STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT DOCUMENTATION PAGE

TR0003 (REV. 10/98)

1. REPORT NUMBER	2. GOVERNMENT ASSOCIATION NUMBER	3. RECIPIENT'S CATALOG NUMBER
CA15-2461		

4. TITLE AND SUBTITLE	5. REPORT DATE
Field Operational Test of Tools for Facilitating Smart Travel Choices Through Real-Time Information	November 30, 2015
	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Kun Zhou, Yanqiao Wang, Jingquan Li, Marty Wachs, Joan Walker, Huadong Meng, Jason Friedman and Wei-Bin Zhang	UCB-ITS-PRR-2016-06

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. WORK UNIT NUMBER
California PATH Program, University of California at Berkeley 1357 46th St., Richmond, CA 94804	
	11. CONTRACT OR GRANT NUMBER

12. SPONSORING AGENCY AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
California Department of Transportation Division of Research and Innovation P.O. Box 942873, MS 83 Sacramento, CA 94273-0001	
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTAL NOTES

16. ABSTRACT

This report documents an effort to assess whether integrated multimodal real-time traveler information can encourage travelers to consider transit as a more viable choice. Under the sponsorship of the California Department of Transportation and in partnership with the Los Angeles Metropolitan Transportation Authority, California PATH developed and field tested Trip2go -- a suite of web-based and mobile-phone-based applications incorporating real-time transit and highway condition information. Both objective and surveys were collected to support statistical and modeling analyses to evaluate the effectiveness of real-time information in making choice decisions. The evaluation results show that travelers can be influenced by real-time travel information for both mode and time shifts, particularly for no-commuter trips. The mode and time shifts can potentially relieve traffic congestion, reduce fuel consumption and lower tailpipe emissions.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Real-time traveler information, congestion management, mode choice and shift	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. SECURITY CLASSIFICATION (of this report)	20. NUMBER OF PAGES	21. PRICE
Unclassified	112	

Reproduction of completed page authorized

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Field Operational Test of Tools for Facilitating Smart Travel Choices Through Real-Time Information

Draft Final Report

Kun Zhou, Yanqiao Wang, Jingquan Li, Marty Wachs, Joan Walker, Huadong Meng, Jason Friedman and Wei-Bin Zhang

California PATH Program,

Institute of Transportation Studies, University of California at Berkeley

Department of Urban Planning, University of California at Los Angeles

V2.0 November 30, 2015

Executive Summary

This study has shown that mode shift by commuters can potentially help relieve traffic congestion, reduce fuel consumption, lower tailpipe emission, as well as enable travelers to make the trip less stressful and more productive or pleasurable. Real-time multimodal travel information, when presented in an integrated and timely manner, may influence commuters' travel decisions. The goal of the Smart Travel Choice (STC) project is to investigate approaches to encourage and enable travelers to make choice decisions to select a mode or the time of commute in order to avoid peak-hour travel, which subsequently would help to reduce traffic congestion, energy use and emissions, by reducing the number of single occupancy vehicles on highways.

To achieve the project objectives, the project team has worked with the project sponsor, the California Department of Transportation (Caltrans), to analyze potential field operational sites and have selected the metropolitan Los Angeles area because of the larger community of travelers, the availability of parallel transportation networks and the feasibility of measuring the effectiveness of how integrated multimodal traveler information may affect travelers' perception of transit service and encourage mode shift. The selected project test site includes freeway, arterials, transit routes served by the Los Angeles County Metropolitan Transportation Authority (MTA) and a couple of neighboring transit agencies and parking facilities in LA County. The initial planning study also developed both subjective and objective Measures of Effectiveness (MOEs) for evaluation, ranging from the evaluation of the performance of the provided information service to the users' perception of usability and the potential influence of traveler information for change of travel behavior.

The project team developed and implemented 'Trip2Go' – a multimodal traveler information system for the Los Angeles region. Trip2Go integrates a suite of mobile-phone-based and web-based applications to provide travelers with real-time, multimodal traveler information. The Trip2go planner allows travelers to plan and compare trips using any combination of driving and/or transit based on travel time, costs, and the carbon footprint. Trips can be planned on either web or phone based Trip2go app and enable travelers to receive real-time en-route updates and alerts on bus or train arrival times and incident alerts on driving routes using users' mobile app. The mobile phone application gives travelers an alert when approaching their stop. An important feature of the Trip2go app is the data logging capability that is able to archive the trip searching activities by the users, the traffic and transit conditions when trip plans are made, and the GPS trajectory information of the travelers throughout their trips. The trip planning features were compared with other trip planners and results were determined to be comparable. The project team conducted thorough field testing to evaluate the accuracy of the arrival predictions for MTA buses and to debug the Trip2go features until the performance was considered acceptable by the team members.

With support of LACMTA and other stakeholder agencies in LA County, the project team conducted four rounds of recruitment for a field operational test (FOT) of Trip2go between February 2015 and September 2015, a total of three hundred sixteen people signed up to volunteer for the field test. The survey results show that the majority of the volunteers were recruited through LA Metro Blogs. Using predetermined selection criteria, eighty-three

volunteers were qualified for the Trip2go field test. Among these volunteers, sixty-five travelers participated in the entry survey and were invited to participate in the FOT. Thirty-seven users finished at least one daily survey. Eighteen volunteers completed at least ten trips. Among all participants, one thousand one hundred thirty five full trip activities were recorded. Additionally, Trip2go was used three hundred thirty four times for trip advisory purposes. As some users may make trip plans and then follow their plans without keeping Trip2go active, we deem some of the planned trips real trips as well. Throughout the field operational tests, high quality travel behavior data (origin, destination, and mode of travel) was collected how travelers use multimodal traveler information was evaluated and the effectiveness of such information on travel behavior change was assessed.

A statistical and quantitative evaluation was conducted to assess the usability and performance of the Trip2go system, the effectiveness of real-time multimodal information on travelers' behavior for improvement of travelers' perception of transit service and the likelihood of such information for encouraging mode shift. Daily surveys were also administered with each volunteer during the course of the field test period and added with more comprehensive surveys at the beginning and the conclusion of the field test.

Feedback from users indicated that they positively value the information provided in comparison with some of the well-established trip planning apps. Around 50% of users were satisfied with the performance of Trip2Go. The exit survey results show nearly 25% of users used real-time information more than before participating in this experiment. Fifty percent of users say they were still using Trip2Go for their commute information at the time when they completed their exit surveys, among which 20% of users used it for non-commute information and en-route alerts. The users thought that Trip2Go was useful in determining how to reduce emissions, which bus or train route to take and what mode to use. While Tri2go offered more real-time information, as a research tool, it has some limitations and shortcomings. The research team made every effort to incorporate real-time information for transit services in the test site. However, schedule information was used for some routes because not all transit agencies offer real-time information. As a result, trips plans involving schedule information were considered inaccurate by the users. AsTrip2go is released for limited public use, the users tends to compare Trips2go's functionalities and user interface design with other publically available trip planners and have provided constructive suggestions for improvements. However, due to limited resources and time, some of the suggested improvements cannot be implemented.

The results show that information provided by Trip2go has influenced their trip decisions. Particularly, nearly 40% of travelers changed their plans for non-commute trips after consulting with Trip2go, among which 50% of the changed trips involved a different travel mode. For commute trips, we found that real-time information has a larger influence on driving travelers adjusting their routes and departure times and has more influence on the departure time for transit users. Survey results show that less than 20% commuter trips are likely influenced by real-time information and most of the changes involve time and route adjustments as opposed to mode change. Only four of 327 trips changed mode from transit to driving. Of those involving time change (earlier or later by at least 15 minutes), 37% drove, 15% used a carpool and 42% used transit. As most of the subscribers of LA Metro Blogs are transit users, a majority of the volunteers used transit only. Some of the transit riders do not have cars. Thus, changing mode

may not be an option for some of these volunteers. Driving trips for commuting was a small portion of the total trips collected. Only 20% of the 69 participants are drivers, when the data is interpreted proportionally there can be a higher percentage of behavior change for drivers.

Based on the data collected through this project, behavioral response models from surveys and database were used to analyze travelers' behavioral responses to traffic in order to quantify the value of information and quantify the impact that information has on travel choices. After the stated preference experiment was conducted, choice models were developed of the behavioral response to traffic information in hypothetical settings. The trip data obtained from the users who made more than 10 trips were processed to develop choice models of behavioral response to information. The models explain the travel choice made (mode, route, time of day) as a function of the attributes of the alternatives, the information acquired, the purpose of the trip, and the socio-demographics of the traveler. Results of the modeling shows that the travelers tend to choose their typical travel mode, which is consistent with the fact that only a small portion of users change their intended mode. The model also indicated that longer travel time would result in lower probability of choosing certain modes. Alternatively, shorter travel time could trigger travelers to choose an alternative mode. From the analysis of survey responses and model estimations, we may conclude that real-time information can change travelers' travel behavior by advising them to avoid incidental traffic congestion, subsequently helping to relieve congestion.

