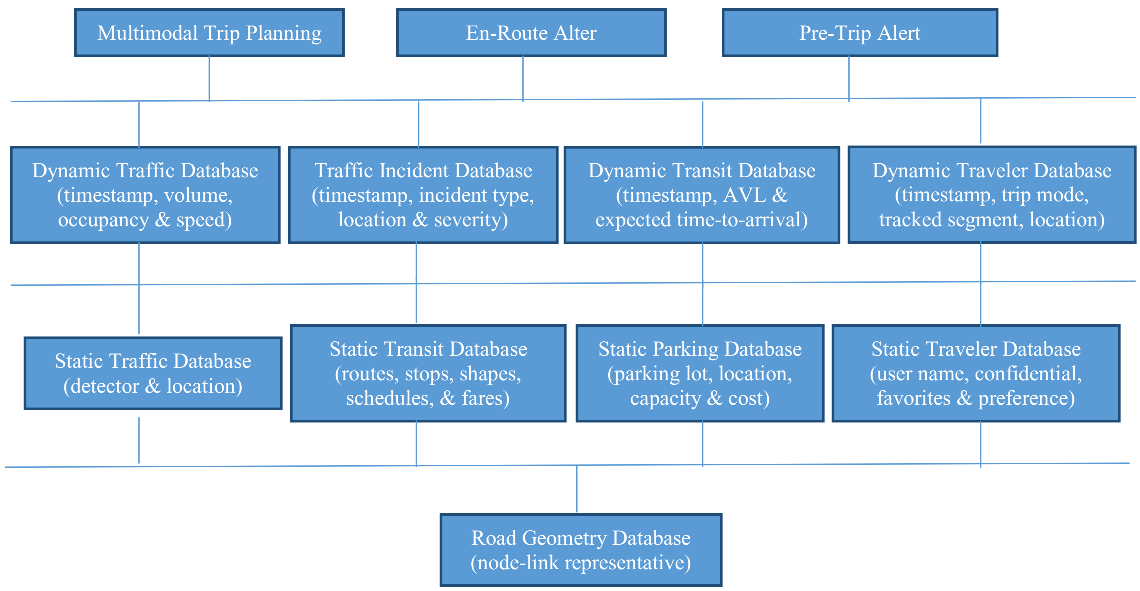

Figure 2-7 Layered Database Structure

2.4.2 Road Geometry Database

The underlying road network, including intersections and road segments, is represented by node and link. A node can be an intersection/junction or an intermediate road point, and a road segment is modeled as a link which connects two adjacent nodes.

The information from each node includes a specified ID, address (usually two crossing road names), latitude, longitude, and a combination of latitude and longitude (see Table 2-3).

Table 2-3 Major Structures for the Node Table

Name	Type	Description
ID	Integer	ID of the node
Latitude	Double	Latitude of the node
Longitude	Double	Longitude of the node
Name	String	Name of the node
LatLong	Point	Combination of longitude and latitude, which is used for speeding up queries

Each segment (road) contains the information of a specified link ID, starting and ending node IDs, road length, road category, road name, etc. (see Table 2-4).

Table 2-4 Major Structures for the Segment Table

Name	Type	Description
LinkID	Integer	ID of the road segment
StartNode	Integer	ID of starting node
EndNode	Integer	ID of ending node
LinkLength	Double	Length of the segment
ST_NAME	String	Name of the segment
FUNC_CLASS	Integer	An indication of road category: local, arterial, freeway, etc.

2.4.3 Static Traffic Database

Static traffic database stores the configuration of traffic loop detectors, including ID, location, number of lane of the detector, and the representation of the detector location on underlying road network (i.e., LinkID of the segment the detector is on, and the distance to the start node of the segment) (see Table 2-5).

Table 2-5 Major Structures for the Detector Table

Name	Type	Description
DETECTOR_ID	Integer	ID of the loop detector
Latitude	Double	Latitude of the detector
Longitude	Double	Longitude of the detector
Num_Lanes	Integer	Number of lanes for the detector measurement
LinkID	Integer	Projected LinkID of this detector on Segment Table
DistanceInto	Double	Distance of the detector w.r.t the start node of the projected Segment

2.4.4 Static Transit Database

Static transit database stores the configurations of the transit network, including Routes, Stops, Patterns, Shapes, Schedules, and Fares.

Major structures of the Routes table contain the agency ID, short route name, route direction, transit type, long route name, route description, starting stops of the route, and ending stops of the route (see Table 2-6).

Table 2-6 Major Structures of the Routes Table

Name	Type	Description
agency_id	Integer	ID of a transit agency
route_short_name	String	Short name of the route
route_dir	Integer	Route direction
transit_type	Integer	Transit type: bus, train, metro, ferry, etc
route_long_name	String	Long name of the route
route_desc	String	Description of the route
route_start	String	Starting stops of the route
route_end	String	Ending stops of the route

Major structures of the Stops table contain the agency ID, stop ID, transit type, stop name, stop description, latitude and longitude of the stop, etc. (see Table 2-7).

Table 2-7 Major Structures of the Stops Table

Name	Type	Description
agency_id	Integer	ID of a transit agency
stop_id	Integer	ID of the transit stop
transit_type	Integer	Transit type: bus, train, metro, ferry, etc
stop_name	String	Name of the stop
stop_desc	String	Description of the stop
stop_lat	Double	Latitude of the stop
stop_lon	Double	Longitude of the stop
lat_lon	Point	combination of longitude and latitude, which is used for speeding up queries

Each route may have a number of patterns at different times of the day. Table RunPattern associates a trip (or run) with a route pattern (see Table 2-8).

Table 2-8 Major Structures of the RunPattern Table

Name	Type	Description
agency_id	Integer	ID of a transit agency
route_short_name	String	Short name of the route
start_date	String	Starting date of the schedule
day	String	Weekday, Saturday, or Sunday
route_dir	Integer	Route direction
run	Integer	Run per a directional route, starting from 1 as the first trip
pattern_id	String	Route pattern ID

Table Route_stop_seq is to define the pattern of stops in order. Major structures of table Route_stop_seq contain the agency ID, short route name, route direction, run ID, pattern ID, stop ID, and sequence of stop, and time point flag (see Table 2-9).

Table 2-9 Major Structures of the Route_stop_seq Table

Name	Type	Description
agency_id	Integer	ID of a transit agency
route_short_name	String	Short name of the route
route_dir	Integer	Route direction
pattern_id	String	Route pattern ID
stop_id	Integer	Stop ID
seq	Integer	Sequence of the stop in the trip
tp_flag	Integer	Time point or not

Table Route_shape_seq describes the road path for the corresponding route patterns, with major table elements defined in Table 2-10.

Table 2-10 Major Structures of the Route_shape_seq Table

Name	Type	Description
agency_id	Integer	ID of a transit agency
route_short_name	String	Short name of the route
route_dir	Integer	Route direction
pattern_id	String	Route pattern ID
latitude	Double	Latitude of the shape point
longitude	Double	Longitude of the shape point
seq	Integer	Sequence of the shape point

Major structures of Schedules table contain the agency ID, short route name, starting date of schedules, day of week, route direction, run ID, stop ID, sequence of stop in the trip, scheduled time, availability days, time point flag, etc. (see Table 2-11).

Table 2-11 Major Structures of the Schedules Table

Name	Type	Description
agency_id	Integer	ID of a transit agency
route_short_name	String	Short name of the route
start_date	String	Starting date of the schedule
day	String	Weekday, Saturday, or Sunday
route_dir	Integer	Route direction
run	Integer	Run per a directional route, starting from 1 as the first trip
stop_id	Integer	Stop ID
Seq	Integer	Sequence of the stop in the trip
schedule	String	Published or estimated schedules
avail_days	String	For Weekday trips only, since some trips are available only for specific days, say Tuesday only
tp_flag	integer	Time point or not

Two types of fare table are designed to fit with transit agency's definition on transit fares: Fare_on_route Table for uniformed fares on routes, and Fare_on_stops Table for zone-based fares (see Table 2-12 and Table 2-13, respectively).

Table 2-12 Major Structures of the Fare_on_route Table

Name	Type	Description
agency_id	Integer	ID of a transit agency
route_short_name	String	Short name of the route
price	Integer	Prices of a trip in the unit of cents
currency_type	String	Currency type (USD by default)
transfers	Integer	The number of allowable transfers

Table 2-13 Major Structures of the Fare_on_stops Table

Name	Type	Description
agency_id	Integer	ID of a transit agency
origin_id	Integer	ID of the origin stop
destination_id	Integer	ID of the destination stop
price	Integer	Prices of a trip in the unit of cents
currency_type	String	Currency type (USD by default)
transfers	Integer	The number of allowable transfers

2.4.5 Static Parking Database

The Static parking database stores the configurations of transit park-and-ride facilities. The Table Parking Lot is for definition of a parking lot, which includes the ID of parking lot, ID of train station, the capacity and filling-up rate of the parking lot, the number of spaces for handicap, parking lot type, ID of the agency, the latitude and longitude of the parking lot, and parking lot description (see Table 2-14). Table Parking Fee includes the ID of the parking lot, ID of train station, ID of the agency, and parking fee (see Table 2-15).

Table 2-14 Major Structures of the Parking Lot Table

Name	Type	Description
u_id	Integer	Parking lot ID
u_station_id	Integer	Train station ID
u_inventory	Integer	Capacity of the parking lots
u_handicapped	Integer	The number of spaces for handicap
u_fillup_rate	Integer	In percentage
u_type	Integer	Parking lot type
u_agency_id	Integer	ID of agency
latitude	Double	Latitude of the parking lot
longitude	Double	Longitude of the parking lot
s_desc	String	Parking lot description

Table 2-15 Major Structures of the Parking Fee Table

Name	Type	Description
u_agency_id	Integer	ID of agency
u_id	Integer	Parking lot ID
u_station_id	Integer	Train station ID
Fee	Integer	Parking fee

2.4.6 Static Traveler Database

The Static travel database stores information about the user account (Table 2-16) and favorites (Table 2-17).

Table 2-16 Major Structures of the User Account Table

Name	Type	Description
UserID	Integer	Unique identification number of a user
UserName	String	User name for login into account
UserPass	String	Password for login into account

Table 2-17 Major Structures of the User Favorites Table

Name	Type	Description
UserID	Integer	Unique identification number of a user
TripName	String	User defined name for the favorite trip
OrgAddress	String	Address of the origin location for the favorite trip
DestAddress	String	Address of the destination location for the favorite trip
OrgLat	Double	Latitude of OrgAddress
OrgLon	Double	Longitude of OrgAddress
DestLat	Double	Latitude of DestAddress
DestLon	Double	Longitude of DestAddress
TripMode	Integer	Mode of travel, i.e., driving, transit or park-and-ride
DepTime	Time	Time to start the trip
DayOfWeek	String	Day-of-week for the favorite trip

2.4.7 Dynamic Traffic Database

Real-time travel time information is stored in table Real_time_traffic (see Table 2-18).

Table 2-18 Major Structures of the Real_time_traffic Table

Name	Type	Description
LinkID	Integer	The ID of the road link
Dir	Integer	Direction of the link
AvgSpeed	Double	Average speed on the link
RecordedDate	Date	Date when the average speed was recorded
RecordedTime	Time	Time when the average speed was recorded

The archived travel time information can be post-processed to obtain traffic pattern information, which categorizes average travel time and travel time variation as functions of day-of-week and time-of-day periods (Table 2-19).

Table 2-19 Major Structures of the Traffic_Pattern Table

Name	Type	Description
LinkID	Integer	The ID of the road link
Dir	Integer	Direction of the link
DayOfWeek	String	Day-of-week for the traffic pattern
fromTime	Time	Start time-of-day for the traffic pattern
endTime	Time	End time-of-day for the traffic pattern

2.4.8 Traffic Incident Database

The traffic incident database stores the information about lane closures (planned and due to accidents) and traffic accidents (Table 2-20).

Table 2-20 Major Structures of the Traffic_Incident Table

Name	Type	Description
IncidentId	String	Unique ID that specifies the traffic incident
RecordedDate	Date	Date when the incident was reported
RecordedTime	Time	Time when the incident was reported
IncidentType	Integer	Type of incident, i.e., closure, accident
IncidentStatus	Integer	Status of the incident, i.e., unconfirmed, confirmed, scheduled, terminated
Severity	Integer	Severity of the event, i.e., none, minor, major
startTime	DateTime	Start time of the incident
clearTime	DateTime	End time of the incident
latitude	Double	Location of the incident – latitude in degree
longitude	Double	Location of the incident – longitude in degree
Link_ID	Integer	ID of the road link the incident is on
description	String	Text description of the incident

2.4.9 Dynamic Transit Database

The dynamic transit database stores information about real-time transit vehicle's location data and expected time-to-arrival data.

Real-time raw transit AVL data is stored in table gps_fixes, which includes the IDs of the transit vehicle and agency, real-time speed, latitude, longitude, and date, time, and milliseconds when the real-time information was recorded (see Table 2-21).

The raw real-time data is then processed, and a prediction algorithm is applied. The predicted arrival time to a transit stop is then generated. The information is stored in table

PredVehArrTime, which includes agency ID, route ID, vehicle ID, direction, stop ID, and predicted date, time and milliseconds (see Table 2-22).

Table 2-21 Major Structures of the gps_fixes Table

Name	Type	Description
VehID	Integer	ID of the transit vehicle
RecordedDate	Date	Date when the real-time location was recorded
RecordedTime	Time	Time when the real-time location was recorded
RecordedMs	Integer	Milliseconds when the real-time location was recorded
Speed	Double	Real-time vehicle speed
latitude	Double	Real-time latitude of the transit vehicle
longitude	Double	Real-time longitude of the transit vehicle
agency_id	Integer	ID of the transit agency

Table 2-22 Major Structures of the PredVehArrTime Table

Name	Type	Description
RecordedDate	Date	Date when the real-time location was recorded
RecordedTime	Time	Time when the real-time location was recorded
RecordedMs	Integer	Milliseconds when the real-time location was recorded
AgencyID	Integer	ID of the agency
Route	Varchar	Transit route
VehID	Integer	Vehicle ID
Direction	Integer	Direction of the route
StopID	Integer	Stop ID
PredictedDate	Date	Predicted date when the vehicle will arrive
PredictedTime	Time	Predicted time when the vehicle will arrive
PredictedMs	Integer	Predicted milliseconds when the vehicle will arrive

2.4.10 Dynamic Traveler Database

The dynamic traveler database stores information about 1) user's enquiring activities of the multimodal information system, including planning a multimodal trip, confirming/canceling a recommended travel option, checking expected arrival time for transit routes, and requiring updates on expected arrival times for confirmed trips, 2) server's responding data messages for enquiring, and 3) user's trip journey data (i.e., GPS data of actual travel). User's enquiring activities could be initiated from either a smart phone or using the Internet. User's trip journey data are obtained from the smart phone.

Table UserEnquiringHistory stores all enquiring activities from each registered user, either with a smart phone or using the Internet (see Table 2-23).

Table 2-23 Major Structures of the UserEnquiringHistory Table

Name	Type	Description

UserID	Integer	Unique identification number of a user
RecordedDate	Date	Date when the enquiring was recorded
RecordedTime	Time	Time when the enquiring was recorded
EnquiringType	Integer	Type of enquiring, i.e., trip planning, checking transit information, requesting update on arrival time, confirming a recommended trip, etc.
Enquiring URL	String	The URL sent to the server for enquiring real-time information. The URL has defined format for different type of information.

Table TrackingTrips stores the recommended travel options in responding to users' trip planning requests, with comparison parameters of trip time, costs, and estimated emissions (see Table 2-24). Data elements of *RequestMode*, *ExpDepDate*, *ExpDepTime*, *OrgLat*, *OrgLon*, *DestLat* and *DestLon* are from the planning a trip enquiry URL, and the rest of the data elements are associated with recommended travel options by mode.

Table 2-24 Major Structures of the TrackingTrips Table

Name	Type	Description
UserID	Integer	Unique identification number of a user
RecordedDate	Date	Date when the enquiring was recorded
RecordedTime	Time	Time when the enquiring was recorded
RequestMode	Integer	Requested mode of travel
ExpDepDate	Date	Expected date for travel
ExpDepTime	Time	Expected time to start travel
OrgLat	Double	Latitude of origin location
OrgLon	Double	Longitude of origin location
DestLat	Double	Latitude of destination location
DestLon	Double	Longitude of destination location
TripID	String	Unique identification string to specify one recommended travel option
TripMode	Integer	Recommended mode of travel, i.e., driving, transit, or park-and-ride
TripStatus	Integer	Idle, confirmed, canceled
TripStartDate	Date	Date to start the trip recommended by the server
TripStartTime	Time	Time to start the recommended trip
TripEndDate	Date	Expected date to reach trip destination
TripEndTime	Time	Expected time to reach trip destination
DrivingDist	Double	Total driving distance (when it's applicable)
WalkingDist	Double	Total walking distance (when it's applicable)
TripCost	Double	Total costs for the trip
TransitCost	Double	Transit fare (if applicable)
ParkingCost	Double	Parking fees (if applicable)
TripEmissions	Double	Total emissions for the trip

Each recommended travel option could consist of several segments including driving, walking/transfer, and transit. Table TrackingTripSegments stores the detailed segment information associated with the recommended trip (see Table 2-25).