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Acknowledgement

1. Introduction:

Despite the substantial improvements made through infrastructure upgrades and various congestion mitigation efforts, congestion on highways in metropolitan areas persists, costing travel time, fuel and money, hindering economic development, and negatively impacting the environment. On-going highway improvements and traffic management through deployment of intelligent transportation systems (ITS) technologies have improved services on existing roads. However, congestion persists because traffic demand in almost all metropolitan areas approaches or exceeds the available capacities of the highway systems. An alternative to continuously building highway capacity is to manage travel demand to reduce congestion.

While one may argue whether 60% of highway congestion, mostly during peak periods, is non-recurrent, a significant portion of incident-caused congestion is attributed to the fact that demand exceeds capacity. Mode shift from single occupancy vehicles to transit buses will reduce the total number of vehicles on the road, significantly reducing fuel consumption and emissions. As an example, **Figure 1-1** displays freeway performance (PeMs) data for U.S. Interstate I-110, depicting that freeway travel speed varies dramatically between 10 mph and 70 mph when traffic demand is more than 3000 vehicles/hour across all lanes on I-110. When traffic demand is below 3000 vehicles/hour, the travel speed is stable at the free flow speed of 65mph. Analysis of the I-110 corridor shows that if some drivers are motivated to use transit during peak hours or to travel at off peak periods to reduce the total number of vehicles to approximately 3000, it is highly possible that the large variation of the travel speed will be eliminated and the freeway can be kept at a free flow speed of 65 mph, resulting in congestion relief and reduction of trip time and costs for all travelers. Congestion relief also provides fuel savings and emission reductions for the vehicles remaining on the highways.
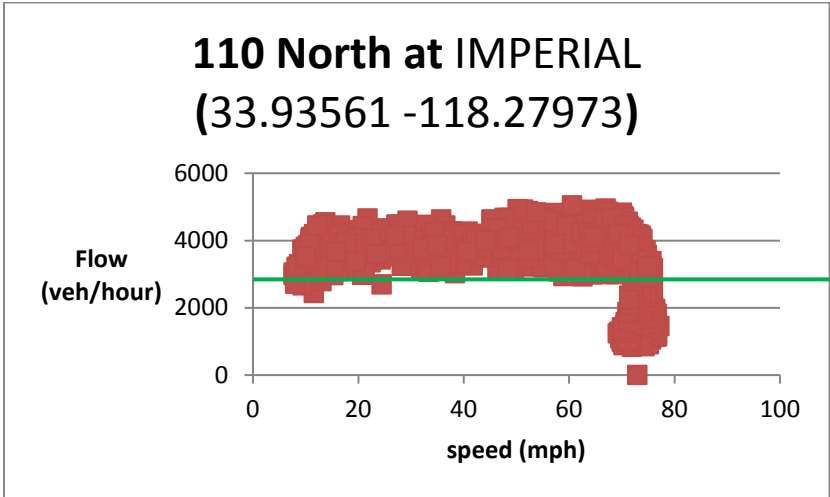

Figure 1-1 Speed vs. Flow Relationship Diagram US710N at Washington
and 110N at Imperial

Demand management and smart land use have been viewed as foundations for transportation management. Use of various tools to encourage people to change travel behavior and to

collaborate with the transportation systems can be cost-saving alternatives to increase highway and public transit capacity. However, existing demand management tools, including traveler information, road pricing, incentives to encourage mode shifts and carpooling have not been widely used in the United States for various reasons. Their effects on congestion relief have not been very well understood.

1.1 The Concept of Incorporating Travelers as a Solution for Congestion Relief

The ability to change travel behavior depends as well upon the extent to which alternative choices are made available by the transportation network itself. The general perception is that the public transportation system in the United States has not been effectively utilized. APTA data show that only about 1-2% of the travelers in the US use public transit as a mode of choice for their commute. However, transit users are concentrated in urban areas where congestion most frequently occurs, particularly in regions that have well connected rail transit services. Data, as summarized in Table 1, shows that rail transit riders account for 20% to 40% of travelers along the major corridors in the San Francisco Bay Area. Transit has become more attractive an option for travelers as a result of gasoline price increases since 2008. APTA reported a record 4.36 percent ridership increase overall for transit systems and a 12% increase for commuter and light rail systems in 2008 compared with a year earlier. Data from subsequent years show that after gas prices moderated, travelers who changed to transit tended to stay with transit. APTA data also show, through gas price increases between 2002 and 2008 and again in 2012, that travelers can be motivated to change their travel behavior when travel options are available and viable, and that once travelers get used to the alternative travel mode, they often continue to use such a mode.

There are various reasons for travelers not to choose transit. Travelers tended to think transit is slow and transit station parking lots are full. For many travelers, taking transit requires one or more transfers between modes. It is not unusual for travelers who have not experienced transit as an alternative to not know their travel alternatives. Research conducted by the University of Southampton in the United Kingdom shows that the majority of travelers do not even consider their modal alternatives for their journeys. Moreover, 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. The challenge lies in what 'triggers' can motivate a large enough traveler population to change travel mode and result in substantial reduction of traffic congestion. Until today, there have been inadequate motivations triggering them to change mode. Demand management tools, including real-time multimodal traveler information, are one means by which to encourage travelers to move from single occupancy vehicles to transit or to travel during non-peak hours, thereby reducing or eliminating congestion levels.

Commuters account for a large percentage of travelers in metropolitan regions, particularly during congested peak periods. Reaching the congestion relief goal requires informed participation of a large number of travelers. 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. Mode shift by commuters can potentially relieve traffic congestion, reduce fuel consumption, lower tailpipe emissions, as well as enable travelers to make the trip less stressful and more productive or pleasurable. Use of real-time traveler information can be an effective means to empower travelers to change their travel behavior for achieving demand reduction.

Advanced Traveler Information Systems (ATIS) such as regional 511 systems are an important tool for encouraging people to change their travel behavior and consequently have the potential to improve the overall transportation system. However, survey results show that mode shift encouraged by an ATIS system was observed to be low. The key reasons for the low response rate to real-time information for mode shift are due to the lack of accuracy and alternative options in ATIS information that prevents the driver from shifting mode. A real-time information system can be most effective if it is tailored to the travelers' interests. 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 [Kenyon, 2003]. An ideal system minimizes effort for the users in acquiring information on mode choice options and is able to expose the user to information on such options even if they had not intended to consider or review a mode choice decision when accessing the service. Integrated multimodal information systems that provide travelers with information about more than one mode of travel may be preferable to travelers than presenting traffic and transit information independently. Properly presented integrated multi-modal information with high accuracy and proper level of detail and visualization could help educate drivers to overcome the barriers to modal change.

There have been significant efforts and several on-going programs to encourage travelers to change their travel behavior. '511' traveler information systems provide real-time information helping people to avoid congestion, but most of these system use separate information interfaces for traffic and transit information and trip planning. The lack of real-time multi-model information has prevented travelers from making mode choice decisions based on true comparisons of the travel time between freeway travel and transit. Moreover, existing traveler information systems typically do not have the ability to analyze how people have used such information for their trip decisions and the effect of such information [Kenyon, 2003].

Most of the cited studies on the impact of real-time information are based on an analysis conducted through simulator studies and opinion survey results using "conceived preferences," rather than the outcomes of actual choices. Although the social psychology literature indicates there is a strong link between stated intentions and actual behavior, most of the survey results may not fully represent actual choices nor be consistent with verifiable data on travel patterns. For example, in one survey study, people who indicated interest in carpooling were sent carpool matching lists to form carpools but half of them indicated in a follow-up survey that they really were not interested in carpooling [Dueker, 1977]. The stated preferences for carpooling by solo drivers might not really reflect the actual behavioral change that will take place [Baldassare, 1998]. 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. It is clear that an integrated multimodal information system is needed in order for ATIS to be more effective in helping travelers to use alternative modes more often. This leads to the development of the Smart Traveler Choice (STC) project.

1.2 'Networked Traveler' -- a Study of Effects of Integrated Real-Time Information on Trip Decisions

Researchers have hypothesized that travelers with travel options would benefit from integrated real-time transit arrival time, parking availability information and freeway/arterial travel time, with which travelers would be able to determine the quickest and most convenient way of travel. Moreover, travelers would be less likely to miss a transit ride or get to the transit station without being able to find a parking space. In order to assess how real-time information may affect choice decisions by travelers, California PATH developed a suite of applications named Path2go based on real-time highway, transit and parking information (www.networkedtraveler.org).