Table 2-25 Major Structures of the TrackingTripSegments Table

Name	Type	Description
UserID	Integer	Unique identification number of a user
TripID	String	Unique identification string to specify one recommended travel option
SegSeq	Integer	Sequence number of this particular segment in the recommended trip
SegType	Integer	Type of the segment, i.e., driving, walking, transit
SegLength	Double	Length of the segment
SegStartDate	Date	Expected date to start this trip segment
SegStartTime	Time	Expected time to start this trip segment
SegEndDate	Date	Expected date to finish this trip segment
SegEndTime	Time	Expected time to finish this trip segment
StartNodeID	Integer	Node ID (reference to Table 2-3) of segment start point
StartLat	Double	Latitude of segment start point
StartLon	Double	Longitude of segment start point
EndNodeID	Integer	Node ID (reference to Table 2-3) of segment end point
EndLat	Double	Latitude of segment end point
EndLon	Double	Longitude of segment end point
AgencyID	Integer	Agency ID for transit segment (if applicable)
RouteName	String	Route name for transit segment (if applicable)
RouteDir	Integer	Route direction for transit segment (if applicable)
RunID	Integer	Run ID for transit segment (if applicable)
StartStopSeq	Integer	Stop sequence ID (associated with RunID) for boarding
EndStopSeq	Integer	Stop sequence ID (associated with RunID) for alighting

Finally, Table TrackingResults stores user's current location (GPS received from the smart phone), the tracked status of the confirmed trip, and the alert/update information sent to the smart phone (see Table 2-26).

Table 2-26 Major Structures of the TrackingResults Table

Name	Type	Description
UserID	Integer	Unique identification number of a user
TripID	String	Unique identification string to specify one recommended travel option
RecordedDate	Date	Date when this data entry was recorded
RecordedTime	Time	Time when this data entry was recorded
CurLat	Double	Current user location - latitude
CurLon	Double	Current user location - longitude
LatestAlertType	Integer	Type of en-route alert/update sent to the smart phone
SegSeq	Integer	Sequence number in the recommended trip the use is currently on
SegType	Integer	Type of the current segment, i.e., driving, walking or transit
DistToDest	Double	Distance to the end point of the current segment
TimeToDest	Double	Expected travel time to the end point of the current segment
TripStatus	Integer	State of the confirmed trip, i.e., idle, detoured/deviated, missed transfer, etc.
UserStatus	Integer	State of the user data communicating with the server, i.e., idle, inactive

3 Development of Integrated Multimodal Information Tools

This section presents the design and development of an integrated multimodal information system conducted under this project. The testing and evaluation of the developed system on traveler behavior change and congestion relief is on-going under a continuation of this project, therefore, the testing and evaluation results will be included in another project report.

3.1 Development of Acquiring, Parsing, Processing and Management Tools for Collecting Multimodal Transportation Data

As described in Section 2.3, there are multiple data sources for collecting multimodal transportation data in Los Angeles County (see Table 2-1). Table 3-1 lists the accessible means and format of data feed for each type of the multimodal data sources. Of these data sources, GTFS and NextBus data are publicly-accessible, while NAVTEQ and RIITS network data require a data sharing agreement with the data provider. The project team has established the data sharing agreement with both NAVTEQ and RIITS for collecting static and real-time multimodal transportation data in Los Angeles County.

Table 3-1 Lists of Multimodal Data Sources and Accessible Means

Data Type	Agency Providing Data	Access Means / Format	Institutional Arrangement	API Documentation
GTFS Data	LA Metro	Web API / Zipped text files	Public Accessible	See Ref. Google 2013a
Road Network Data	NAVTEQ	Web API / Compressed shape files	Established data sharing agreement	See Appendix A
Traffic Incident Data		Web API / HTTP XML		
Metro Rail AVL	NextBus	Web API / HTTP XML	Public Accessible	See Appendix B
Metro Bus AVL	RIITS	Web API / SOAP XML	Established data sharing agreement	See Appendix C
Traffic Data (Static & Real-Time)				

GTFS data feed includes several CSV (comma-separated values) text files, including *routes.txt, stops.txt, trips.txt, stop_times.txt* and *shapes.txt*, among others. GTFS data feed does not include pattern information. For a particular route specified by route name and direction, there could be multiple patterns traveling on different streets and making stops at different stop locations. For example, LA Metro Line 10/48 East has 18 patterns. Pattern information is critical for trip planning, as one physical bus can service all stops associated with a particular pattern while switching patterns requires a transfer, even traveling on the same route. Software tools have been developed to read and process GTFS data feed (files), convert the static transit configurations provided by the GTFS data feed into the format specified by the STC static transit database and tables (see Section 2.4.4), and insert the static configurations into related MySQL tables.

A set of software tools have been developed to periodically query multimodal transportation data feeds from data providers listed in Table 3-1, parsing the data feeds based on agency provided

API documentation, and archiving the data into related MySQL tables (see Sections 2.4.3, 2.4.7, 2.4.8, and 2.4.9). Note that the software tools have become customary for each data provider and even for different data types from the same data provider, as the requirements specified in the API documents.

Real-time transit AVL data are provided from two sources, i.e., RIITS for transit buses and NextBus for rail transit. Data elements from these two data sources are not identical, particularly, the AVL data need to match with the service pattern that the transit vehicle is providing. The project team also developed software tool to merge real-time bus/train AVL with GTFS to form uniform data entry for archiving into MySQL tables.

3.2 Development of Integrated Database

The centralized and layered database architecture and structure have been presented in Sections 2.1 and 2.4, respectively. Acquiring and processing of multimodal (traffic and transit) data and related database and MySQL tables have been discussed in Section 3.1. This subsection addresses the development of the capability of capture traveler's information enquiring activities and actual travel behavior data.

As an example, John is going to attend a meeting in Los Angeles' Downtown area. He used the STC mobile App to plan his trip from home to the meeting place, with his expected arrival time. John was presented with three travel options of 1) driving, 2) park-and-ride and 3) taking transit, with comparison of travel time, costs and emissions at a glance. John decided to take option 2) as the meeting place is near the transit station and he felt convenient to get to the park-and-ride lot, he confirmed option 2) and started his journey. While driving to the park-and-ride lot, the STC mobile App notified John (through text-to-voice) that there is a small traffic incident on the way to the parking lot. John decided to stay with the planned trip as it does not seem to him that the incident could cause too much delay. While waiting for his train, John was notified by the STC mobile App, again through text-to-voice, that his train will arrive in about 2 minutes. John took the train as recommended and when it is near to his departure station John was notified that the train will arrive at his stop in about 2 minutes. John departed the train and arrived at his meeting place on-time.

In order to study John's travel behavior in response to real-time traveler information provided to him, the following data need to be stored for his journey from home to the meeting place:

- Input to the multimodal trip planning request (origin, destination, expected arrival time);
- Recommended travel options by mode, i.e., options of 1), 2) and 3) mentioned above, which represent the current multimodal transportation (traffic and transit) conditions at the time of making a trip planning request;
- John intended (confirmed) travel option based on presented comparisons of three options;
- En-route updates and alerts, which represent the change of multimodal transportation condition; and
- John's actual journey data (sequence of GPS location points), which indicate the actual mode/route that John used for his trip.

From the recorded data, we can analyze:

- How the real-time information influenced John's trip decision;
- Difference in travel time between the predicted value at the time when making a trip planning request and the actual travel time; and
- Difference in travel time for other recommended travel options than the one John chose.

The dynamic traveler database described in Section 2.4.10 was designed in such way to capture all related multimodal data and traveler behavior to support the behavior analysis. All the data communicated between the client (web/phone) and server will be stored on the server, including trip planning input, recommended trips, confirmed trip, en-route GPS traces, update and alerts.

3.3 Development of Multimodal Trip Planner for Larger Metropolitan Area

Under the previous Networked Traveler project, a multimodal trip planning system was developed and tested on the U.S. 101 corridor between San Francisco and San Jose. Compared with the 101 corridor, Los Angeles County is a much greater region in both the geographic size and the size of its transit network (i.e., number of transit routes and connection points between routes). Travelers can only enter/exit the transit network and make transfers within the transit network at transit stops/stations. Although the physical path is fixed (at fixed locations), the feasible connection also depends on real-time transit operation and in nature is dynamic. This dynamic characteristic makes multimodal trip planning a complex computational problem for larger metropolitan areas. This subsection describes the improved multimodal trip planning algorithms in order to improve the response speed of trip planning, particularly for larger metropolitan area.

Efficient itinerary planning for public transit is critical to travelers in urban areas. Several automatic itinerary planners have been developed in the literature (e.g., Peng and Huang (2000), Horn (2003), Lo et al. (2005), Cherry et al. (2006), Tan et al. (2007), and Zografos and Androutsopoulos (2008)), and made publicly available online (e.g., Google Transit, Bay Arena 511, and Chicago RTA).

Transit itinerary planning is closely related to the shortest path problem. However, transit itinerary planning under uncertainty is much more challenging than the shortest path problem due to several inherent features in the transit itinerary planning. First, transit itinerary planning contains multiple starting and ending nodes as passengers typically do not specify the starting and ending stops. Instead, passengers generally provide an origin and a destination address. Our empirical tests show that often over ten closest stops are required in order to obtain good itinerary plans. Multiple starting and ending nodes make transit itinerary planning much more computationally challenging than the classic one-to-all shortest path problem. Second, with pre-specified transit schedules, additional considerations must be given in the model to incorporation of passenger waiting. This planning problem then belongs to the category of time-dependent shortest path problems (Tong and Richardson 1984, Ziliaskopoulos and Mahmassani 1993, Chabini 1998). Finally, different starting nodes often correspond to different starting times since the walking distances from the origin can be different.

Figure 3-1 illustrates the architecture of the developed multimodal trip planning system.

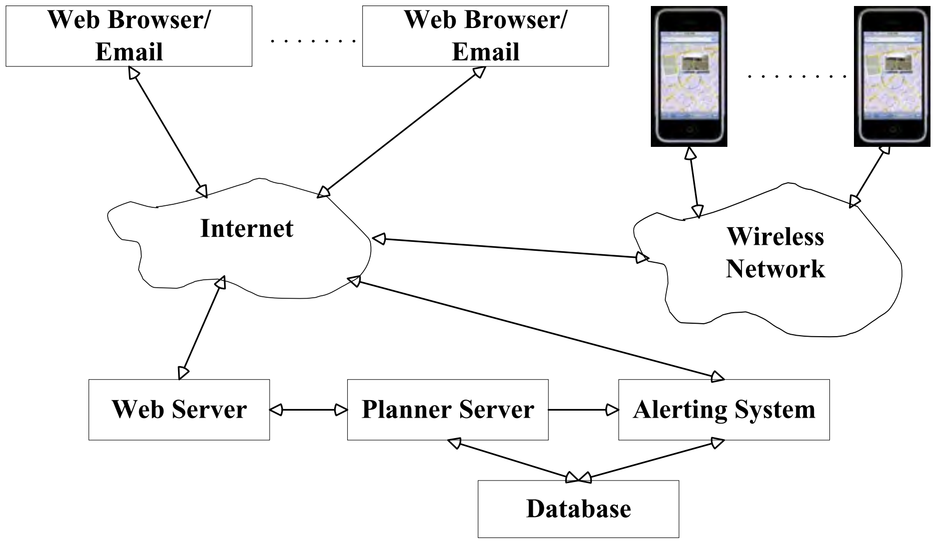

Figure 3-1 Architecture of the Multimodal Trip Planning System

3.3.1 Offline Pre-Computation: Constructing the Underlying Network

We first describe the architecture of the trip planning server. Then, we present the construction of underlying networks to support multiple travel modes.

Figure 3-2 presents the architecture of the trip planning server, which is designed to handle concurrent requests. Each request is handled by a planning thread. The planning algorithms are based on the underlying networks to determine good trip options. Due to the nature of multi-modal transportation, our underlying network consists of different types of nodes, including intersections, bus stops, train stations, parking lots, and transit time points. We then construct two types of networks: the road and transit networks as follows.

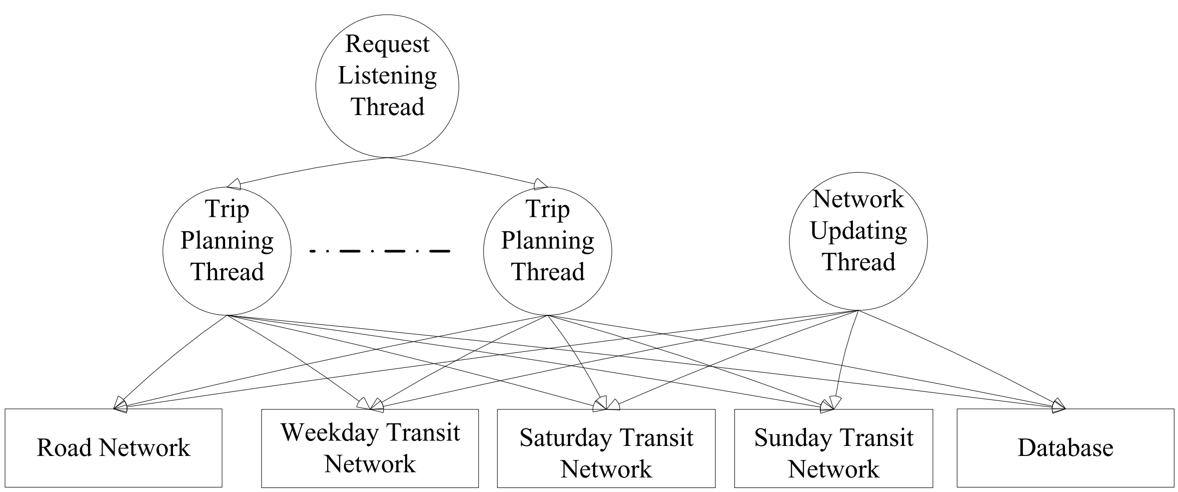

Figure 3-2 Architecture of the Trip Planning Server

3.3.1.1 Constructing the Road Network for Driving and Walking

The road network consists of intersections, transit stops and parking lots. The time points are excluded in the road network. The road network includes arcs between intersections, arcs between intersections and transit stops, and arcs between intersections and parking lots. An example can be seen in Figure 3-3, where bus stops are connected to nearby intersections. The road geometry data in our system is from NAVTEQ. The stop and parking lot data are from various transit agencies. The static arc cost is calculated based on the distance and posted speed limit. The arc cost will be updated based on real-time traffic data.

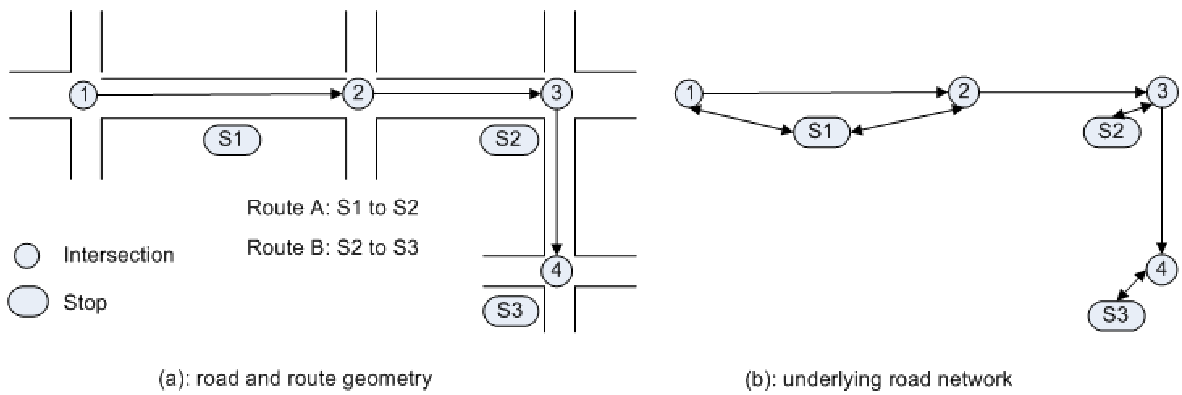

Figure 3-3 An Example of the Underlying Road Network

The walking mode presents two potential issues: (1) walking on freeways is disallowed; and (2) for one way roads, walking may be allowed in both directions. Each arc in the underlying network is associated with certain indicators to show if the road is a freeway, local street, two-way or one-way road. The planning algorithm will examine the road type and transportation mode together to see if it is reasonable to use the road.

3.3.1.2 Constructing the Time-Expanded Network for Transit

The transit networks include transit stops, parking lots, and time points. The arc types are: a stop to related time points, a parking lot to related time points, time points to time points of the same route (i.e., for transit trips), time points to time points of different routes (i.e., for transfers), time points to stops, and time points to parking lots. Transfers between different routes are very important in the underlying network construction. We examine the possible transfers based on the static schedule data and minimum transfer time. If the transfer is infeasible, the corresponding arc is disabled in the underlying networks. The cost of transit trip arcs is defined as the trip time. The cost of walking arcs (i.e., transfers, walking to the first stop, or walking from the last stop) is defined as the walking time plus the potential waiting time. The underlying network is periodically updated based on real-time traffic and transit time, which will be discussed in detail in a subsequent section of this report.

If a shortest path is based on an acyclic network, there exist special efficient algorithms. However, the transit network includes cycles. For example, a circular route may exist. In order to obtain an acyclic network, a bus stop in the transit network is split into two bus stops: a starting bus stop and an ending bus stop. Such a stop splitting strategy leads to an acyclic transit network. Figure 3-4 presents an example of the underlying transit network, where route A has two trips and route B has one trip. There is one transfer arc from the first trip of route A to the trip of route B. It should be mentioned that for convenience, we do not split each bus stop in Figure 3-4.