'Networked Traveler' was conducted under the sponsorship of the U.S. Department of Transportation Research and Innovative Technology Administration (RITA) and the California Department of Transportation, in partnership with the Metropolitan Transportation Commission, Santa Clara Valley Transit Agency, San Mateo Transit Authority and private partners including Navteq, ParkingCarma, and SpeedInfo.

The US101 corridor in the San Francisco Bay Area was selected as the test site, and has been one of the most congested highways in California. Parallel to the US 101is a major arterial highway El Camino Real (also known as State Route 82), a commuter rail (Caltrain) and the Bay Area Rapid Transit system (BART). A number of bus routes are operated by San Mateo Transit Authority (SamTrans), San Francisco Muni (Muni) and Santa Clara Valley Transportation Agencies (VTA) in the vicinity of the corridor. These nearby transit systems have excessive capacities during peak hours, offering alternative commute choices for travelers.

The US101 corridor is well instrumented to provide real-time freeway performance data. In order to provide real-time multimodal information, PATH made institutional arrangements and developed interfaces to receive real-time data from Muni, Samtrans and BART. PATH also instrumented all Caltrain trains and selected VTA buses with AVL for real-time data. The field test corridor Figure 1-2 shows the system architecture of Path2go. The data feed includes data inputs, the Path2go system and freeway changeable message sign systems.
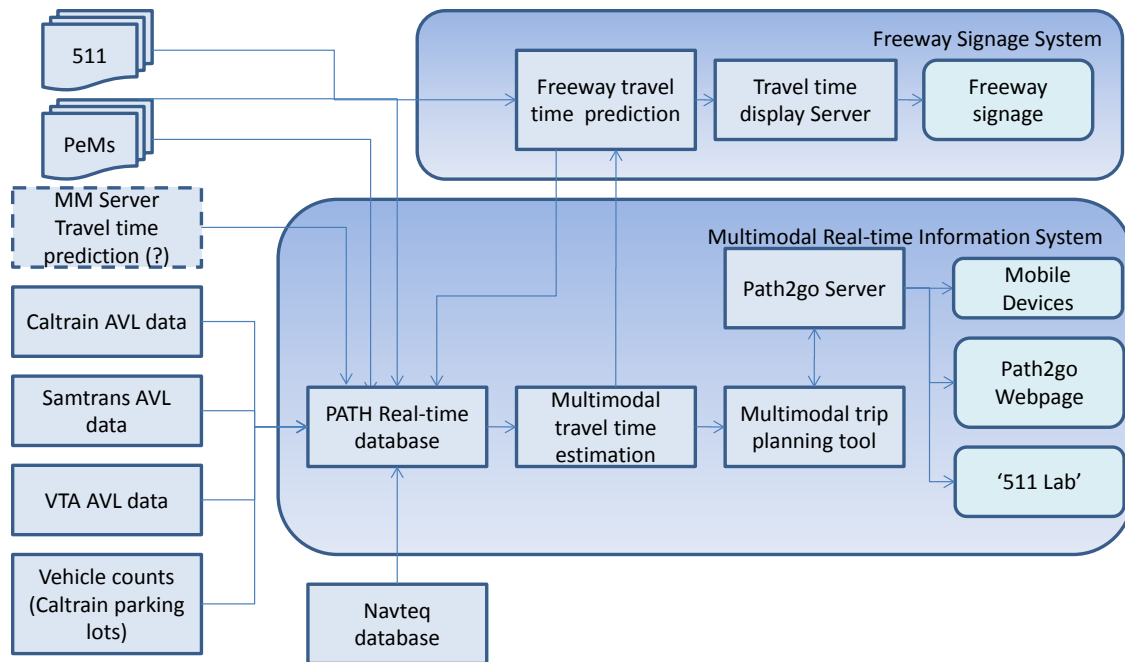
Figure 1-2 System architecture of Path2go

A dynamic multi-modal transit and traffic network was implemented as part of the trip planning engine. A dedicated thread on the server updates the network using real-time transit arrival information and real-time traffic data periodically [Li, 2012]. Multi-source time-dependent shortest path algorithms for the transit-only or park-and-ride mode based on users' expected departure time (via a forward algorithm) or arrival time (via a backward algorithm) has been designed to achieve trip planning goals with acceptable computational time. Path2go was designed as a server-based system, making it possible to evaluate the potential influence of real-time multimodal traveler information on mode choice decisions.

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 multimodal real-time information. Substantial efforts were devoted to develop the Path2go applications and user interfaces as well as to ensure the reliability of real-time information, which is a significant factor to influence travelers' pre-trip departure time and route-switching decisions, as well as the en-route path changing decisions.
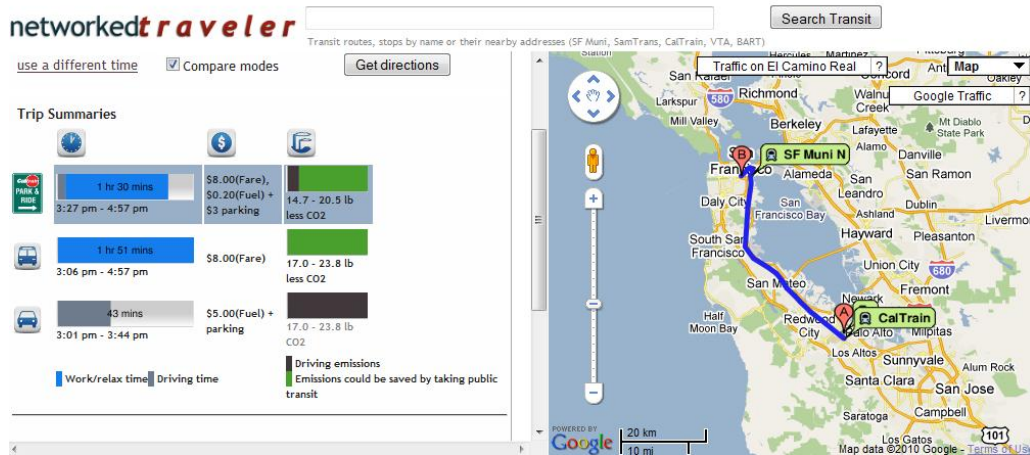
Figure 1-3 Integrated multimodal traveler information user interface.

The web-based trip planner, as shown in Figure 1-3, enables 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 carbon footprint. Once a trip has been planned, it can then be sent to a user's smart phone (iPhone, Android or Windows Mobile platforms) to receive real-time updates on the bus/train arrival times and arrival audio alerts before actual bus/train station arrivals. In addition to receiving information about the planned trips made using the web-based trip planner, the mobile phone clients can also be used to plan for transit trips, obtain real-time status updates and provide alerts during a trip. Path2go also displays the real-time highway and transit travel time and parking availability on freeway overhead Changeable Message Signs (CMS) before a major transit station along the US101 corridor during the rush hour. This information can potentially inform travelers about their transit options when highway congestion occurs.

Field testing of Path2Go was conducted between August and November, 2010, involving volunteer commuters along the US101 corridor who had access to PATH2Go web-based trip planning tools and smart phone applications. 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 changes in travel behavior. In addition to the data collected, users were invited to take a detailed survey at the end of the field testing. Data were analyzed by an independent evaluator to evaluate the effectiveness of the integrated real-time multi-modal information and if it likely encouraged travelers to consider transit as a viable option [Jasper, 2011].

PATH2Go application users were asked to provide feedback. 244 surveys regarding the demographic characteristics and data usage were received. In addition, 50 web surveys and 31 cell phone surveys were also collected. The survey results indicate that the commute trip distance is variable with the median trip distance of slightly less than 20 miles. Most of the trips undertaken by the respondents were less than 45 minutes. More than 40% of the respondents reported using two or more modes for commuting. In addition, 60% of the survey takers considered transit as a mode of choice, followed closely by driving at about 55%. Carpooling and other mode choices remained unfavorable to a majority of respondents. When asked about

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the number of traffic information sources utilized, about one quarter of the respondents indicated that they did not seek such information, while 43% used one information source only. 511 information services were considered the most popular type of information source, used by over 40% of the respondents, followed by Google with a 30% usage rate.

Through the web surveys, two-thirds of the respondents considered the PATH2Go applications were 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. Users also inputted comments for possible technical and service improvements such as to load/save favorite maps and incorporate information for AC Transit. The cell phone survey received positive overall ratings, with more than half of the users finding the application useful. However, the high dissatisfaction rate shows that there is still space for improvements, particularly the user interface.