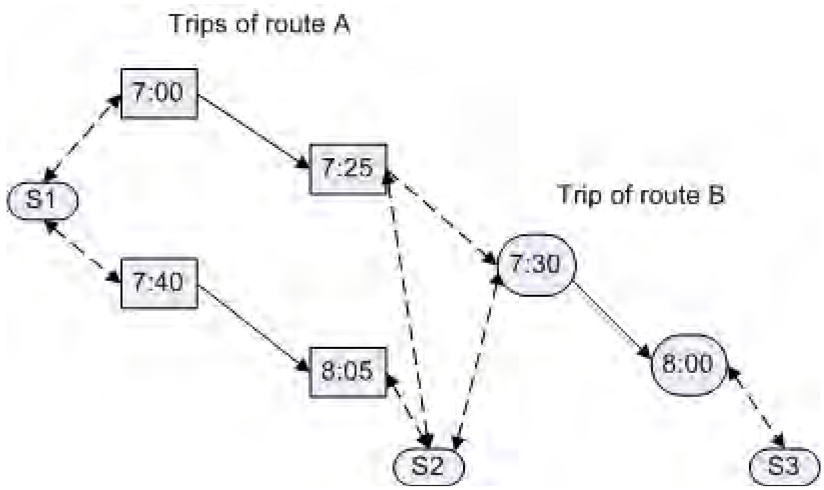

Figure 3-4 An Example of the Underlying Transit Network

Designing transfers between different routes is crucial to obtain reasonable trip plans. Bus routes serve many bus stops (i.e., 100 stops for some routes in San Francisco). Only a small percentage of bus stops have time points. These stops are called *time-point stops* in this paper. Bus stops that do not have associated time points are called *non-time point stops*. Some trip planners allow passengers to transfer to a different route only if both stops have time points. Such an approach significantly reduces the size of the underlying network and decreases the response time of the planning server. However, our preliminary studies show that certain trips are inappropriate with such a design. If transfers are allowed at both time-point stops and non-time point stops, the network size is very large, thus significantly increasing computational time. In order to handle the trade-off between improving trip reasonableness and reducing computational time, we use different distance thresholds for transferring at different types of stops: for two time-point stops, the maximum allowable transfer distance is set as 800 meters; otherwise, the maximum distance is set as 100 meters. Certain simple averaging methods are used to estimate the static arrival time to non-time point stops based on the route schedule and distance between stops.

Since most transit agencies have different services on weekday and weekends, we construct three transit networks: weekday transit network, Saturday transit network, and Sunday transit network, each of which contains the time points for that day. It is worthy to note that all the networks are shared by the trip planning threads (see Figure 3-2) for saving computer memory. The road network and transit networks are often very large due to the number of intersections and time points. Therefore, it is critical for planning threads to share the data.

3.3.2 Offline Pre-Computation: Reducing the Network Size

Reducing the network size is of critical importance to mitigate the computational challenge in real-time. Transit itinerary planning can become very large in metropolitan areas. For example, the transit network of San Francisco Municipal Railway (MUNI), the seventh largest transit system in the U.S. in ridership, consists of 81 lines, about 4500 stops and 430K time points at weekdays. LA Metro has a much larger network than MUNI. In addition, different transit routes may be very close to each other in urban areas.

Figure 3-5 A Large Number of Transfer Points between Routes 205 and 550 (See Red Dashed Box)

For example, Figure 3-5 shows a portion of the transit network for LA Metro. We can see that route 205 and 550 are parallel for some parts of the route. Therefore, there are many transfer points between two routes. However, it is not necessary to include many transfer points between two routes. One of the earliest transfers is sufficient to ensure the connectivity.

In our pre-computation program, we check the potential connections between two routes, and select the earliest time point for transfer. Such a strategy significantly reduces the size of the network.

3.3.3 Real-time Planning: Searching Algorithms for the Shortest Path Problems

We describe the trip planning algorithms that support three travel modes: driving, transit, and parking-and-transit. If users choose the mode of transit or driving-parking-then-transit, we first select the transit stops or parking lots that are near the origin. Then, the transit stops nearby the destination are determined. Our experiments show that good trips may be omitted if insufficient nearby stops are used; say fewer than 10 stops for our case studies by our preliminary tests. Currently, for each origin and destination, we select 50 nearby bus stops. For the mode of transit or driving-parking-then-transit, we actually solve three shortest path problems: (1) from the origin to nearby transit stops or parking lots; (2) from the destination to the nearby transit stops; and (3) from the transit stops or parking lots that are close to the origin to the transit stops that are close to the destination. These routes will be combined together to yield an overall route.

There are three situations where the one-to-one shortest path problem needs to be solved: (1) driving mode with an origin and a destination; (2) driving or walking from the origin to the first bus stop or parking lot; and (3) walking from the last bus stop to the destination. We implement a Dijkstra algorithm to solve the one-to-one shortest path problem.

The overall real-time trip planning algorithms for the transit mode are as follows.

Overall procedure

Inputs: the (1) origin, (2) destination, (3) departure time (or arrival time), and (4) travel mode

Step 1: Call the Geo-coding service to obtain the latitudes and longitudes of the origin and destination addresses.

Step 2: Query the geometry database and obtain the nearest intersection for the origin and destination, respectively.

Step 3: If the travel mode is driving, apply the Dijkstra algorithm to obtain the shortest path from the origin intersection to the destination intersection. Go to Step 8.

Step 4: If the travel mode is transit or driving-parking-and-transit, query the database to obtain nearby transit stops (for the transit mode) or parking lots (for the driving-parking-and-transit mode) for the origin intersection. Query the database to obtain nearby transit stops for the destination intersection.

Step 5: Apply the Dijkstra algorithm to obtain the shortest path from the origin intersection to each nearby stop or parking lot and determine the corresponding travel times. Similarly, apply the Dijkstra algorithm to obtain the shortest path from each nearby stop to the destination intersection.

Step 6: Push all the nearby stops or parking lots of the origin intersection into the candidate list and call the multi-source searching algorithm.

Step 7: Merge transit trips generated in Step 6 and walking or driving trips generated in Step 5 together to produce overall trips.
Step 8: Conduct the trip dominance and output the remaining trips to client programs.

The multi-source searching algorithm, which is based on topological sorting, is presented as follows.

Multi-source searching algorithm

Inputs: (1) origin stops or parking lots with the arrival and travel times and (2) destination stops

Step 1: Push all the origin stops into the candidate list. Set the cost for each node in the candidate list as the travel time.
Step 2: When the candidate list is not empty
- **Step 2.1:** Remove a node from the candidate list and call it node *n*.
- **Step 2.2:** For each out-going arc of *n*:
  - **Step 2.2.1:** If the current arc is disabled, return to Step 2.
  - **Step 2.2.2:** If the arrival time to the head node of the current arc is later than its departure time (i.e., for transfer arcs), return to Step 2.
  - **Step 2.2.3:** If the head node of the arc is outside the search box, return to Step 2.
  - **Step 2.2.4:** If the currently optimal cost of the head node of the current arc is more than the cost of the tail node of the current arc plus the cost of the current arc, update the cost of the head node and set its predecessor node as the tail node.
  - **Step 2.2.5:** Reduce the in-degree of the head node by one. If the in-degree of the head node equals zero, push it to the candidate list.

Step 3: Return the shortest path for each destination stop.

Note that Steps 2.2.1, 2.2.2, and 2.2.3 are to examine the feasibility of extension. Step 2.2.4 is to update the cost of a node if necessary. Step 2.2.5 is to implement the topological sorting based on the acyclic underling transit network.

Finally, it is worth mentioning that our algorithm consists of a forward algorithm and a backward algorithm: the forward algorithm is in play when users specify the departure time, while the backward algorithm is used when the expected arrival time is specified. The two algorithms have similar operations except their initial sources and the arc scanning method.

3.3.4 Real-Time Speedup

We also develop the following strategies to reduce the computational time in real-time. First, we implement an A* algorithm for walking and driving. A* may be seen as a heuristic shortest path algorithm, which generally performs much faster than the Dijkstra algorithm.

Second, we implement an early termination strategy in the multi-source searching algorithm. With such a strategy, once certain destination stops are reached, the algorithm will stop. We are testing the performance of this strategy.

Third, we are going to implement a priority heap data structure with the Dijkstra algorithm. The priority heap can facilitate the determination of the label with the minimum cost, thereby reducing the time of the Dijkstra algorithm.

3.4 Design of STC Mobile and Web Applications

Travelers can interact with the STC multimodal traveler information system either through the mobile App or via Internet. Depending on the nature of the mobile App and Web, STC features as described in Section 2.2 need to be designed to fit the mobile and Web characteristics.

3.4.1 Common Features for Mobile and Web Applications

The common STC features for both mobile and web applications include:

- User preference setting, favorite saving and synchronization with the STC server
  Users shall be able to set their preference of travel and to save their favorite trips with desired name (c.f., home to work) through both the mobile and web interfaces, and the preference settings and favorites should be able to synchronized with the STC server.
- Check current traffic condition
  Users shall be able to virtually see the current traffic condition on a map. Google is providing the Traffic Overlay API for color-coded traffic conditions. Both the mobile and Web application shall incorporate this feature for users to capture the current traffic condition at a glance.
- Check transit arrival information at particular stop/station (can be saved as favorite)
  Users, who want to have a quick access of transit information, either on-the-go (with mobile phone) or with a computer (web), shall be able to use this feature for planning their arrival time at the stop/station in order to catch a bus/train, without trip planning.
- Multimodal pre-trip planning
  Users shall be able to plan a multimodal trip on both mobile and web, and shall be able to compare the recommended trip options at a glance. The recommended trips should be overlaid with a map for visualization, with different color schemas for different modes.
- Collection of travelers' information enquiring activity data
  Users' information enquiring activities (e.g., trip planning, checking current traffic condition, and checking transit arrival information) shall be able to communicate with the STC server and be archived at the server database. As all the information enquiring requires data exchange with the server through web-based APIs (see Section 3.5), the server will store all the information enquiring, which identifies the types of information enquiring.

When designing the interfaces for the mobile App and the website, the following issues needed to be considered not to confuse users treating the two client interfaces as two separate applications:

- Use of the same application name and app icon;
- Use of the same set of icons for walking (person), driving (car) and taking transit (bus/train), transit stop/station, construction, incident; and
- Use of the similar color schemas for overlaying recommended trips on the map.

3.4.2 Unique Features for Mobile Application

The advantage and convenience of the mobile App is for on-the-go, so the main unique STC features for mobile App, in addition to those described in Section 3.4.2, are providing en-route guidance and alerts, and collecting travelers' journey data (mobile phone GPS data).

- Driving navigation
  Driving navigation is essential for traveling in an unfamiliar area, particularly for guiding a traveler to take transit in a location that he or she is not familiar with. Developing a navigation tool is out of the scope of this project. Instead, the existing mobile navigation tools, such as Google Navigation, shall be integrated with the STC mobile app, and a user shall have the option of using Google Navigation to guide his/her driving trip.
- Text-to-speech for en-route alter
  Users shall be able to receive en-route alerts through text-to-speech, without using the mobile phone. This feature is required for driving but it is also helpful for other modes as well (i.e., transit, walking).
- Collecting mobile phone location data and communicating the data with the server
  The capability of collecting travelers' journey data and associating the journey data with real-time traffic and transit conditions is one of the main features of the STC system for supporting the study of travelers' response to real-time information. Therefore, the mobile App shall be able to turn on/off the embedded GPS receiver as required to collect journey data and to communicate the data to the STC server.
- Adjusting GPS querying rate and data communication rate with STC server
  Continue querying GPS location and communicating with the server could drain the phone battery quickly and reduce the usability of the information tools. The STC system is designed in such a way that the server is able to track a user's location along the planned trip and dynamically determine the GPS querying rate and data communication rate with the server. The mobile App shall be able to implement the dynamic querying and communication rates to reduce battery consumption.

The design and implementation of the mobile App interface should also consider the current physical and existing functions on the mobile platform, to have the App integrated with a mobile platform as much as possible. For example, to utilize the physical phone buttons (Back, Home, and Manual) without adding similar software buttons on the screen.

3.4.3 Unique Features for Web Application

Due to the size and resolution advantages of computer screens, the web application shall include the additional features as account management and user surveys.

- User account management
  Users shall be able to check their historical travel in terms of benefits they gained by taking the recommended trip by the multimodal trip planning.
- Synchronizing confirmed trip with mobile App
  Users shall be able to plan a multimodal trip, compare recommended travel options, and confirm their desired travel option. The confirmed trip shall be able to synchronize with the user's mobile App through the STC server such that the user can continuously receive en-route updates and alerts on the mobile phone, without the need for re-planning the trip with the mobile App.
- User survey
  User surveys will be conducted on the web, where users will be reminded to take the surveys.

Although the web application aims to be primarily accessed from a computer, users could access the website with their mobile phone. Therefore, when designing the web interface, the scalability of properly displaying information on both computers and mobile phones should be considered.

3.4.4 Design Mockups

Preliminary design for mobile and web applications have been conducted to implement aforementioned features and design consideration. Design mockups for mobile App is presented in Appendix D, which includes 1) the screen flow diagram for activities initiated from the five function tags: Map for nearby awareness and search, Favorites, Lines for transit schedules and real-time expected arrival information, Trips for trip planning, comparison and visualization, and Options for preference setting, and 2) major screens for Android phone and iPhone.

The screenshots of intermediate mobile App release (for reviewing) are attached in Appendix E, including 6 screenshots of implemented screen design on the Android phone. Preliminary website design mockups are attached as Appendix F, including 7 design stacks.

Note that the design mockups and screenshots presented here are the preliminary design not the final design. The design and application implementation are on-going under the continuation of this project.

3.5 Development of API Specification Document for Data Sharing between Client and Server

In order to provide STC features as described in Section 2.2, the clients (i.e., mobile and web applications) need to exchange data with the STC server, including

- Creating account (registration)
- User login and authorization
- Synchronization of user preference and favorites
- Checking real-time traffic and transit information
- Pre-trip planning
- Confirming/canceling a recommended trip
- Synchronization of confirmed trip
- Receiving location-based en-route alters

A set of APIs has been identified for severing these client-server communication needs, and the specification for these APIs has been developed (see Appendix G). The API specification document will be used for implementing real-time client-server communication in the continuation of this project.

4 Summary and Next Steps

Advanced Traveler Information Systems (ATIS) have been deemed an important tool for encouraging people to change their travel behavior and consequently have the potential to improve the overall transportation system. However, the effects of travel information on travelers' trip decision making and on the transportation network have not been well-understood, mainly due to the lack of integrated transportation data and travel journey data.

Under the Networked Traveler (NT) project sponsored by the USDOT and Dynamic Passenger Information (DPI) System project sponsored by Caltrans, PATH has developed an integrated multimodal information system named Path2go to help users make trip decisions based on real-time multimodal information and to collect trip journey data for investigating the impacts of real-time multimodal traveler information on travelers' decision making and on the transportation system. Evaluation study conducted by an independent evaluator found that the Path2go application performed well with regard to its capability to integrate real-time, multimodal information, the accuracy and reliability of the information, its effectiveness in helping users to reduce waiting time at transit stop/station and overall travel time, and its effectiveness in encouraging travelers to consider transit as a more viable choice. However, the limited scope of the NT FOT (4 months of FOT period with en-route information provided only to transit users on one corridor) limited the number of potential users (particularly choice drivers) to participate in the field tests. As a result, the influence of traveler information on decisions of time to travel was not measured and the impact on congestion relief was not measurable.

This project is the continuation of the NT and the DPI projects, to further enhance the previous multimodal real-time information tools and to collect integrated multimodal transportation data and users' journey data through an extensive FOT, such that the study of travelers' responses to information and the evaluation of the impacts of behavior changes on traffic can be performed with real-world data.

The enhancement of the multimodal information tools include:

- Expended real-time data coverage to attract more users
  The targeted FOT area was moved from the 101 corridor in the San Francisco area to Los Angeles County. The project team has mitigated the multimodal information system to LA County. Multimodal transportation data sources and data providers have been identified, including RIITS, NextBus and NAVTEQ. The project team has established a data sharing agreement with these data providers to collect multimodal transportation data in real-time. A set of data querying, parsing, processing and management tools have been developed and implemented for multimodal transportation data collection. Traffic and incident data being collected cover the entire LA County region, and transit real-time data being collected cover the entire bus and rail fleets of LA Metro.
- Providing more features and better real-time information to encourage model shift

The previous information tools only provide en-route guidance and alerts for transit users. In order to encourage mode shit from driving to transit, new STC features, particularly designed for choice drivers, are now integrated with the current tools. More specifically,

- o En-route traffic incident alert is now included for the driving mode to inform the users about dynamic changes on their driving path;
- o Text-to-speech is enabled for en-route traffic incident alert such that it won't distract the user from driving;
- o The mobile App is integrated with Google Navigation App to provide turn-by-turn guidance, which is essential for choice drivers to shift to transit in unfamiliar environments; and
- o Pre-trip alert is included to provide suggestions on commute alternative.

The enhanced multimodal information tools are now actually multimodal, providing traveler information in both pre-trip planning and en-route guidance and updates.

- Improved the design of mobile and web interfaces
  The project team has analyzed feedback and comments received from users who participated in the NT FOT and has re-designed (through project contractors) the mobile and web interface to improve the usability of the multimodal information tools. The improvements include 1) more graphics for users to visualize the road conditions and compare different travel options recommended by the multimodal trip planner, 2) additional convenience for users to save their favorite trips/destinations and for users to enquire real-time information or to plan a multimodal trip with the saved favorites, and 3) simplified web pages and mobile phone screens to allow users to capture the information more easily.
- Improved multimodal trip planning algorithm
  In large metropolitan area, such as LA County, the complexity of the road and transit networks considerably increases the computational complexity of multimodal trip planning and thereby increases the response speed. The previous trip planning algorithm has been modified to overcome this challenge. In the improved multimodal trip planning algorithm, the planning problem is modeled as time-dependent shortest path problems, and strategies for offline pre-computation of underlying road and transit networks and online speedup of searching for shortest path were implemented to reduce the computational time in real-time.
- Improved integrated database
  The database structure has been modified to improve the efficiency of data sharing, and archiving integrated travelers' journey data with multimodal transportation data, which is essential for the development and calibration of behavior models, and assessment of effects of real-time information on behavior change and congestion relief.

Next steps include

- STC system integration, debugging and improvement
  Component testing of the integrated multimodal information tools, including mobile App, web application, server-centralized trip status tracking, alert generation and data archiving, and communications between components will be conducted to identify and correct the major issues related with each component. Internally testing of the integrated STC system will be conducted to identify and correct issues that could affect pilot testing and field operation testing.
- Pilot testing
  A small scale field test of the integrated STC system will be conducted with volunteers from LA Metro and Caltrans District 7 employees. The pilot test will identify issues in the STC system in the field operational environment. Identified problems will be further debugged in the laboratory environment and corrected to prepare the system to be ready for the field operational test.
- Field operational test
  A 12-month FOT will be conducted after the pilot test to collect real-world travel behavior data and associated multimodal transportation data.
- FOT evaluation
  Statistical analysis of behavior responses will be conducted using the collected real-world data. Models of travel choice making and prediction of behavior responses to real-time information will be developed and calibrated to estimate the impacts of real-time information on behavior changes. Impacts of real-time information on traffic will be also evaluated.

  Focus group studies will be conducted to evaluate users' perceptions of the strengths and weaknesses of the integrated information tools and to make recommendations for improvements as it evolves.

This report documents the design and development of the integrated multimodal traveler information system. The testing and evaluation of such a system on traveler behavior changes and congestion relief is on-going as a continuation of this project, and will be included in another project report.

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Appendix A. NAVTEQ Incident Feed

Incident Feed

Version 2.0

NAVTEQ

Date:
April 30, 2010

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Appendix B.   NextBus Public XML Feed

NEXTbus Incorporated

Public XML Feed

Revision 1.22
April 4, 2013

Appendix C. RIITS Integration Instruction

LACMTA

Regional Integration of Intelligent Transportation Systems (RIITS)

INTEGRATION INSTRUCTIONS

Version 1.0

December 2004

Prepared by:

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Technology Corporation

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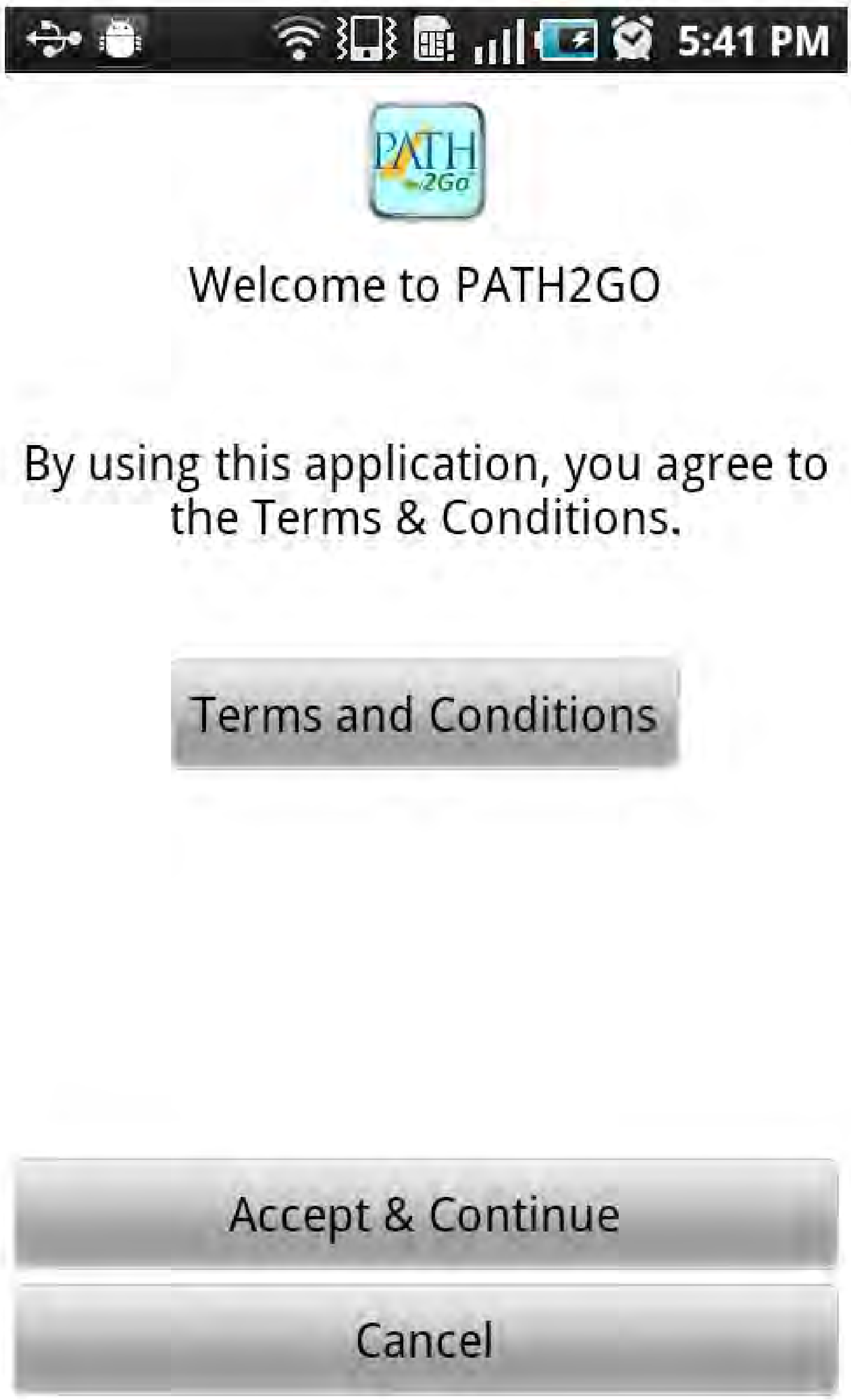
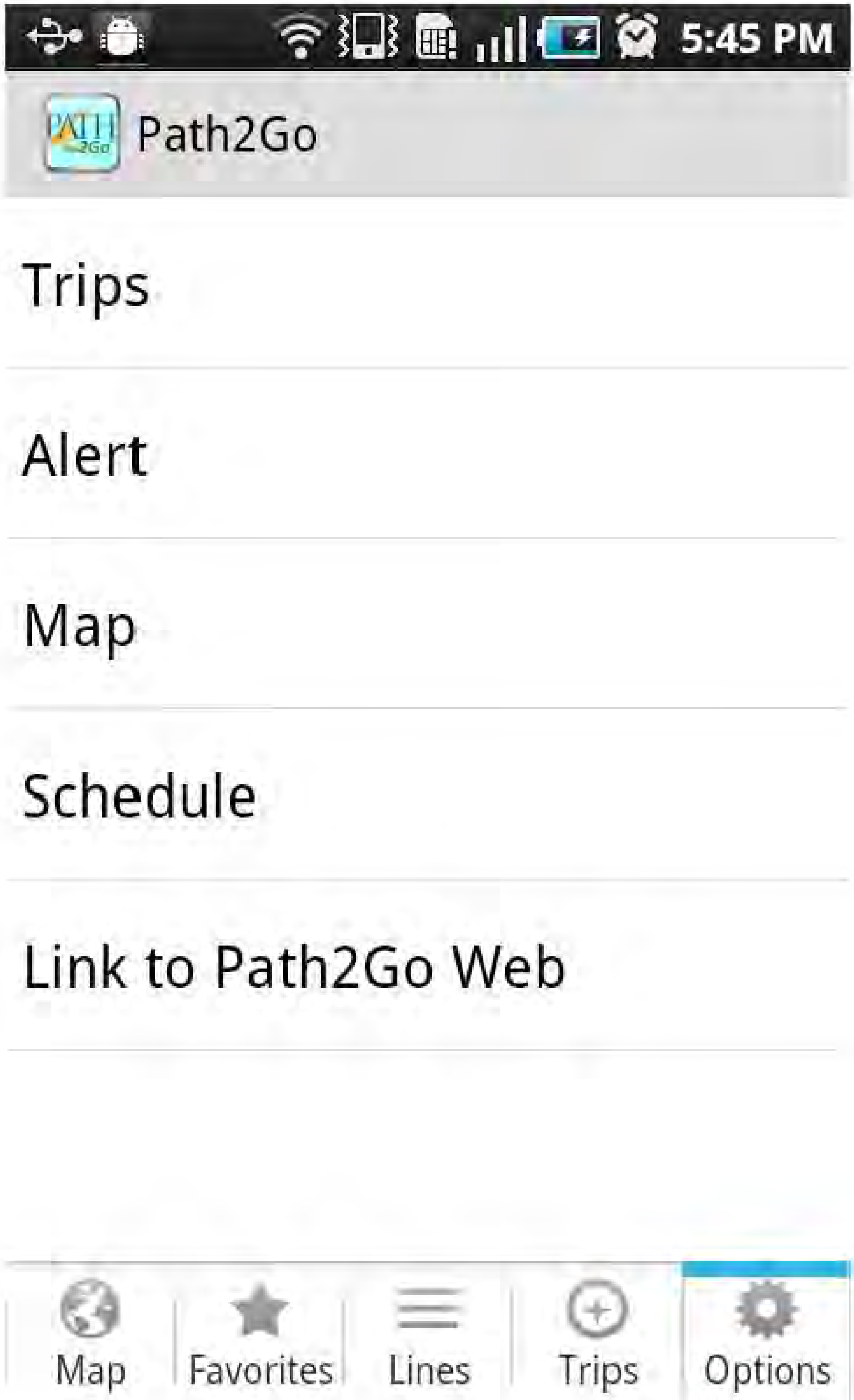
Appendix D. Mobile App Design Mockups