Independent evaluation results are summarized in Table 1-1. To answer the key question regarding how Path2go included mode choice decisions, 32% respondents indicated that Path2go makes them more likely to choose an alternative mode while 38% do not[1].

Table 1-1 Survey results from the independent evaluation report

Question	agree/strongly agree	disagree/strongly disagree
Application provided valuable information	56%	14%
Ability of access information for multiple agencies is useful	65%	10%
Information is accurate	40%	12%
Information of path2go makes me feel more confident about using public transit	40%	20%

However, due to sample size limitations, findings are insufficient to generalize. In particular, the characteristics of the travelers and the trip and the influence of traveler information on decisions regarding the time at which to travel were not measured. Further testing, data collection and analysis is necessary to study whether and how traveler information would affect travelers' trip decision behavior.

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[1] The National Evaluation of Networked Traveler-Transit/Smart Parking test,
https://ntl.bts.gov/lib/38000/38500/38548/SafeTrip-21%20NT-TSP%20508%20Files/pt1.htm

1.3   Overview of the Smart Traveler Choice Project

Caltrans and PATH continued the study on whether travelers make trip decisions with respect to travel time and mode shift in response to recommendations provided by a multimodal real-time traveler information system. The primary goal of the Smart Travel Choice (STC) 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 peak hour travel, which would help to reduce traffic congestion, 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.

Under the STC project, an enhanced multimodal traveler information system based on the prior FOT experience conducted along the US101 corridor was implemented in Los Angeles County to improve the functionalities and user interface design for better usability. Both the web interface and mobile interface were redesigned to make the user interface easier to use, more intuitive and with better organized information. A Field Operational Test (FOT) was implemented along two major corridors in the metropolitan Los Angeles area to collect objective and subjective data to evaluate whether travelers would make trip choices including mode shift decisions using specific real-time multimodal information. Data collected from the field tests, including surveys, have been evaluated and modeled to understand behavior for trip decision-making. Travelers' feedback from focus groups was also collected.

This report provides a summary of the STC project. Chapter 2 summarizes enhancements made. Chapter 3 describes the FOT site, test preparation and data collected through field-testing. Chapter 4 provides information from the user surveys and discussions with field test participants. Chapter 5 reports efforts of and results from modeling of trip behavior and how information affecting their trip decisions.

2. Development of trip2go

Under an on-going STC project, substantial improvements were made to the integrated multimodal real-time information system that was developed previously for the Path2go field operational test in the San Francisco Bay Area. The system, now named as Trip2go, was implemented in Los Angeles County.

2.1   Overview of Trip2go System

Tript2go is a multi-modal trip-planning tool that provides side-by-side comparisons of transit, driving, driving to transit and transit-only modes, and sorts options by travel time, cost and environmental impact. Path2go is also a multimodal navigator that gives travelers driving directions along with real-time updates on traffic conditions. If the traveler takes transit or the park and ride option, he/she receives the arrival times for the bus or train together with transfer connection information, as well as an alert when the transit ride approaches the stop or station. Trip2go covers the driving routes for Los Angeles County and transit routes served by the Los Angeles Metropolitan Transportation Authority (both bus and rail) , Foothill Transit, and Long Beach Transit. Trip2go was developed to support a continuous evaluation on how real-time information supports travelers in making travel decisions.

Trip2go integrates a suite of web-based and smart-phone-based applications. The web-based trip planner enables travelers to plan and compare trip options. The user can compare driving, transit and park-and-ride trips based on travel time, cost, and the carbon footprint for the trip. Once a trip is planned, the user can choose to send that trip to the mobile phone application, which turns the mobile device into a navigator.

The Trip2go was built upon the Path2go system together with a functional expansion. Path2go is a transit-oriented application, where en-route updates and alerts are only transmitted to users for their confirmed transit trips. Trip2go incorporates highway travel information into the cellphone clients in order to provide real-time multimodal trip comparisons through mobile devices so users can be better informed about driving under recurrent and non-recurrent travel conditions in their trip decision making. This new function requires integration of historical freeway travel time, real-time traffic incidents and lane closure data into the multimodal trip planning engine. Real-time traffic incident information is also transmitted to users through the "push alert" function for those who chose driving. The multimodal aspects of Trip2go are implemented through a number of new approaches, as follows.

- Archiving and categorizing freeway travel time by time-of-day and day-of-week: Categorization of freeway travel time would be a bound for "normal" travel (i.e., under recurrent congestion). Combining the historical travel time with real-time predicted travel time, users can be better informed about both driving and transit options.

- Map-matching of incident locations with a road dataset and an association of incidents with the driving trip: Real-time incident data needs to be filtered so that only relevant incidents would be included in the trip planning process and provided as en-route driving alerts. However, there are no standard incident coding methods and an incident is

described as text with, for example, "I5", "I-5", "freeway 5" or "5" representing Interstate 5. Software was developed to categorize the incidents and map their locations onto roads identified by link IDs in the Navteq database. The mapped incidents were then associated with users' driving trips to inform them whether "delay is expected" due to the incidents. Relevant database tables were also designed for archiving incident data to support the evaluation study.

- Server-side trip status tracking and en-route updates/alerts mechanisms: With Path2go, a user specifies the origin-and-destination and departure/arrival time for the trip, and receives en-route updates or alerts on selected trips. The decision of en-route updates/alerts is made at the server side. The previous transit-oriented server software to track trip status and generate relevant en-route updates/alerts was expanded to include incident alerts for drivers, to ensure a smooth transition from driving to transit (for drive-to-transit mode), and to maximize the likelihood of only delivering to users incident information relevant to their trips.

Additionally, functions are incorporated for collecting user activity data, such as querying and searching multimodal information with the mobile App, stated intentions of the travel mode, selection of travel mode based on returned trip planning results, and post-trip queries regarding the chosen travel mode.

The Path2go system architecture was modified to incorporate these additional functions and to accommodate the large scope of the deployment site, so that users could perform intended tasks in real time. Figure 2-1 shows the Trip2go architecture.
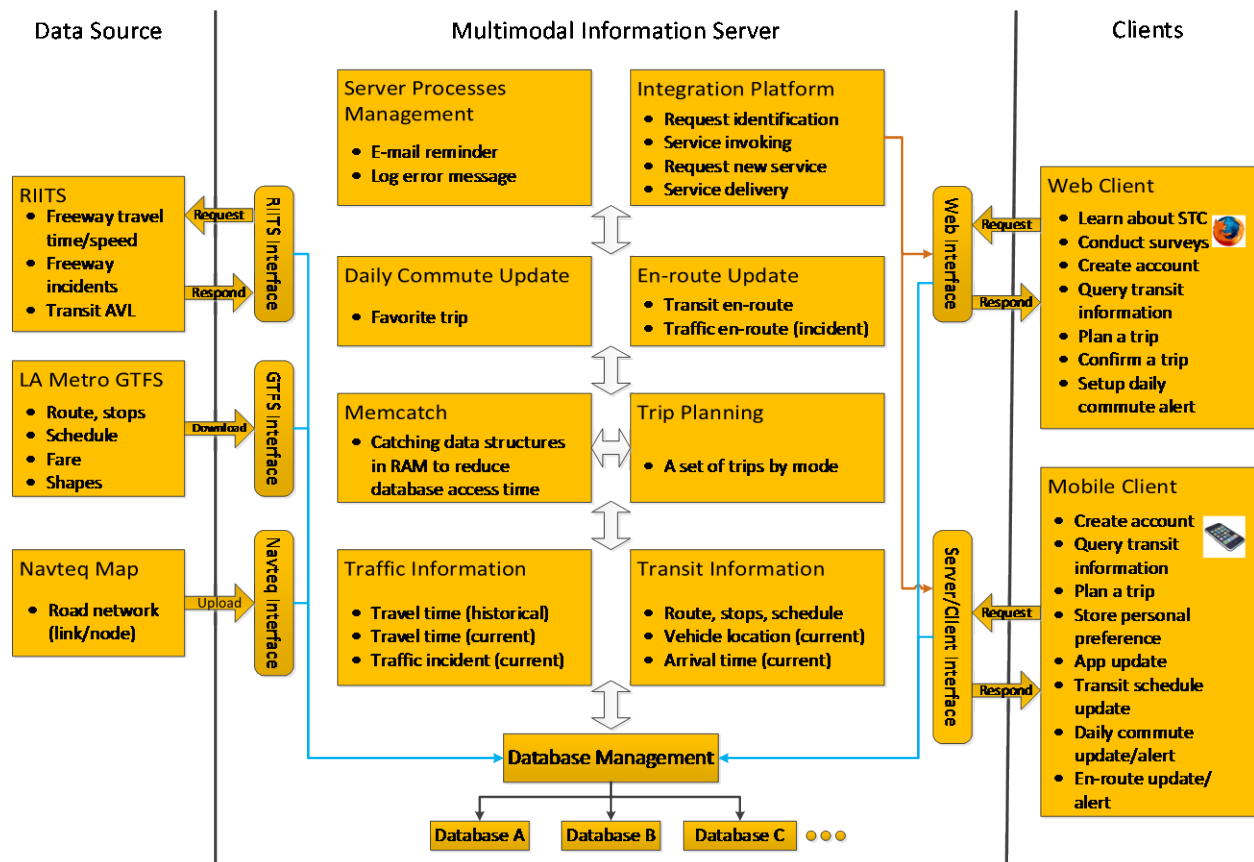
Figure 2-1 Trip2go Architecture

2.2   Trip2go Multimodal Information Server

The planning system architecture is shown in Figure 2-2. . The planning is executed by Transfer.php that sends a message to the Transfer server. The Transfer server then sends the request to the Planning server. Major computation is performed in the Planning server.