Appendix E. Mobile App Design Screenshots

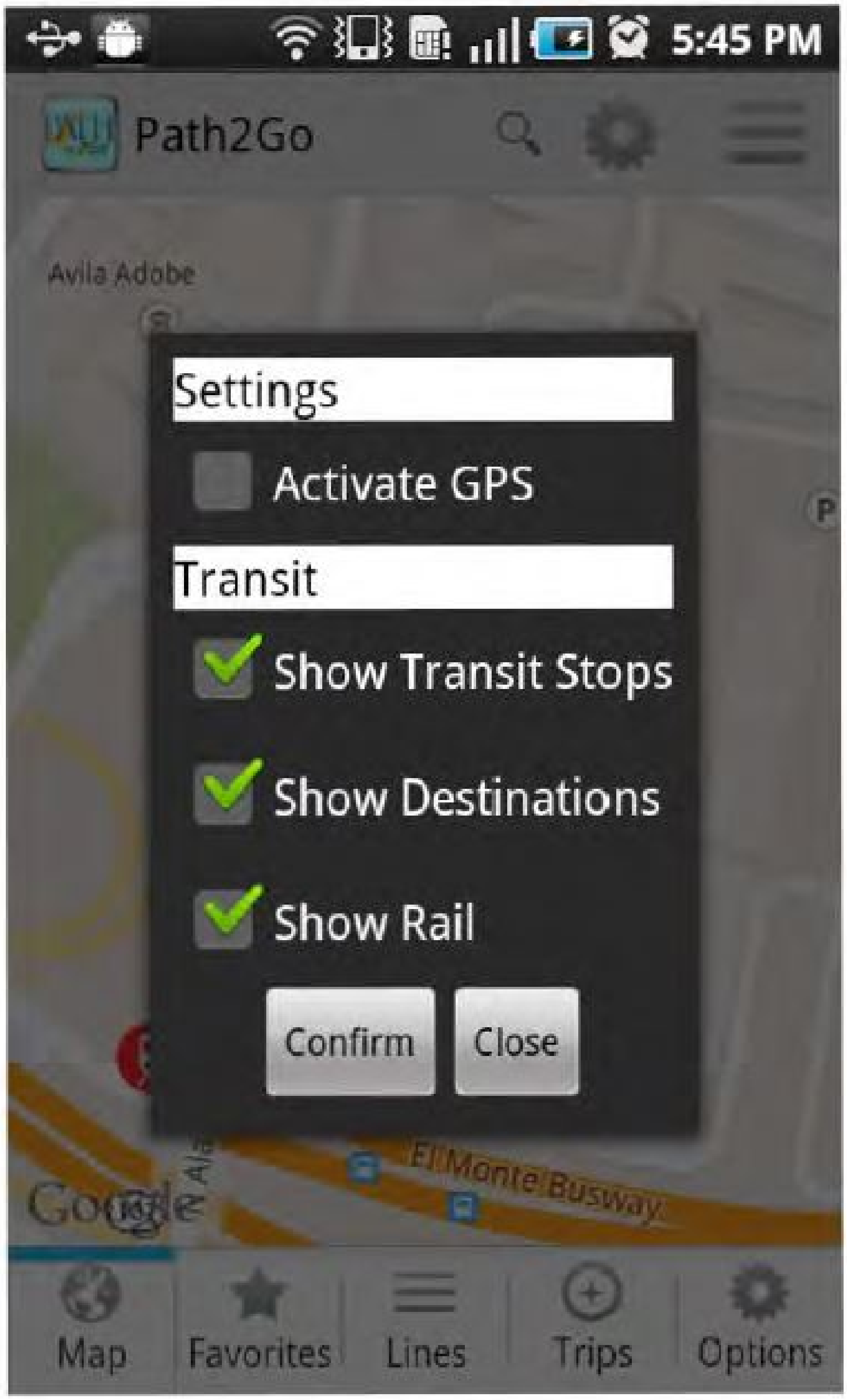
Appendix E.1 Disclaimer Screen



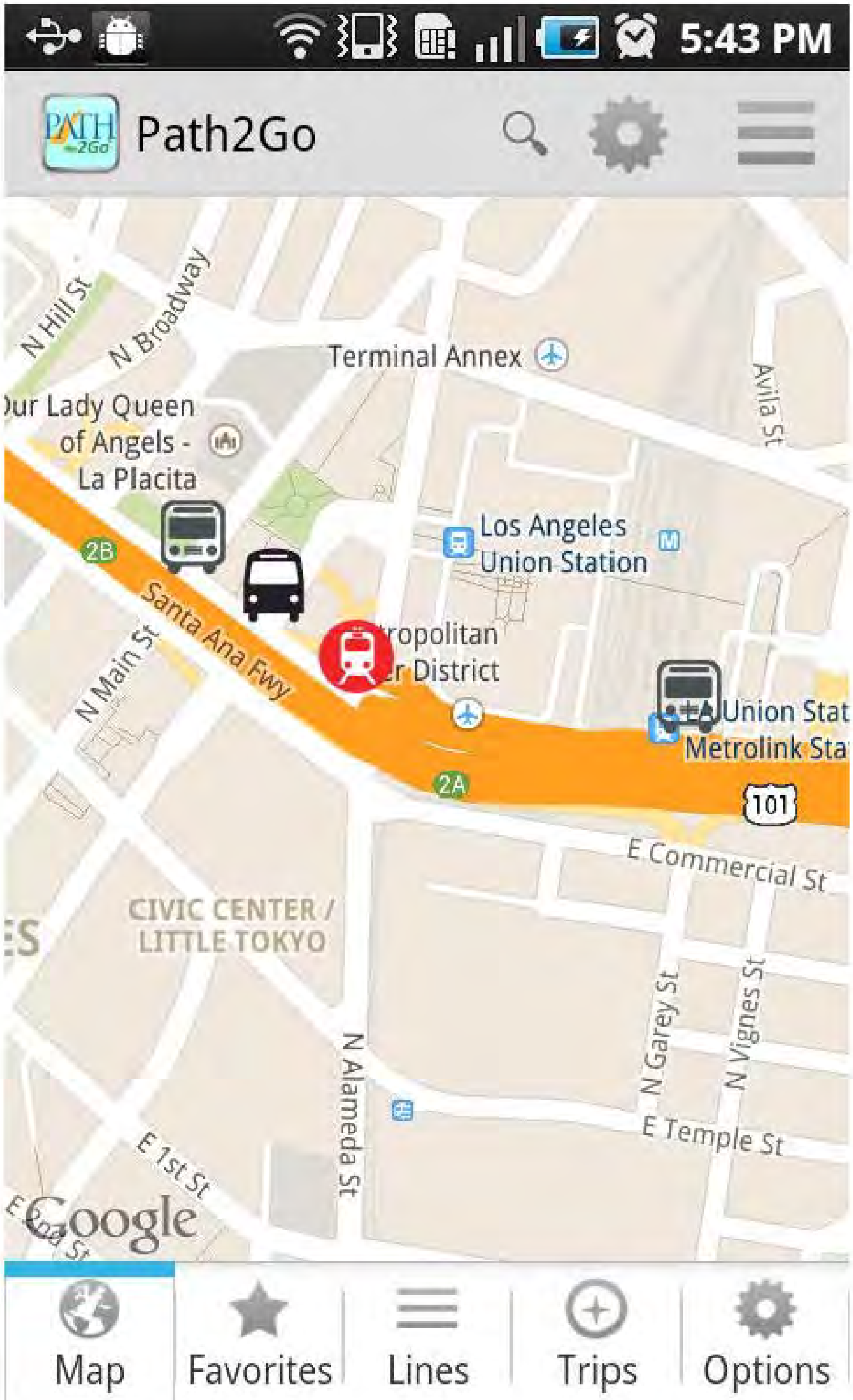
Appendix E.2 Options Screen



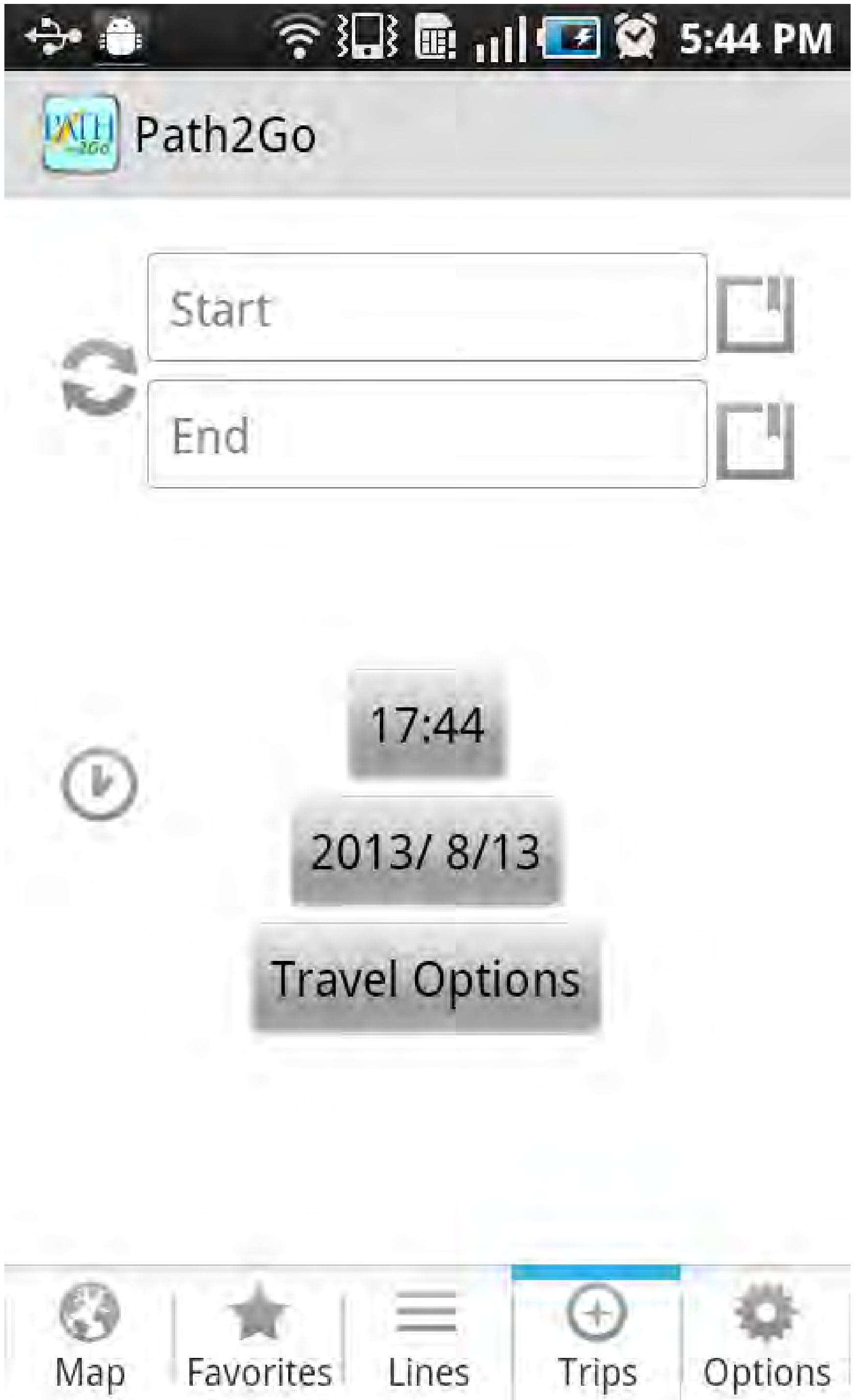
Appendix E.3 Map Preference Screen



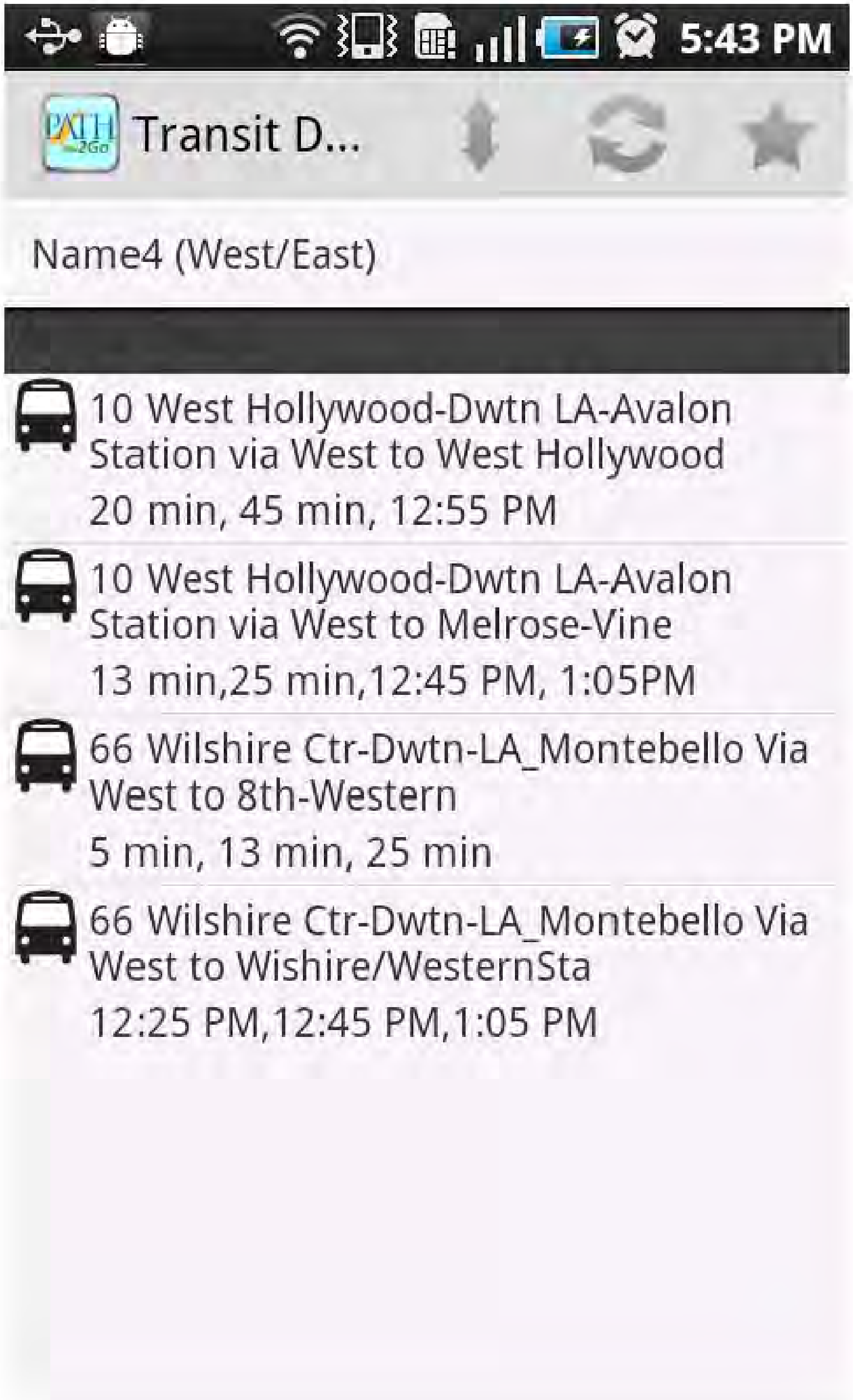
Appendix E.4 Map Screen



Appendix E.5 Trip Planning Screen

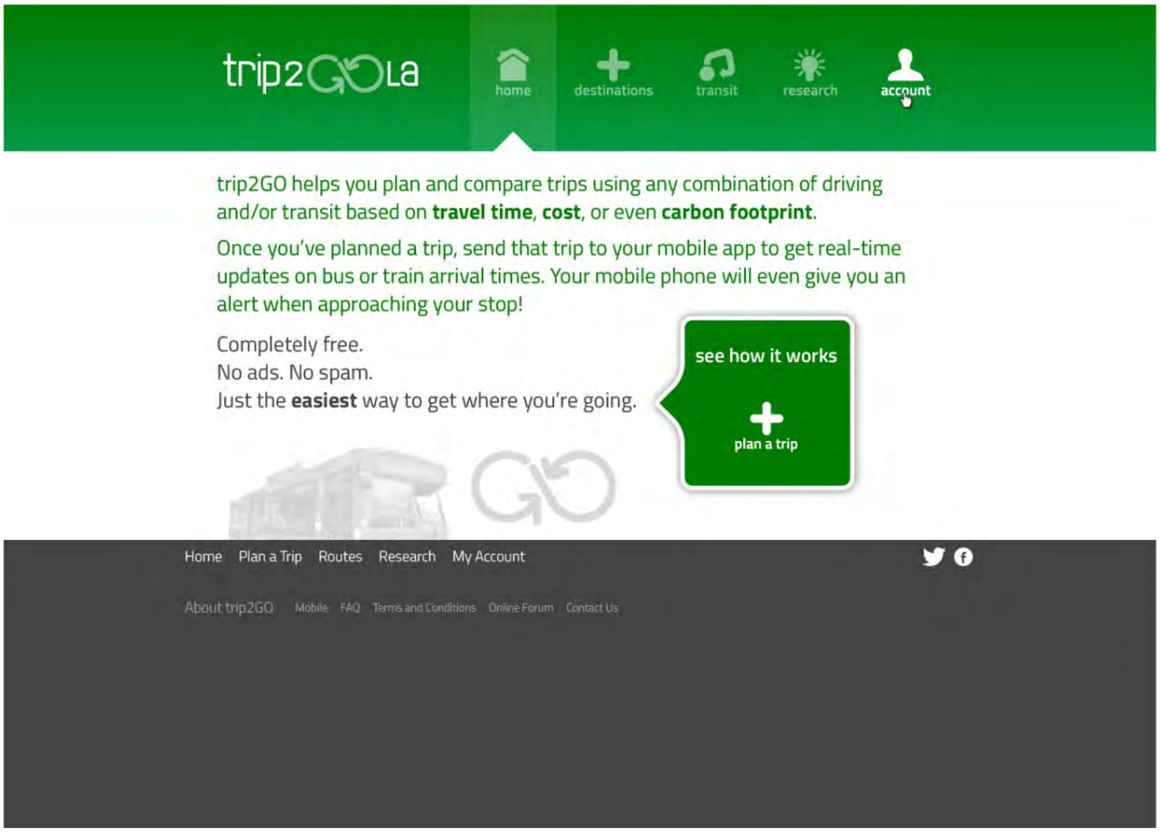


Appendix E.6 Trip Detail Screen

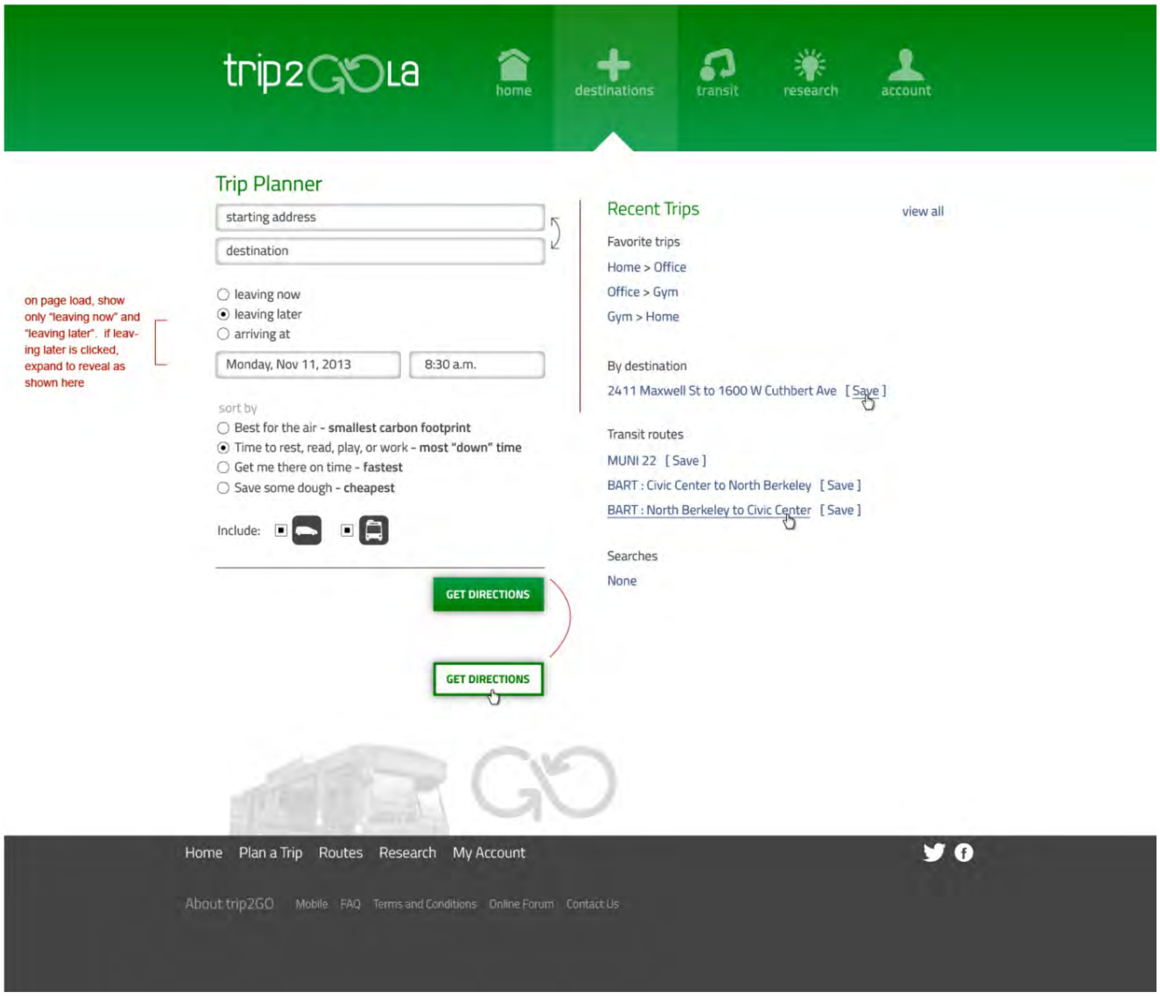


Appendix F. Website Design Mockups

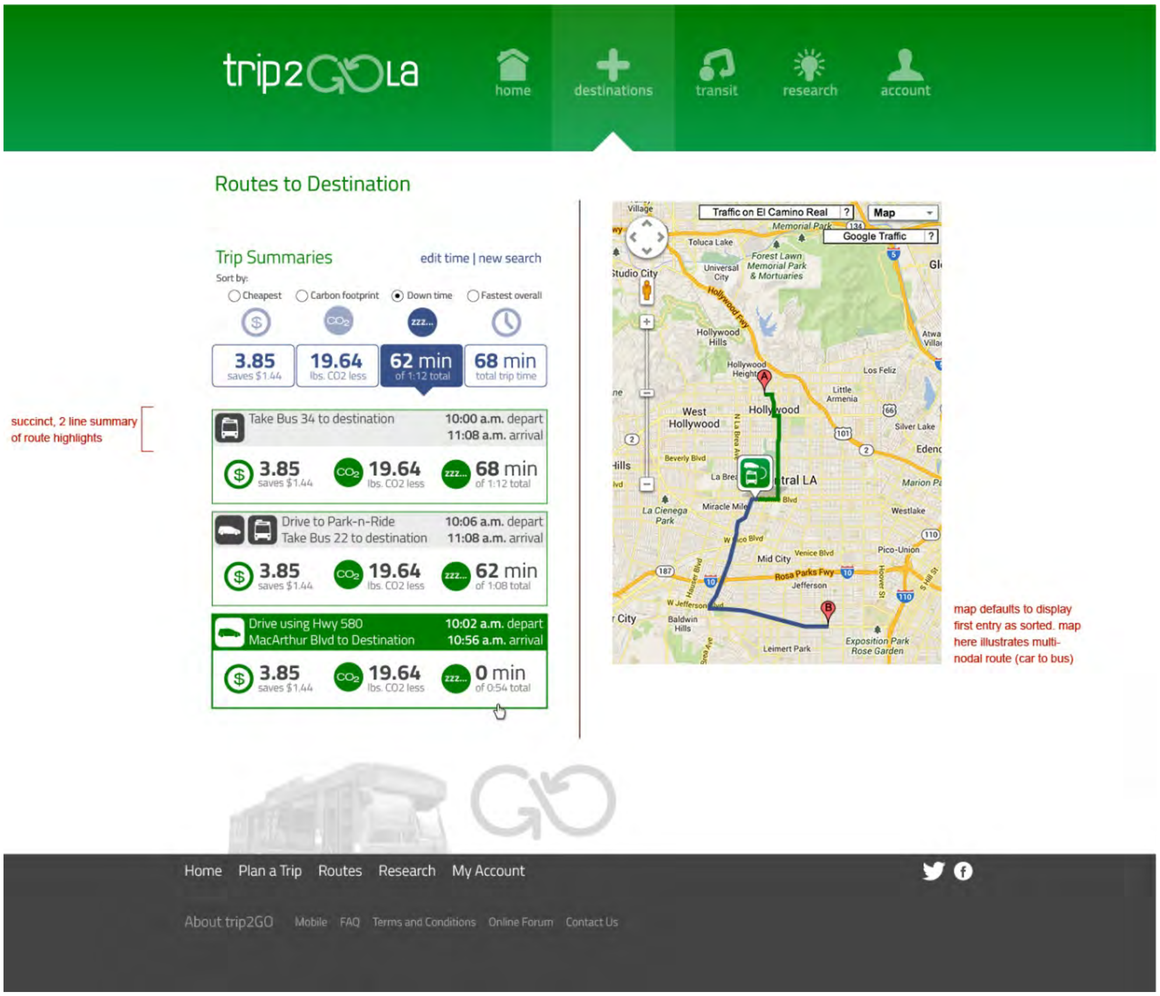
Appendix F.1 Page Home



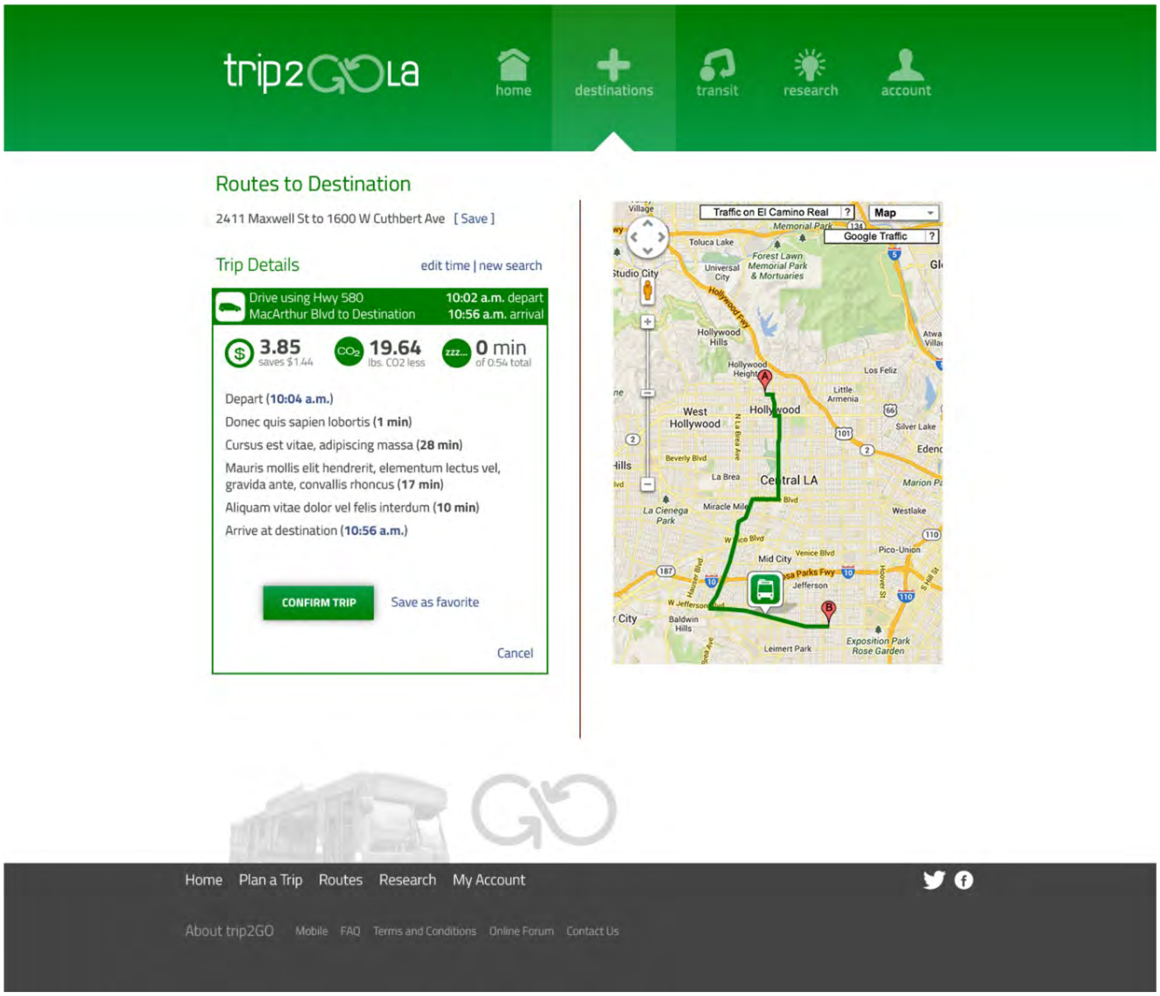
Appendix F.2 Page Trip Planning



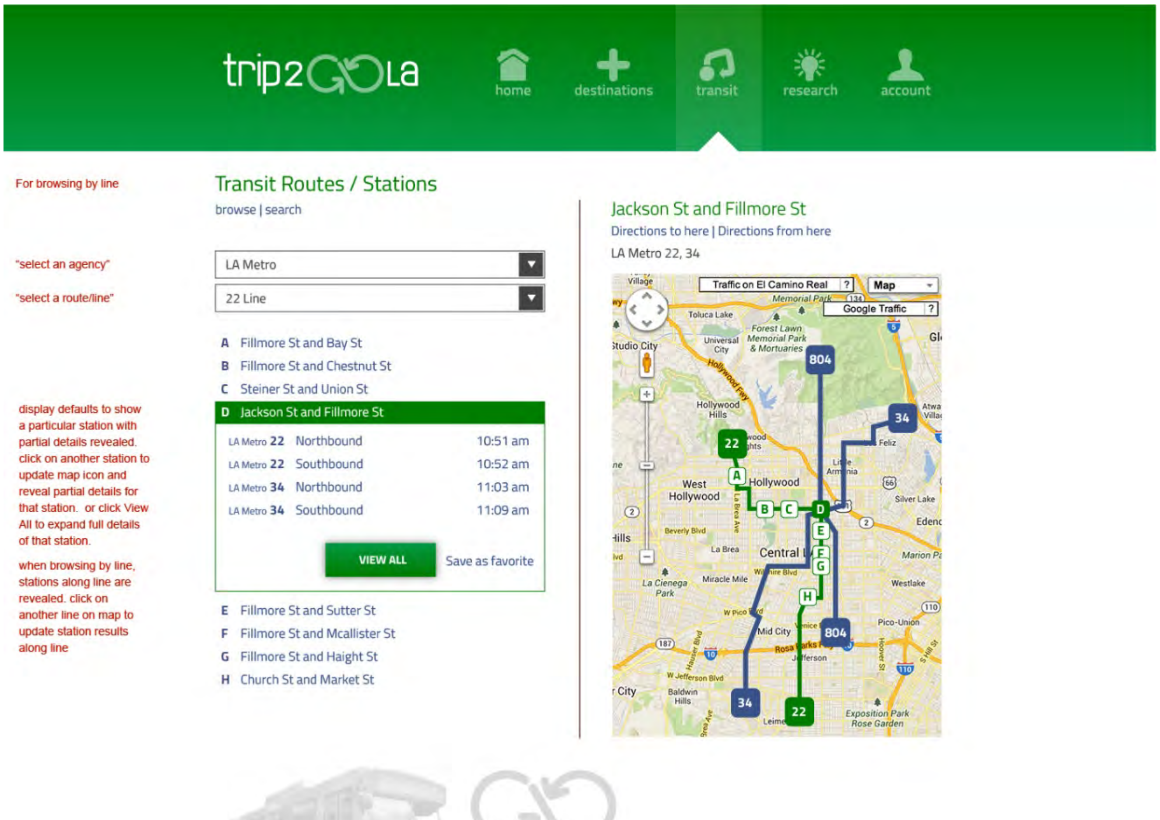
Appendix F.3 Page Trip Comparison



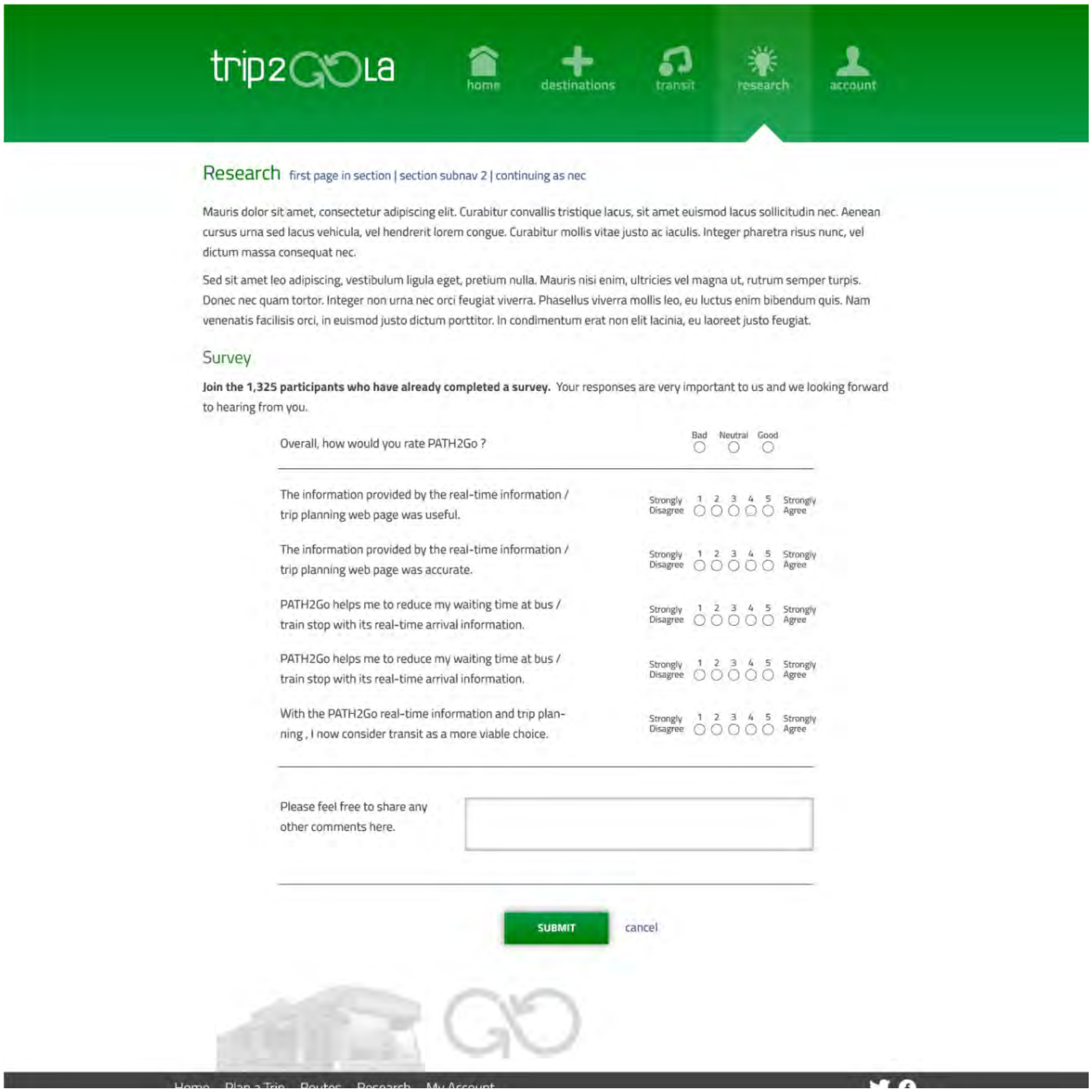
Appendix F.4 Page Trip Details



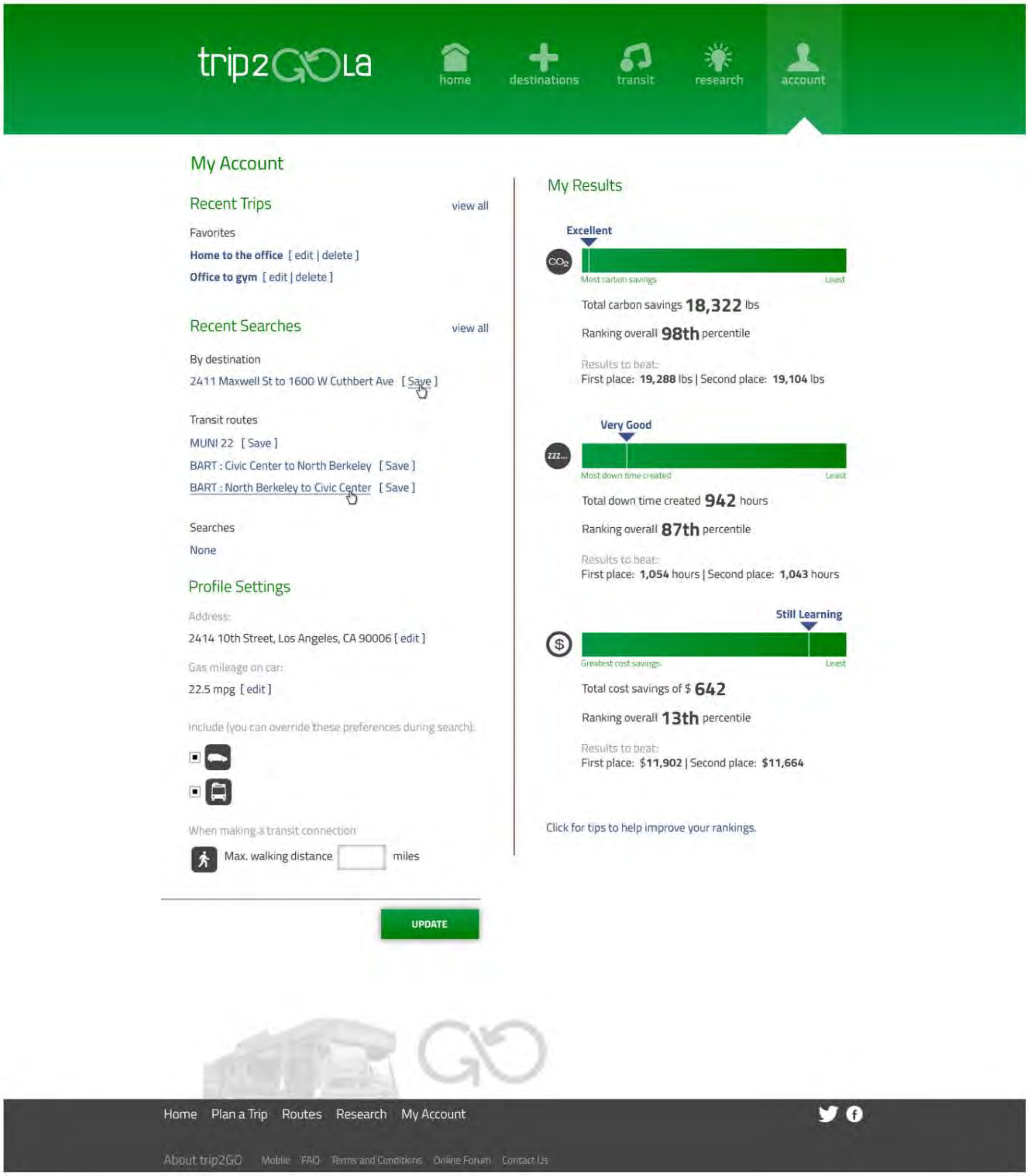
Appendix F.5 Page Transit Information



Appendix F.6 Page Survey



Appendix F.7 Page User Profile



Appendix G. API Specification for Client-Server Communication

Appendix G.1 Message Format for Client-Server Communication

Appendix G.1.1 Registration

Before using the system, the users need to register.

HTTP **POST** method.
URL: http://trip2go.org/planner/register.php

Examples:
http://trip2go.org/planner/register.php?userName=test2&userPass=mytest& firstName =Bus&email=hello@gmail.com&lastName=Tom&phone=510-665-3367&addr=Berkeley

URL Field	Type	Description
userName	String	The user name, obtained at the registration.
userPass	String	The user password.
firstName	String	The first name
lastName	String	The last name
email	String	The email address
phone	String	(**optional**) the phone number
addr	String	(**optional**) the address

The returned XML is like:

```
<root>
    <status>0</status>
</root>
```

Note that the detailed information about the status can be found in Appendix G.4. It is necessary to check if the user name is duplicated, or one or some of mandatory fields are missing.

Appendix G.1.2 User Login and Authentication

The communication with the transit server is secured by authentication. The initial connection will be the client calling getUserID service, which gets the UserID, and at the same time, confirms that the connection between client and server is good and the username password pair is correct.

HTTP **POST** method.
URL: http://trip2go.org/planner/getUID.php

Examples:

http://trip2go.org/planner/getUID.php?userName=test&userPass=mytest

URL Field	Type	Description
userName	String	The user name, obtained at the registration.
userPass	String	The user password.

The returned XML:

The successful login with status 0.

<root>
<status>0</status>
<uID>1</uID>
</root>

The unsuccessful login with status 0.

<root>
<status>-8</status>
<uID>-1</uID>
</root>

Note that the detailed information about the status can be found in Appendix G.4. If the status is not zero, uID is meaningless.

It is necessary to check if the user name or password is wrong, or one or some of mandatory fields are missing.