All at Albany

For comparison request,
generate 3 parallel requests
(driving, transit, parking-ride)

Apache → Transfer.php → Transfer server → Planning server

Default port: 1500

Default port: 1501
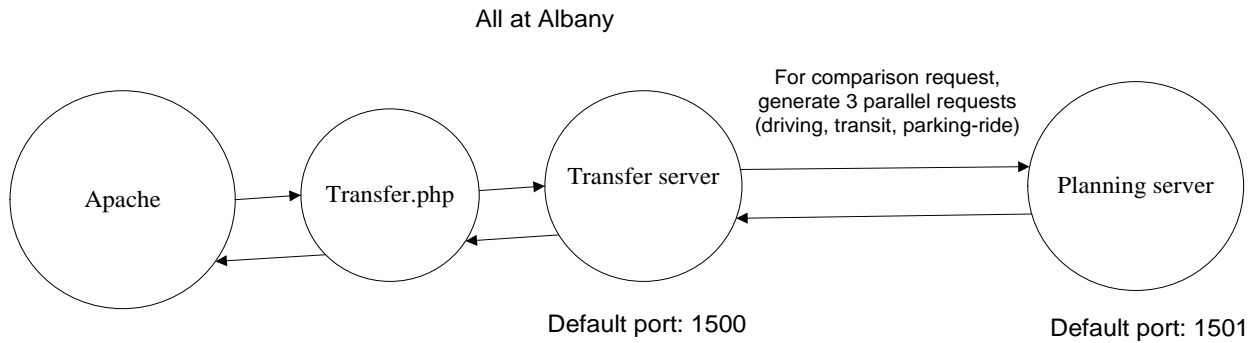
Figure 2-2 The System Architecture

2.2.1 The transfer server

The Transfer server is built in order to execute multiple modes in parallel. There is no built-in support in Php for parallel computing. We then have to implement the parallelism in C++ for the Transfer server.

When a request is received from Transfer.php, the Transfer server first checks if the mode is a combined mode. If so, that is for comparison purposes. The Transfer server then creates three threads, each with a specific mode: driving, transit, and park-and-ride. Each thread sends a message with the specific mode to the Planning server. After all the responses are received from the Planning server, the Transfer server returns the overall result to Transfer.php.

2.2.2 The planning server

Figure 2-3 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.
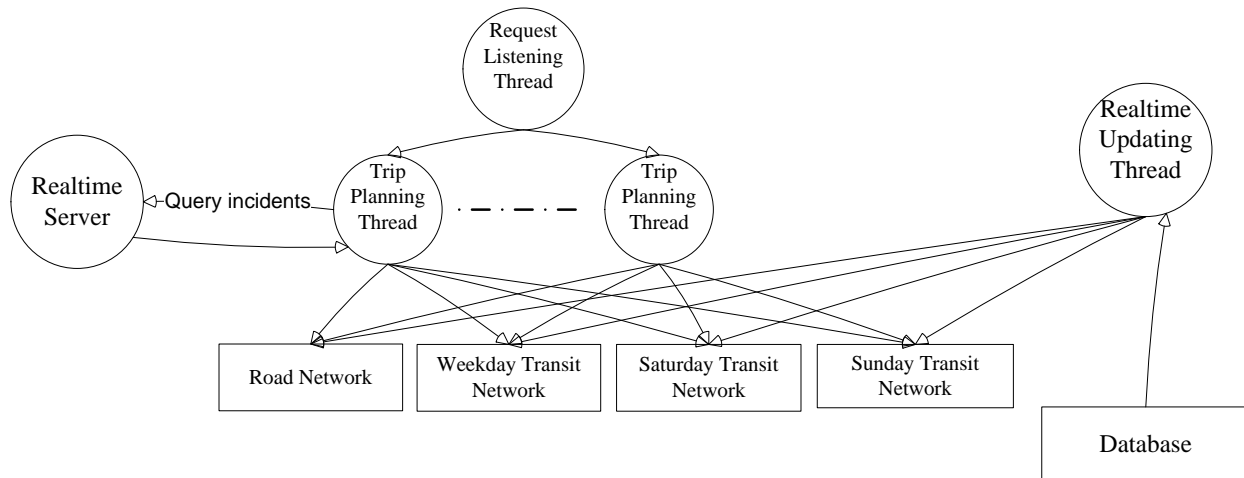
Figure 2-3 The architecture of the trip planning server

The Planning server is implemented by C++ Class TMMTP. The entrance function is xPlanner(). The file is /home/ljq/work/MMTP/V2/Server/src/Planner.cpp. If the request is for driving, the function xDrivingOnly() is called; If the request is from transit only or parking-and-ride, the function xWithTransit() is called.

An upper bound can be specified for walking. For example, we can specify 2000 meters from the origin to the first bus stop, as in the following function *pT_SimpleSP->xSimpleSP_Dijkstra*. i_StartDistLimit is the upper bound. If there is no such upper bound, a negative number (e.g., -1) can be used.

If users choose 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 *100* nearby bus stops. For 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 are combined together to yield an overall route.

A major function that interfaces between the Planning server and the shortest paths algorithms is xArcCostUsing(), as in /home/ljq/work/MMTP/V2/Server/src/Mist.cpp.

2.2.3   Trip planning algorithms

All the algorithms on the shortest paths can be found in /home/ljq/research/lib/SimpleSP. A number of different algorithms have been developed for different purposes.

2.2.3.1 Label setting algorithm for driving and walking

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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 Dijkstra algorithms to solve the one-to-one shortest path problem. The Dijkstra algorithm is a label setting algorithm, and the complexity is $O(n^2)$, where *n* is the number of nodes in the network. The computational performance of the one-to-one shortest path problem may be improved by using the bi-directional Dijkstra algorithm (Ahuja et al., 1993). There are two versions of the Dijkstra algorithms implemented: one with the *linked list* (xSimpleSP_Dijkstra()), the other with the *priority queue* (xSimpleSP_Dijkstra_Heap()). We found that both versions are useful. For a long distance, e.g., driving mode, the priority queue is much better, while for a short distance, e.g., walking to a stop, the linked list provides better results.

2.2.3.2 Multi-source time-dependent shortest path algorithm for utilizing transit

When the transit mode or driving-parking-then-transit mode is selected, users provide the expected departure or arrival time. Some arcs may not be valid with the specified time. For example, if a user expects to depart at 7:00am, the arc from the transit stop to a trip starting at 6:40am is invalid. Therefore, finding paths between two transit stops is a *time-dependent* shortest path problem. In addition, we simply use the time information in the user request to examine if an arc is valid rather than changing the underlying network for a specific request.

The time-dependent shortest path problem has been investigated by forward and backward search methods (Tong and Richardson, 1984, Chabini, 2002, and Huang and Peng, 2002) and dynamic programming (Zografos and Androutsopoulos, 2008). Since the transit network is acyclic, the topological sorting algorithm (Cherkassky et al., 1996) can be used to find shortest paths with the complexity of $O(m)$, where *m* is the number of arcs. Note that *m* is far less than n^2 in sparse networks, thus decreasing the computational time.

We design a multi-source shortest path algorithm for reducing the computational time. In the typical one-to-many shortest path algorithm, only the source node is pushed into the candidate list during the algorithm initialization stage. We first calculate the travel distance from the origin to nearby bus stops. The arrival time to each nearby bus stop can be determined accordingly. Then, these nearby bus stops are pushed into the candidate list with the arrival time. The travel time from the origin is used as the initial cost for each nearby stop or parking lot. Our multi-source shortest path algorithm requires solving only one shortest path problem, thereby substantially reducing the computational time. Details of the multi-source shortest path algorithm are presented []. The overall trip planning algorithms 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 time-dependent shortest path 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 trip dominance and output the remaining trips to client programs.