Appendix G.1.3 Server Interface to get Nearby Stops by GPS Location

HTTP GET method.
URL:
http://planner.trip2go.org:6060/planner/getNearbyStops.php?uID=101&lat=34.179703&lon=-118.3047565
http://planner.trip2go.org:6060/planner/getNearbyStops.php?uID=101&lat=34.179703&lon=-118.304756&agencyID=100&route=94&limit=5

URL Field	Type	Description
uID	int	The user ID obtained by getUserID
lat	double	GPS Latitude
lon	double	GPS Longitude
limit	Int	Number of stops to return (**optional**, default value is 4)
agencyID	int	The transit agency ID (**optional**)
route	String	Indicating which route the user has chosen (**optional. If specified, it must be specified with agencyID**)

Returned is a list of nearby stop ids no more than the given limit.
XML:

```xml
<root>
  <stop>
    <agencyID>100</agencyID>
    <stopID>10241</stopID>
    <distInMeter>0</distInMeter>
  </stop>
  <stop>
    <agencyID>100</agencyID>
    <stopID>4645</stopID>
    <distInMeter>146.75268528993</distInMeter>
  </stop>
  <stop>
    <agencyID>100</agencyID>
    <stopID>5455</stopID>
    <distInMeter>162.67036483387</distInMeter>
  </stop>
  <stop>
    <agencyID>100</agencyID>
    <stopID>13548</stopID>
    <distInMeter>187.5689026344</distInMeter>
  </stop>
  <stop>
    <agencyID>100</agencyID>
    <stopID>13547</stopID>
    <distInMeter>234.66903474039</distInMeter>
  </stop>
</root>
```


Note that the "distInMeter" field is the distance from that bus stop to the lat/lon in meters.

Appendix G.1.4 Server Interface to get a list of estimated arrivals at a transit stop

HTTP GET method.
URL:
http://trip2go.org/planner/getListETAInfo.php?uID=101&agencyID=100&stopIDs=4565
http://trip2go.org/planner/getListETAInfo.php?uID=101&agencyID=100&stopIDs=4565,5455
http://trip2go.org/planner/getListETAInfo.php?uID=101&agencyID=100&stopIDs=4565,5455&route=94

URL Field	Type	Description
uID	int	The user ID obtained by getUserID
agencyID	Integer	The id of the agency (a full list of agencies are available at sysconfigfull.xml file on the server).
stopIDs	Integer	the id(s) of the stop. When ETA at more than one stop is needed, append the extra stop ids with comma, e.g., 100, 308
route	String	(**optional**): if given, only the arrivals of particular route at that bus stop will be returned

Sample XML file
(http://trip2go.org/planner/getListETAInfo.php?uID=101&agencyID=100&stopIDs=4565)


```xml
<root>
  <etainfo>
    <agencyID>100</agencyID>
    <route>152/353</route>
    <dir>152 N. Hollywood Station</dir>
    <stopID>4565</stopID>
    <etas>2:22 PM|0|0</etas>
    <etas>2:33 PM|0|0</etas>
    <etas>2:58 PM|0|0</etas>
    <etas>3:10 PM|0|0</etas>
    <etas>3:23 PM|0|0</etas>
  </etainfo>
</root>
```


Sample XML file
(http://trip2go.org/planner/getListETAInfo.php?uID=101&agencyID=100&stopIDs=4565,5455)


```xml
<root>
  <etainfo>
    <agencyID>100</agencyID>
    <route>152/353</route>
    <dir>152 N. Hollywood Station</dir>
    <stopID>4565</stopID>
    <etas>2:22 PM|0|0</etas>
    <etas>2:33 PM|0|0</etas>
    <etas>2:58 PM|0|0</etas>
    <etas>3:10 PM|0|0</etas>
    <etas>3:23 PM|0|0</etas>
  </etainfo>
  <etainfo>
    <agencyID>100</agencyID>
    <route>94</route>
    <dir>94 Sun Valley</dir>
    <stopID>5455</stopID>
    <etas>2:41 PM|0|0</etas>
    <etas>3:12 PM|0|0</etas>
    <etas>3:42 PM|0|0</etas>
    <etas>4:12 PM|0|0</etas>
    <etas>4:36 PM|0|0</etas>
  </etainfo>
</root>
```


Note that the arrival time with a **leading star "*"** indicates that it is real-time data, and should be displayed on the client with different color / bold face, etc.

Appendix G.1.5 Server Interface to check whether there is an Active Trip for a Particular User

The goal is that the client can go directly to the alert page w/o planning the trip. If so, return the trip ID.

HTTP GET method.
URL: http://trip2go.org/planner/checkActiveTrips.php?uID=101

URL Field	Type	Description
uID	int	The user ID obtained by getUserID

Sample XML file

<root>
<tripID>101_2013-07-30_13:02:46_1_0</tripID>
</root>

Appendix G.1.6 Server Interface to obtain the details of an active trip

HTTP GET method.
URL:
http://trip2go.org/planner/checkTripInfo.php?uID=101&tripID=101_2013-07-30_13:02:46_1_0

The inputs include the user ID and trip ID. The trip ID can be obtained by checkActiveTrips.php.

URL Field	Type	Description
uID	int	The user ID obtained by getUserID
tripID	String	The trip ID, e.g., obtained from checkActiveTrips.php

Sample XML file
The output has the same format for the trip planning results. Please see Appendix G.2 in this document.

Appendix G.1.7 Server Interface to obtain the favorite trips

HTTP GET method.
URL: http://trip2go.org/planner/getFavoriteTrips.php?uID=101

URL Field	Type	Description
uID	int	The user ID obtained by getUserID

Sample XML file

<root>
<trip>
<name>Home To Home</name>
<orgAddr>Berkeley, CA</orgAddr>

```
     <orgLat>37.8713085</ orgLat>
    <orgLon>-122.286271</ orgLon>
     <destAddr>El Cerrito, CA</destAddr>
     <destLat>37.9713085</ destLat>
    <destLon>-122.586271</destLon>
     <mode>1</mode>
     <depTime>14:35</ depTime >

    <day>0111110</day>
  </trip>
  <trip>
     <name>Work to Home</name>
     <orgAddr> A-100-2005</orgAddr>
     <orgLat>37.8713085</ orgLat>
    <orgLon>-122.286271</ orgLon>
     <destAddr> A-100-186</destAddr>
     <destLat>37.9713085</ destLat>
    <destLon>-122.586271</destLon>
     <mode>1</mode>
    <day>0111111</day>
  </trip>
</root>
```


Note that depTime is NOT displayed if it was not provided in addFavoriteTrips. Please see add favorite trip for more details.

Appendix G.1.8 Server Interface to confirm a trip

After the user has selected a trip from the list of trip planning results, the client needs to confirm the trip to the transit server using the following web service:

HTTP GET method.
URL:
http://trip2go.org/planner/confirmTrip.php?uID=101&tripID=101_2013-07-29_13:01:46_1_0

URL Field	Type	Description
uID	int	The user ID obtained by getUserID
tripID	String	The trip ID, e.g., obtained from checkActiveTrips.php

Sample XML file


```
<root>
   <status>-5</status>
</root>
```


The details on the status can be found in section 2.

It is necessary to check if one or some of mandatory fields are missing.

Appendix G.1.9 Server Interface to cancel a trip

The user can cancel a trip if a trip ID is known.

HTTP GET method.
URL:
http://trip2go.org/planner/cancelTrip.php?uID=101&tripID=101_2013-07-29_13:01:46_1_0

URL Field	Type	Description
uID	int	The user ID obtained by getUserID
tripID	String	The trip ID, e.g., obtained from checkActiveTrips.php

Sample XML file

<root>
<status>-2</status>
</root>

Appendix G.1.10 Server Interface to add a favorite trip

The user can add a favorite trip.

HTTP GET method.
URL:
http://trip2go.org/planner/addFavoriteTrip.php?uID=101&name=Work2Home&orgAddr=Cerrito&destAddr=Berkeley&mode=1&orgLat=37.8713085&orgLon=-122.286271&destLat=37.9713085&destLon=-122.586271&day=0111001

URL Field	Type	Description
uID	int	The user ID obtained by getUserID
name	String	The name of a favorite trip. The name should be **unique** among the favorite trips.
orgAddr	String	The address of the origin. In the transit planning, it is possible that starting stops and ending stops are used instead of an address. In such case, orgAddr will store the information about the agency and stops as in **OS in the trip planning API**, for example OrgAddr=A-100-2005-7864- A-2-2010.
orgLat	double	The latitude of the origin
orgLon	double	The longitude of the origin
destAddr	String	The address of the destination. The format is similar to orgAddr. It is possible to store **DS** in the trip planning API.
destLat	double	The latitude of the destination
destLon	double	The longitude of the destination

mode	int	The travel mode: driving only, transit only, parking and ride
depTime	String	The departure time. For example, 11:27. This is **optional.**
day	String	The days of a week in the format of a string (Sunday Monday Tuesday Wednesday Thursday Friday Saturday). For example, 0110101 means that the service is needed on Monday, Tuesday, Thursday, and Saturday. This is **optional.** If not provided, the default string is for the weekday only, 0111110.

Note that the latitude and longitude information can be obtained from the free service provide by Google. **It is needed to obtain such information before calling this API.**

Sample XML file

<root>
<status>0</status>
</root>

The definition of the status can be found in Appendix G.4.

Appendix G.1.11 Server Interface to delete a favorite trip

The user can delete a favorite trip.

HTTP GET method.
URL:
http://trip2go.org/planner/delFavoriteTrip.php?uID=101&name=Work2Home

URL Field	Type	Description
uID	int	The user ID obtained by getUserID
name	String	The name of a favorite trip

Sample XML file

<root>
<status>0</status>
</root>

The definition of the status can be found in Appendix G.4.

Appendix G.1.12 Post Survey Results to the Server

HTTP **POST** method.
URL: http://trip2go.org/planner/makeTripFeedback.php

Example: http://trip2go.org/planner/makeTripFeedback.php?uID=101&tripID=101_2013-07-29_13:01:46_1_0&qID=1,2&aID=3_4,5&comment=Good!

URL Field	Type	Description

uID	int	The user ID obtained by getUserID
tripID	String	The trip ID, e.g., obtained from checkActiveTrips.php
qID	String	The survey question IDs, and separated by comma. For example, if there are 3 questions: A, B, C. qID is A,B,C
aID	String	The answer IDs. For the same question, the answer IDs are separated by underline if there are multiple answers. For the different question, the IDs are separated by comma. For example, the user selects 1 and 2 for question A, 3 for question B, and 1 and 4 for question C. aID is 1_2,3,1_4
comment	String	**Optional**. The comment from the user if there is any.

Note that we use **POST** method since the comment may include a large amount of data.
The survey questions and answers will be provided later and will be integrated into the program.
Sample returned XML file

```
<root>
   <status>0</status>
</root>
```

Appendix G.1.13 Get transit schedule version and update automatically

Transit static system configuration (agency, routes, stops, shapes, patterns, trips, stop_times, etc.) are stored in Sqlite DB trip2go.db. The DB should be stored locally on the phone, and download the new version (if exist) to the phone. Please see document "Trip2go Sqlite Tables.docx" for the description of DB tables.

And each time when the client starts up, it should check the server for an update of transit static configuration version.

URL: http://trip2go.org/planner/sysconfigfull_version.xml

Upon seeing a newer version on the server, the local transit system configurations need to be replaced with the updated version, which can be downloaded with the following URL.

URL: http://trip2go.org/planner/sysconfig.php

Appendix G.2 Trip Planning Service API

Appendix G.2.1 URL

The server URL is: http://planner.trip2go.org:6060/planner/Transfer.php
Append to this URL before the arguments are added.

Appendix G.2.2 Arguments

The following tables present the arguments that may be sent to the planning server. Note that (1) you may send just some of them to the planning server, depending on different situations (see details in later sections); (2) the argument name is case sensitive; and (3) the arguments are separated by &. Following arguments are **mandatory**.

Arguments Name	Description	Example
uID	an unique ID for the user. For web applications, do **NOT** set this argument.	uID=100

Mode	there are four modes:
	driving only, mode = 1;
	transit only, mode = 2;
	park and ride, mode = 3;
	all the three modes, mode = 4
		mode=2
		mode=3

dateSel	Date when users want to make a trip. The format is yyyy-mm-day.	dateSel=2013-08-05
timeSel	Time that corresponds to OD. The format is hh:mm. No need to give the seconds.	timeSel=14:07 (please use Current Time by default, allow the user to change this to another time)

The following table gives the information related to the OD addresses. There are two types: (1) destLat, destLon, orgLat, and orgLon; and (2) OS and DS. **Only one type needs to be specified, depending on different user selections.**

Type 1 inputs the latitudes and longitudes, as seen below. The geo-coding is complete in the client side; and the server does not need to conduct the geo-coding. Note that Google has limitations on each IP. Thus, there are upper bounds on total numbers of geo-coding in 24 hours and in an hour.

destLat	The latitude of the destination.	destLat= 37.759603537729
destLon	The longitude of the destination.	destLon= -122.42435280666
orgLat	The latitude of the origin.	orgLat= 37.310784567034
orgLon	The longitude of the origin.	orgLon=-121.88838429655

Type 2 inputs the starting and ending stop IDs rather than latitude and longitude information.

OS	A flag that indicates the origin agencies and stop IDs. 1: Agency starts with A- 2: Using hyphen to separate the stop IDs if there are more than one stop related to a stop name.	**Example 1:** 1 stop name with two stop IDs Agency is 100; two IDs are 2005 and 7864. OS=A-100-2005-7864 **Example 2**: 1 stop name with one

	3: It is possible to have more than one stops to submit. In such situation, use hyphen to connect them.	stop ID Agency is 2; ID is 2010 OS=A-2-2010 **Example 3:** Two stop names, combining examples 100 and 2 OS=A-100-2005-7864- A-2-2010
DS	Similar to OS. But it is for the destination	**Example 1:** 1 stop name with two stop IDs Agency is 100; two IDs are 2005 and 7864. DS=A-100-2005-7864 **Example 2**: 1 stop name with one stop ID Agency is 2; ID is 2010 DS=A-2-2010 **Example 3:** Two stop names, combining examples 100 and 2 DS=A-100-2005-7864- A-2-2010

Appendix G.2.3 Simple checking at the client side

Our applications are in the Los Angeles Area. If a user inputs the address in a remote area, say Florida, the client side should be able to check it and simply return a warning message. This can be simply done using a box model, where the minimum and maximum values of latitude and longitude of the LA area can be obtained from Google Map.

Appendix G.2.4 URL Examples

Using lat/long:
http://planner.trip2go.org:6060/planner/Transfer.php?uID=100&mode=4&dateSel=2013-08-23&timeSel=5:58:00&destLat=34.055729&destLon=-118.181145&orgLat=34.057182&orgLon=-118.349243

Using stop IDs:
http://planner.trip2go.org:6060/planner/Transfer.php?uID=100&mode=2&dateSel=2013-03-16&timeSel=14:24&OS=A-100-7861&DS=A-100-714

Appendix G.2.5 Output XML Format

If something is wrong, status is not 0. For example,
<root>
<status> 10 <\status>
</root>

Overall Trip Information

This record includes the summary of information, including

key	description
tripID	we use tripID to identify the different trips.

	tripID is a string, which consists of user ID, date, time, mode and an extra number. It is likely that our multi-modal trip planner generates more than one trip for customers.
mode	travel mode
cost	total trip cost in USD.
transitCost	transit cost in USD.
parkingCost	parking cost in USD.
duration	trip duration in minutes
startTime	starting time of the trip
endTime	ending time of the trip
drivingDist	(1) with the driving-only mode, the distance from origin to destination in meters; (2) If the transit is involved, the distance from origin to the first stop/parking lot.
walkingDist	(1) with the driving-only mode, that is 0; (2) if the transit is involved, it is the distance from last stop to the destination
ems	CO2 emissions in kg

For example,

```
    <trip tripID="100_2013-09-
25_14:58:15_2_0" mode="2" cost="3.00" transitCost="3.00" parkingCost="0.00"
ems="0.00" drivingDist="19" walkingDist="26" duration="63" startTime="5:59"
endTime="7:03">
```

Segment Information

Each trip is decomposed into several subtrips, referred to as *segment*. For example, the first segment is to take the train; the second segment is to walk to the bus station for bus 390; and the third segment is to take the bus 390. The transfer process is part of walking.

This record includes the information for each segment of a trip, including

key	description
segID	segment ID, an integer.
segType	segment type and is used for distinguishing driving, walking and taking transit. Walking is 1, driving is 2, and transit is 3. The transfer process is part of walking.
startNodeID	the intersection ID if driving only; the transit station ID if transit. It is a negative number if no information is available, for example when transfer.

startTime	starting time of the segment
startLat	latitude of the starting stop (with the transit) or node (driving or walking)
startLon	longitude of the starting stop (with the transit) or node (driving or walking)
endNodeID	
endTime	
endLat	
endLon	Similar to the counterpart for the starting point
agencyID	represent the agency that owns the transit route. No this key if SegType is not equal to 3.
routeName	the route direction. No this key if SegType is not equal to 3.
routeDir	the route direction. No this key if SegType is not equal to 3.
run	the run for the transit trip. No this key if SegType is not equal to 3.
startSeq	the sequence of starting stop in the run, corresponding to StartNodeID. No this key if SegType is not equal to 3.
endSeq	the sequence of ending stop in the turn, corresponding to EndNodeID. No this key if SegType is not equal to 3.

An example:

```
&lt;segment segID="1" segType="3" startTime="6:00" endTime="6:26" startLat="34.0
57182" startLon="-118.349243" endLat="34.042995" endLon="-
118.260818" agencyID="100" routeName="28
East"routeDir="0" run="4" startNodeID="7861" endNodeID="5368" startSeq="7" en
dSeq="39">
```

Latitude and Longitude Information under the Segment Level

This record includes latitude and longitude that are associated with a segment of a trip. For the trip involving transit, the starting stop, the alighting stop and the stops in between (and in the future the shape points will also be included) are listed in natural order.

```
<point lat="34.057182" lon="-118.349243"/>
<point lat="34.057117" lon="-118.346046"/>
<point lat="34.057041" lon="-118.342690"/>
<point lat="34.056957" lon="-118.340187"/>
<point lat="34.056885" lon="-118.336288"/>
<point lat="34.056759" lon="-118.333580"/>
<point lat="34.056171" lon="-118.331566"/>
<point lat="34.055103" lon="-118.327713"/>
<point lat="34.054901" lon="-118.325890"/>
<point lat="34.054367" lon="-118.322525"/>
<point lat="34.053791" lon="-118.320923"/>
<point lat="34.053020" lon="-118.318810"/>
<point lat="34.052441" lon="-118.314629"/>
```

Note that a complete example can be seen in the Appendix.