The multi-source time-dependent shortest path algorithm, which is based on topological sorting, is presented as follows:

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 multi-source time-dependent 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.

2.2.3.3 Further reducing response time by limiting search space

(a) original and enlarged boxes   (b) an example of curved routes
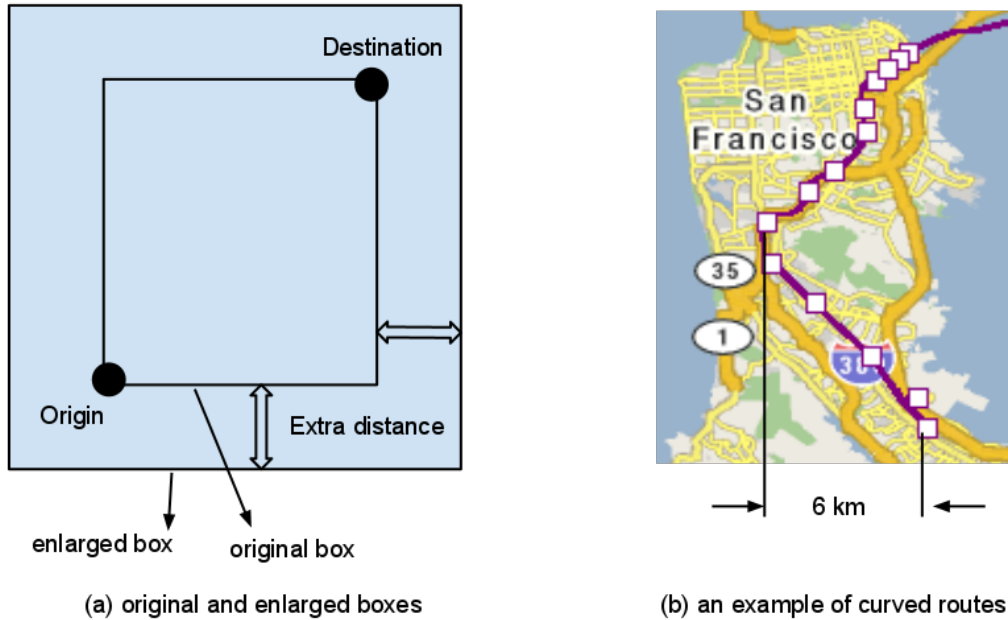
Figure 2-4 An example of the use of enlarged box to limit node visiting

The underlying network is generally very large for metropolitan areas because there are a large number of transit services provided by various agencies. In order to further reduce the computational time, we use a box to limit the nodes that the algorithm is visiting. After the origin and destination are given, we can construct a box where the origin and destination are two diagonal nodes (e.g., see Figure 2-4(a)). However, it is possible that some good trips are omitted by this box. Therefore, we enlarge this box so that four lines of the box are moved outward. It depends on different locations when we decide the extra values so that no optimal solutions are omitted. In our case studies, the most curved transit route occurs in a metro route, where the horizontal distance is approximately 6 km (see Figure 2-4 (b)). Most bus routes are direct. In fact, the route directness is an important measurement for designing bus routes (Transportation Research Record 1996). For conservative purposes, we included an extra 8 km distance for rail routes and 5 km for bus routes.

Note that every node in the transit network has a latitude and longitude. The following procedure is used to approximate the latitudes and longitudes of four nodes of the enlarged box: 1° of latitude = 69 miles, and 1° of longitude = 69 × cos(latitude) miles. If the latitude and longitude of a new node is outside this enlarged box, this new node is not considered by the algorithm.

The feature is implemented with a data structure sTripOD.

```
typedef struct sTripOD
{
    S32     fMinLat;
    S32     fMaxLat;
    S32     fMinLong;
    S32     fMaxLong;
```

```
   //for rail, we use the larger range
   S32     fMinLatForRail;
   S32     fMaxLatForRail;
   S32     fMinLongForRail;
   S32     fMaxLongForRail;
}sTripOD;
```

xSimpleSP_GOR() and xSimpleSP_Dijkstra() take this parameter.

We also use another heuristic rule to reduce the computation time. If the number of paths found is more than a given threshold, the algorithm terminates. xTerminate() in /home/ljq/research/lib/SimpleSP/src/KthSP.cpp is for this purpose. Currently, we set the threshold as 5, and it works well.

2.2.4   Post Preprocessing

After the multi-source time-dependent shortest path algorithm is completed, we can retrieve a shortest path for each nearby ending bus stop. While the essence of most multi-modal trip planners is to seek good travel routes for the given origin, destination and starting/arrival time, finding good routes is far more complicated than solving a simple shortest path problem. For example, different users may have different preferences. Some users may prefer trains to buses. It is difficult to model these preferences using quantitative weights. Therefore, multi-modal planners generally provide several good routes to users so that they can choose the best one from these routes by themselves.

On the other hand, many shortest paths may be very similar. For example, suppose there are two stops on the same route; and both of these two stops are close to the destination. Therefore, two associated trips are almost the same except for the last bus stop and walking route to the destination. It is necessary to examine the similarity between trips. We design certain dominance rules to discard trips. First, for all the trips, we determine the following criteria: minimal number of transfers, earliest arrival time, latest departure time, minimal travel distance from the origin to the first stop, minimal travel distance from the last stop to the destination. If the value of a criterion for trip T is considerably worse than for the best trip, trip T is discarded. Such dominance rules effectively reduce similar trips.

2.2.5   XML Generation

After the shortest path problems are solved, we need to associate each node in the shortest path with the actual information, say bus stop, time point, intersection, etc. The information is filled out by C++ Class TOutput, as in /home/ljq/work/MMTP/V2/Server/src/Output.cpp. The format can be seen in Trip2go APIs. In addition, we also write the results into the database in TOutput class.

2.3   Trip2go Mobile Application

Building upon the Path2go application, and Los Angeles County Metropolitan Transportation Authority's (Metro) *Go Metro* Android App, California PATH developed a mobile application (app) named Trip2go. The app has online and offline capabilities that commuters may utilize to effectively use the regional transportation system, particularly the regional bus and rail system. The app was designed to assist users with trip planning, give them dynamic information and alert them of relevant events. The mobile application provides multimodal pre-trip planning functions and en-route trip alerts/updates. En route transit alerts include bus / train arrivals, passenger alighting alerts and trip update information. An en route driving trip provides traffic incident alerts.

The Trip2go mobile phone application currently runs on the Android phone platform. The app provides the following functions:

- Check real-time Expected Time-of-Arrival (ETA) of buses / trains using an mobile phone (when not intending to plan a trip);
- Plan trips based on current traffic and transit condition;
- Compare different local transportation options, including driving, transit and drive-to-transit;
- Select a trip based on travel time, convenience, fare or carbon footprint;
- Download trip option that were made using the Trip2go website; and
- Step-by-step navigation for all modes, including
    - Turn-by-turn navigation for driving and walking segments (through Google Map);
    - Construction and/or congestion ahead alerts while driving (text-to-speech);
    - Bus/Train arrival alerts while waiting or making transfers (text-to-speech); and
    - "Your stop next" alerts while onboard a bus/train (text-to-speech)

The user only needs to login once to use the Trip2go mobile app. Figure 2-5 shows a screenshot of the Trip2go app interface. There are 5 tags. The user can view current traffic conditions, search an address and save it as Favorites from the Map tag. The Favorite tag displays the Favorite transit stop/station, destinations to travel, and favorite trip options that the user has previously saved. Favorites are automatically synched with the Trip2go website, so the traveler only needs to save 'Favorites' on either the website or the mobile device. The Lines tag displays transit route/stop information by transit operator. The Trips tag is where one plans a trip on the mobile device. The Options tag lets the user set alert options (Sound, Vibration, Text-to-Speech), and other options of using the Trip2go mobile app.
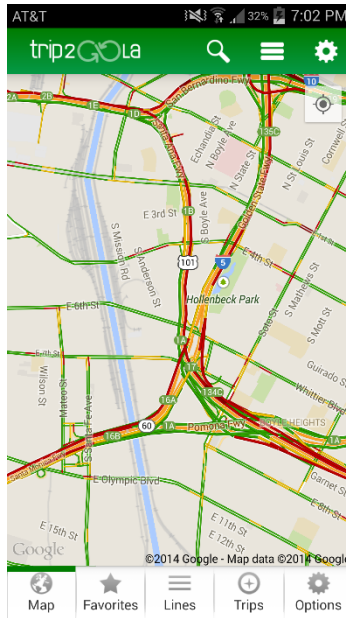
Figure 2-5 Trip2go Mobile Interface

Check real-time transit expected time-of-arrival at a stop/station:
The app enables the user to save a stop/station as one of the Favorite Stops. To add a stop/station as a Favorite Stop, one can go to the Lines tag, select the route, direction and stop/station from the list, and click the 'start' on the top green bar to save it as a Favorite. By clicking stop/station under the Favorites tag, the app displays arrival times for up to five next buses/trains.

Plan a trip on the mobile device:
There are two ways that the user can plan a trip with the mobile device, from the Trips tag or from the Favorites tag. The figure below (Figure 2-6) shows a screenshot of the Trips page on the mobile device. By default, it is assumed that the traveler starts to travel from his/her current location and is ready to start a trip. The user can change the Origin location by inputting an address, and/or change the time to start travel by clicking the 'Current Time' button and selecting the desired departure time. After inputting the destination address and clicking the 'Travel Options' button, the user is provided with recommended travel options by mode, similar to planning a trip on the Trip2go website described above. The user can save the frequent travel destinations and trip options as Favorites, such that the user does not need to manually input addresses. To plan a trip to a saved Favorite Destinations, click Favorite→Destinations→saved destination, the app returns to the Trips tag with destination automatically filled. To plan a trip for a saved Favorite Trip (both origin and destination of the trip have been previously saved), click Favorite→TRIPS→saved trip, the app goes to the 'Trips' page with both origin and destination of the travel automatically filled. The user can also directly access Favorites from the Trips tag, by clicking the bookmark at the end of the address line (Figure 2-6).

To save an address as a Favorite Destination on the mobile device, click Map tag and input the address on the top bar, then click Search button on the mobile device. The traveler can then see a

white pin located on the address that he/she is searching. Click the pin to save it as a Favorite Destination (Figure 2-6).

Compare Travel Options:

Figure 2-6 shows a screenshot for recommended travel options by mode of travel. Click on any of the three recommended travel display details for the selected travel option. The user can save the trip option as a Favorite Trip by clicking the "start" on the top bar, and/or clicking "CONFIRM TRIP" to select the trip. The user then can let the Trip2go app navigate him/her to the end of one's trip.

Trip Planning with Mobile App

Save Address as a Favorite

Trip Comparison

Trip Details

Figure 2-6 screenshot of comparison for recommended travel options by mode of travel

2.4 Trip2go Web Application

The Trip2go website enables users to achieve the following functions:

• Plan trips based on current traffic and transit conditions;
• Compare different local transportation options, including driving, transit and drive-to-transit;
• Select the trip based on travel time, convenience, fare or carbon footprint;
• Send the planned trip to the smart phone and continue to receive en-route alerts and updates on the mobile device while traveling on the trip (need to login Trip2go website and install Trip2go Android mobile app)
• Review one's accomplishments for recent travels (i.e., carbon savings, cost savings compared with driving, and relax times gained by taking transit), and the ranking among all registered participants (need to login Trip2go website).

Figure 2-7 shows the screenshot of the Trip2go website Home page. Note that the white triangle mark indicates the active website page.
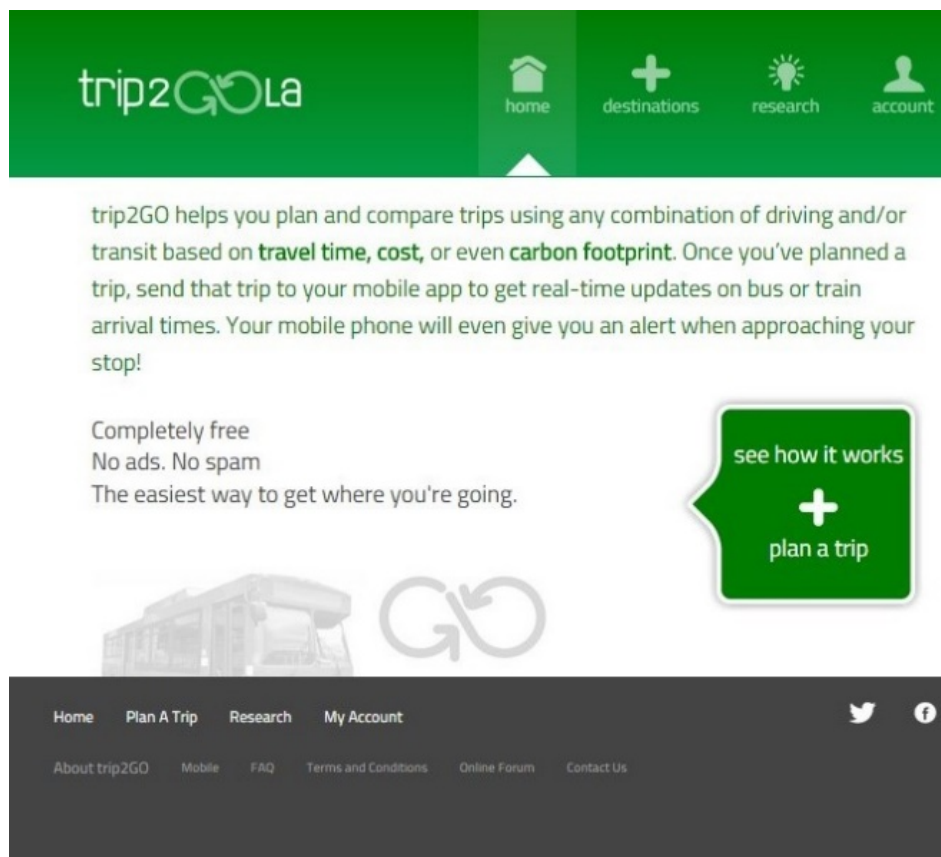
Figure 2-7 screenshot of Trip2go website Home page

Using the Trip2go website for some of its features, such as sending a planned trip to the mobile device or reviewing one's accomplishments, requires logging in to one's Trip2go account.

The user can plan a trip similar to using Google Map or WAZE by inputting the Origin and Destination addresses for the trip (see Figure 2-8 (a)), and then clicking the 'GET DIRECTIONS' button to view the recommended travel options (see Figure 2-8 (b) for an example). When logged in, the user can also plan a trip by clicking one of the previously saved Favorite Trips, and the Origin and Destination address boxes is automatically filled with the selected Favorite Trip.

(a) Trip2go Website Trip-Planning Page

(b) Comparison of Travel Options
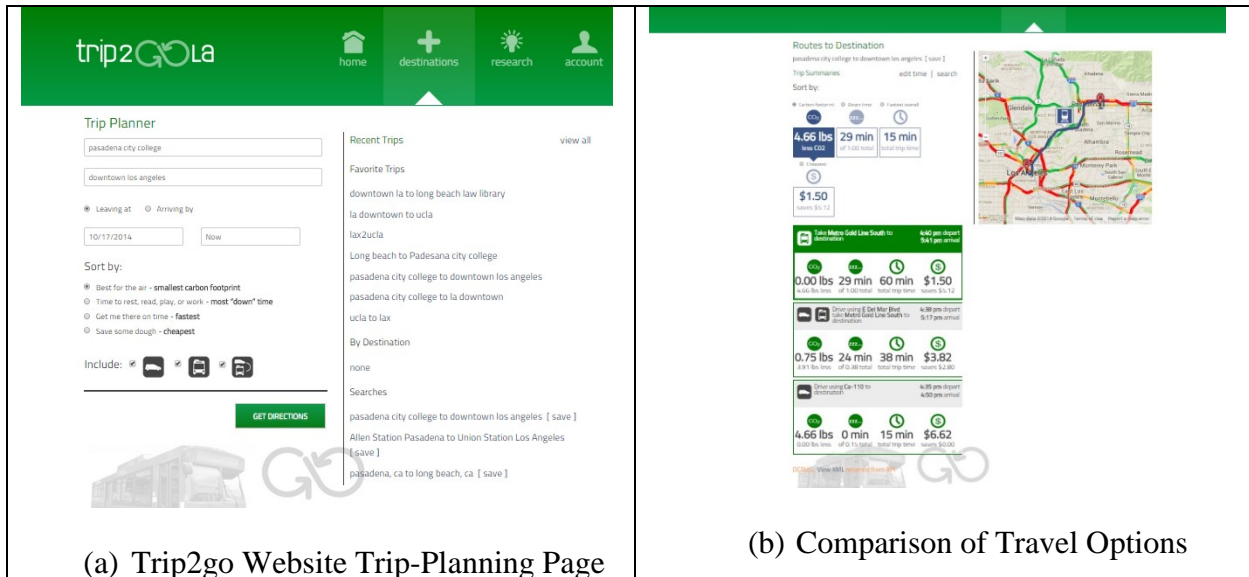
Figure 2-8 Inputting the Origin and Destination