Appendix G.3 En-route update/alert API

HTTP **POST** method.
URL:
http://trip2go.org/dpiVII/postGPSArray?uidMD5=xxxxx&pwdMD5=xxxxx&fmt=xxxxx&postfmt=xxxx

URL Field	Type	Description
uID	int	The user ID obtained by getUserID
tripID	String	The trip ID, e.g., obtained from checkActiveTrips.php
postFmt	String	in the HTTP POST body: The GPS data is in XML format. Please refer to the XSD file and sample XML file.

- Sample "XML" file of the GPS data posted to the server

Sample file :


```
< ?xml version= »1.0 » encoding= »UTF-8 » ?>
<ns0:GPSArray  xmlns:xsi='http://www.w3.org/2001/XMLSchema-instance'
  xmlns:ns0='DPI.serverEntities'
  xsi:schemaLocation='DPI.serverEntities gpsschema.xsd'>
<GPSRecords>
  <uID>101</uID>
   <tripID>101_2013-07-30_13:02:46_1_0</tripID>
      <GPSRecord index="1">
         <latitude>37.2</latitude>
         <longitude>-122.9</longitude>
         <UTCTime>2009-07-21 15:22:10</UTCTime>
         <speed>12.6</speed>
         <heading>320.7</heading>
      </GPSRecord>
      <GPSRecord index="2">
         …
      </GPSRecord>
</GPSRecords>
 </ns0:GPSArray>
```


The returned alert message:

Field	Type	Description
uID	Int	A unique ID for each user generated by the transit server.

currentTripSegmentID	Int	The current trip segment id	
tripSegmentType	int	Indicating the current status of the user: Driving or on transit	
		BUS=0	User is on bus (or waiting at bus stop / transferring)
		TRAIN = 1	User is on train (or waiting at bus stop / transferring)
		DRIVING=3	User is driving
alertID	int	The ID of the alert message, can be one of the following values:	
		ALERTID_INFO_ONLY=2001	not an alert; information only
		ALERTID_CONTROL_ONLY = 2011	The message is to be sent to the client for the sole purpose of controlling the GPS on/off or sampling period, etc. Not to be displayed to the user.
		ALERTID_TRANSIT_TIME_TO_TRANSFER =2021	Time to transfer alert: display.msg contains message title ("Time to alighting stop at ") and display.msgTime contains the time to go. This alert could be repeated.
		ALERTID_TRANSIT_YOURSTOP=2022	Your stop alert: display.msg contains message title ("your stop next in ") and display.msgTime contains the time to go.
		ALERTID_TRANSIT_VEHICLE_COMING=2023	Bus /train is coming update (informational): display.msg contains message title ("your bus /train is coming in ") and display.msgTime contains the time to go. This message could be repeated.
		ALERTID_DRIVING_ROAD_CONSTRUCTION =2031	If in the driving mode, provide the information about the potential road construction before the current location
		ALERTID_DRIVING_INCIDENT =2032	If in the driving mode, provide the information about the potential road accident before the current location
		ALERTID_DRIVING_PARKANDRIDE (ALERT) = 3001	TBD
		ALERTID_DRIVING_PARKINGAVAILABLE (INFORMATIONAL)=3002	TBD
		ALERTID_DRIVING_PARKINGLOTFULL (ALERT) = 3003	TBD
alertType	Int	A flag which can be one of the three values:	
		ALERT_NEW= 1	a new alert

		ALERT_REPEATED= 2 — a repeated alert (e.g., The subsequent update of "your bus is coming in 10 minutes", say in 9 minutes, 8 minutes, etc);
Control	**structure**	The fields which control the client behavior: This structure is valid for all messages except for ALERTID_NONE.
gpsOnOff	Int	Can be one of the two values: ON =1 — GPS should be on (client should do the test to see if the GPS is currently on, if not, turn it on, otherwise nothing need to be done). OFF = 0 — GPS should be off. When GPS is off, clients should send request to the server every clientRequestPeriod seconds, with an empty request body.
gpsSamplingPeriod	Int	Required sampling period of GPS data (in secs.) Say, 10 indicates that GPS data sampled every 10 seconds should be good enough (and therefore recommended to save communication bandwidth and reduce delay).
clientRequestPeriod	Int	Suggested client request period in seconds. Say, 30 means client does not need to request for new alert for less than 30 seconds period.
Display	Structure	The fields that controls the way the alert being displayed: (only valid when 92lerted != ALERTID_NONE and 92lerted != ALERTID_CONTROL_ONLY)
showDurationInMins	Integer	(Maximum) Number in minutes that this alert should be displayed
agencyID	Integer	The id of the agency (the id can be mapped to an agency name using the system configuration file, therefore the client can display an icon using the local icon library).
stopID	Int	The stop id (this should be combined with agency id to look up at the data configuration file for the stop address)
routeType	Integer	Indicating the type of the route (for choosing the right **icon / color**, etc) 0 — BUS 1 — TRAIN 3 — DRIVING
travelTime	Integer	Number of **seconds** to travel from **current location** to the alighting stop When msgtype = 0, it is the transit travel time from the boarding stop to alighting stop; When msgtype = 1 (on transit), it is the travel time from current location to the alighting stop;
route	String	The name of the route (long version, with route id and direction)
vehLat	Double	Latitude of the approaching vehicle This information is provided for the Google Maps visualization of the current progress of trip: The GPS location of the vehicle approaching this stop can be displayed on a map. At the same time, the GPS location of the bus stop / train stop should be available via the data configuration file (look up using the agencyid and stop id)
vehLon	Double	Longitude of the approaching vehicle
ETA	String	The next arrivals in the following format *6:30AM,6:45AM While a star before a time indicates that the ETA is real-time, and should be displayed at client differently (such as a different color, bold face, etc). For msgtype=0, this is the arrival time of next bus / train, For msgtype = 1, this is the arrival time at destination (transfer point), and will contain only one eta.
distToIncident	Double	In the driving mode, the distance to the potential incident location. The unit is meter.
incidentDesc	String	Incident description, for example "construction", "accident", etc
msgType	Integer	Indicating the type of the message 0 — Before trip or transferring 1 — Onboard a bus or driving 2 — Arrived

Sample XML out

```xml
<UserAlert>
<control>
        <gpsOnOff>1</gpsOnOff>
        <geofencing>2</geofencing>
        <gpsSamplingPeriod>10</gpsSamplingPeriod>
        <clientRequestPeriod>23</clientRequestPeriod>
</control>
<trigger>
        <dtrecorded>Mon Jun 14 11:26:34 PDT 2010</dtrecorded>
        <dtalerteffectivefromISO>2010-06-14 11:26:34</dtalerteffectivefromISO>
        <timeISO>2010-06-14 11:26:34</timeISO>
        <validlinkid>-1</validlinkid>
        <dtalerteffectiveuntil>Mon Jun 14 11:27:34 PDT 2010</dtalerteffectiveuntil>
        <constrainttype>0</constrainttype>
        <dtISO>2010-06-14</dtISO>
        <validlon>0.0</validlon>
        <dtalerteffectivefrom>Mon Jun 14 11:26:34 PDT 2010</dtalerteffectivefrom>
        <dtalerteffectiveuntilISO>2010-06-14 11:27:34</dtalerteffectiveuntilISO>
        <priority>5</priority>
        <validheading>0</validheading>
        <validrangemeters>-1</validrangemeters>
        <validlat>0.0</validlat>
</trigger>
<alerttype>2</alerttype>
<tripsegments>
        <warn/>
        <routetype>0</routetype>
        <tripsegmentid>0</tripsegmentid>
        <alighting>5644</alighting>
        <etainfos>
                <time>1276540071</time>
                <realtime>true</realtime>
                <route>71-HAIGHT-NORIEGA Inbound</route>
                <traveltime>1506</traveltime>
                <vehLon>-122.47628</vehLon>
                <vehLat>37.76548</vehLat>
                <ETA>11 :27 AM</ETA>
        </etainfos>
        <etainfos>
                <time>1276540599</time>
                <realtime>true</realtime>
                <route>71-HAIGHT-NORIEGA Inbound</route>
                <traveltime>1561</traveltime>
                <vehLon>0.0</vehLon>
                <vehLat>0.0</vehLat>
                <ETA>11:36 AM</ETA>
```

</etainfos>
<htmlmsg/>
<agencyid>5</agencyid>
<msgtype>0</msgtype>
<boarding>4720</boarding>
</tripsegments>
<tripsegments>
<warn>Next Train at 11:30 AM will NOT stop at your stop</warn>
<routetype>1</routetype>
<tripsegmentid>1</tripsegmentid>
<alighting>13</alighting>
<etainfos>
<time>1276542540</time>
<realtime>false</realtime>
<route>Fremont – Daly City</route>
<traveltime>900</traveltime>
<vehLon>0.0</vehLon>
<vehLat>0.0</vehLat>
<ETA>12 :09 PM</ETA>
</etainfos>
<htmlmsg/>
<agencyid>2002</agencyid>
<msgtype>0</msgtype>
<boarding>33</boarding>
</tripsegments>
<tripsegments>
<warn/>
<routetype>0</routetype>
<tripsegmentid>2</tripsegmentid>
<alighting>3051</alighting>
–
<etainfos>
<time>1276544400</time>
<realtime>false</realtime>
<route>390 South</route>
<traveltime>2880</traveltime>
<vehLon>0.0</vehLon>
<vehLat>0.0</vehLat>
<ETA>12 :40 PM</ETA>
</etainfos>
<etainfos>
<time>1276546200</time>
<realtime>false</realtime>
<route>390 South</route>
<traveltime>2880</traveltime>
<vehLon>0.0</vehLon>

```
                <vehLat>0.0</vehLat>
                <ETA>1 :10 PM</ETA>
            </etainfos>
            <htmlmsg/>
            <agencyid>1</agencyid>
            <msgtype>0</msgtype>
            <boarding>595</boarding>
        </tripsegments>
            <userid>1768532026</userid>
            <numbersegments>3</numbersegments>
        <display>
            <msgNumber/>
            <URLAudio/>
            <baudiblealert>true</baudiblealert>
            <userLongitude>-122.030731</userLongitude>
            <allowmultiplealert>false</allowmultiplealert>
            <showdurationInmins>1</showdurationInmins>
            <agencyIcon/>
            <msg/>
            <URLImage/>
            <userLatitude>37.331689</userLatitude>
        </display>
        <tripid>7</tripid>
        <alerttypestr>Repeated alert</alerttypestr>
        <constraintstr>Time based</constraintstr>
        <95lerted>1009</95lerted>
        <currenttripsegmentid>0</currenttripsegmentid>
        <alertidstr>Bus / Train Coming Alert</alertidstr>
        <alertAvailable>true</alertAvailable>
        <tripsegmenttype>0</tripsegmenttype>
        </UserAlert>
```


Appendix G.4 Error Message

For the HTTP POST / GET methods, the server might encounter an error during the processing, to include:

(1) Authentication error: most of the APIs requires uidMD5 and pwdMD5, the authentication is applied for each call, and whenever failed, an error message will be given;
(2) Database query / persistence error;
(3) Invalid data error, etc.

Whenever an error happens, an error message will be returned regardless of what message the HTTP GET or POST is expecting.


```
<root>
  <status>-1</status >
</root>
```

The error codes include:

Error Code	Explanation
0	successful
-1	Inputs are wrong
-2	No such user ID or trip ID
-3	Server authentication failed
-4	Service unavailable
-5	Wrong trip status. This can happen at confirmTrip. For example, if a user attempts to confirm trip that is not in the state of UNCONFIMRED, return this error.
-6	Duplicated user name. Happens in the registration.
-7	No such user name. Happens in get user ID.
-8	Wrong password. Happens in get user ID.
-9	Request mode is wrong
-10	Latitude and longitude are beyond the LA region
-100	Other errors

Appendix G.5 An Example of the planning input and output

Inputs: http://planner.trip2go.org:6060/planner/Transfer.php?uID=100&mode=4&dateSel=2013-08-23&timeSel=5:58:00&destLat=34.055729&destLon=-118.181145&orgLat=34.057182&orgLon=-118.349243

Outputs:

This XML file does not appear to have any style information associated with it. The document tree is shown below.

<root>
<status>0</status>
<trip tripID="100_2013-09-25_14:58:15_2_0" mode="2" cost="3.00" transitCost="3.00" parkingCost="0.00" ems="0.00" drivingDist="19" walkingDist="26" duration="63" startTime="5:59" endTime="7:03">
<segment segID="0" segType="1" startTime="5:59" endTime="5:59" startLat="34.057301" startLon="-118.349083" endLat="34.057182" endLon="-118.349243" startNodeID="0" endNodeID="0">
<point lat="34.057301" lon="-118.349083"/>
</segment>
<segment segID="1" segType="3" startTime="6:00" endTime="6:26" startLat="34.057182" startLon="-118.349243" endLat="34.042995" endLon="-118.260818" agencyID="100" routeName="28 East" routeDir="0" run="4" startNodeID="7861" endNodeID="5368" startSeq="7" endSeq="39">
<point lat="34.057182" lon="-118.349243"/>
<point lat="34.057117" lon="-118.346046"/>
<point lat="34.057041" lon="-118.342690"/>
<point lat="34.056957" lon="-118.340187"/>
<point lat="34.056885" lon="-118.336288"/>
<point lat="34.056759" lon="-118.333580"/>
<point lat="34.056171" lon="-118.331566"/>
<point lat="34.055103" lon="-118.327713"/>
<point lat="34.054901" lon="-118.325890"/>
<point lat="34.054367" lon="-118.322525"/>
<point lat="34.053791" lon="-118.320923"/>
<point lat="34.053020" lon="-118.318810"/>
<point lat="34.052441" lon="-118.314629"/>
<point lat="34.052521" lon="-118.311310"/>
<point lat="34.052517" lon="-118.308800"/>
<point lat="34.052486" lon="-118.306488"/>
<point lat="34.052490" lon="-118.304321"/>
<point lat="34.052505" lon="-118.299744"/>
<point lat="34.052513" lon="-118.298050"/>
<point lat="34.052528" lon="-118.294907"/>
<point lat="34.052364" lon="-118.291405"/>
<point lat="34.052296" lon="-118.287872"/>
<point lat="34.052299" lon="-118.284363"/>

<point lat="34.051521" lon="-118.279686"/>
<point lat="34.050198" lon="-118.276741"/>
<point lat="34.048996" lon="-118.274048"/>
<point lat="34.048351" lon="-118.272606"/>
<point lat="34.047302" lon="-118.270302"/>
<point lat="34.045883" lon="-118.267151"/>
<point lat="34.044922" lon="-118.264183"/>
<point lat="34.044357" lon="-118.263008"/>
<point lat="34.043678" lon="-118.261932"/>
<point lat="34.042995" lon="-118.260818"/>
</segment>
<segment segID="2" segType="1" startTime="6:26" endTime="6:31" startLat="34.042995" startLon="-118.260818" endLat="34.039600" endLon="-118.261917" startNodeID="-1" endNodeID="-1">
</segment>
<segment segID="3" segType="3" startTime="6:34" endTime="7:03" startLat="34.039600" startLon="-118.261917" endLat="34.055729" endLon="-118.181145" agencyID="100" routeName="70 East" routeDir="0" run="8" startNodeID="5371" endNodeID="714" startSeq="6" endSeq="33">
<point lat="34.039600" lon="-118.261917"/>
<point lat="34.042133" lon="-118.259552"/>
<point lat="34.045010" lon="-118.256882"/>
<point lat="34.046772" lon="-118.255264"/>
<point lat="34.049313" lon="-118.252899"/>
<point lat="34.053043" lon="-118.249359"/>
<point lat="34.054054" lon="-118.248413"/>
<point lat="34.054417" lon="-118.246956"/>
<point lat="34.054699" lon="-118.242706"/>
<point lat="34.057507" lon="-118.240082"/>
<point lat="34.057842" lon="-118.236633"/>
<point lat="34.056568" lon="-118.232193"/>
<point lat="34.056107" lon="-118.230598"/>
<point lat="34.054466" lon="-118.225090"/>
<point lat="34.055256" lon="-118.223228"/>
<point lat="34.056419" lon="-118.220337"/>
<point lat="34.058804" lon="-118.216415"/>
<point lat="34.060326" lon="-118.214310"/>
<point lat="34.057583" lon="-118.209930"/>
<point lat="34.056252" lon="-118.206871"/>
<point lat="34.055408" lon="-118.204933"/>
<point lat="34.054405" lon="-118.202530"/>
<point lat="34.054268" lon="-118.200882"/>
<point lat="34.054497" lon="-118.197937"/>
<point lat="34.054413" lon="-118.195107"/>
<point lat="34.054874" lon="-118.188499"/>
<point lat="34.055367" lon="-118.183395"/>

<point lat="34.055729" lon="-118.181145"/>
</segment>
<segment segID="4" segType="1" startTime="7:03" endTime="7:03" startLat="34.055729" startLon="-118.181145" endLat="34.055771" endLon="-118.180862" startNodeID="-1" endNodeID="-1">
<point lat="34.055771" lon="-118.180862"/>
</segment>
</trip>
</root>