Recommended travel options:

Trip2go provides up to three travel options, one for each mode of travel (i.e., transit, drive-to-transit or park-and-ride, and driving). The Trip Summaries page (Figure 2-6) displays a comparison of recommended travel options in terms of trip travel time, cost and carbon footprint by mode of travel, as shown in the three boxes on the left side, respectively. For transit mode, the value of the carbon footprint is zero as the transit vehicle still operates whether the traveler takes the transit option or not. For drive-to-transit and driving modes, the carbon footprint is the additional amount of carbon dioxide generated by driving a car. The Map on the right side shows the travel route for a particular mode of travel, corresponding to the green-bar highlighted travel option on the left side. By single clicking another mode option box, the Map draws the travel route for the corresponding mode option. If the user would like to see more details about a recommended travel option, double click the travel option box and the Trip Details page provides the trip details (Figure 2-9). The user can save

this trip option as a Favorite by clicking 'Save as Favorite' link. If the user wants to take the recommended trip option and continue to receive en-route alerts and updates with his/her mobile device, double click the green "CONFIRM TRIP" button, and the trip option is automatically sent to the mobile device (Figure 2-9).

| Trip Details Page | Trip Confirmed (Mobile Device) |
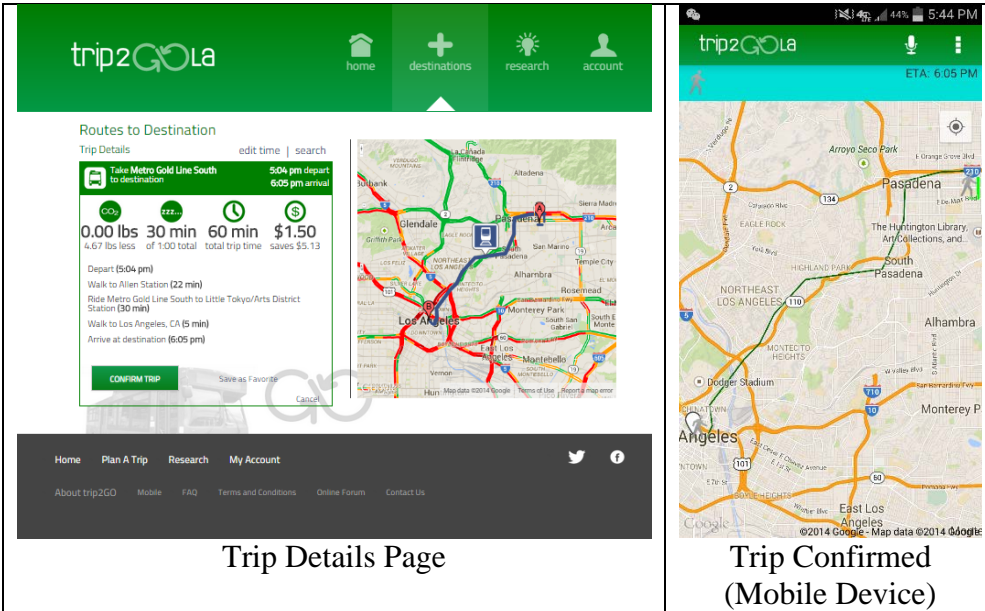
Figure 2-9 Trip Details page

The user can review his/her accomplishments on the Trip2go webpage. When logged in to the Trip2go website from the Account page, the user can see his/her accomplishments in terms of savings of carbon, relax time or work time and the cost by taking transit more (right side of Figure 2-10). It also displays the ranking of one's accomplishments among all Trip2go users, and the highest ranking value in each category. Take transit more to put the ranking higher!

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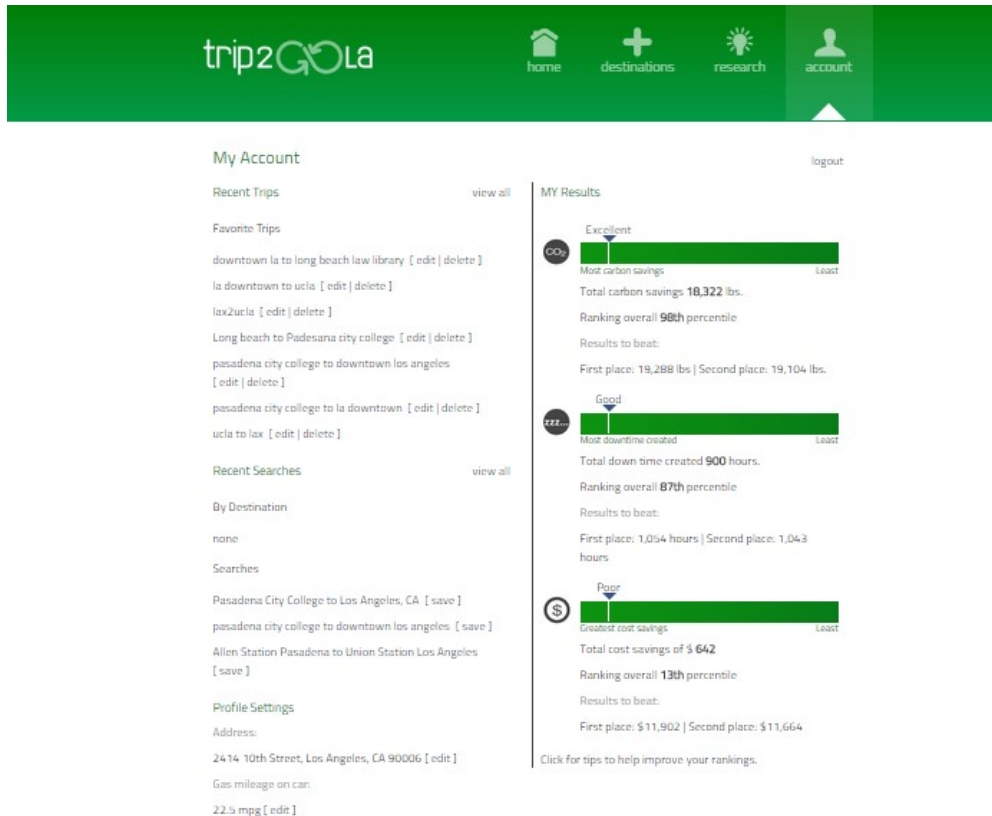
Figure 2-10 Website Account Page

2.6 System Integration and Debugging

Trip2go has been going through a significant redesign process for improved usability with added functionality to support multimodal information. The multimodal central server functions including a database, trip planner, web interface, mobile client and various functions for interfacing with mobile client have all been redesigned. The project team has integrated the mobile client with the central server, where the multimodal trip planner is located. Systematic debugging and testing of the current Path2go prototype were conducted to identify issues with the prototype system in the areas of 1) client-to-server and server-to-planning-engine communications, 2) multimodal and users data collection, 3) archiving and categorization, and 4) mobile application's usability, performance and reliability; and to ensure the overall design objectives are met. Quality testing was conducted on each system component including the multimodal trip planner and cellphone clients to isolate potential problems and then to address issues of system integration. Path2go was then improved accordingly based on the quality testing results to become ready for pilot testing.

The Path2go mobile client is the primary user interface for providing and collecting multimodal traveler behavior data. The Path2go mobile prototype has been tested at the last stage of the trip2go development to include communications testing with server APIs for information exchange. The performance and reliability of the mobile prototype was tested to ensure the UI flow, alert mechanism and presentation, personalized and trip data gathering and uploading are correctly implemented on both the client and server side for the entire trip. After the testing,

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Path2go was integrated in a laboratory environment, where an emulated client GPS was used to generate trips and GPS updates. Trip planning results and en-route updates/alerts were then sent to the mobile application on the phone. This approach enabled a wide range of scenarios to be tested under a controled environment for easy debugging and issue isolation. Server-side trip status tracking and en-route update/alert generation mechanisms was also been debugged and tested. Improvement on both server and client side was made accordingly, based on the testing results to become ready for small scale field testing.

Various debugging and quality testing of all Trip2go components were conducted to validate the performance of Path2go components that support mobile applications, to identify issues that may affect users' willingness to continuously use the Path2go mobile application, and to resolve them promptly. The testing was conducted by the project team both in the lab environment as well as at the test site. Testing was also done to validate the accuracy of transit arrival time prediction.

The accuracy assessment was evaluated at time-points when ground-truth data are not available. The returned result and response time of the trip planning engine was another focus of the testing. Response times of trip planning due to the enhancement of the planning algorithm improved. Planning results were compared with the Google Planner to identify potential issues with our trip planner, in terms of whether reasonable trips are missing and how the returned trips are associated with traffic incidents, total travel time and number of transfers, etc. The trip-planning algorithm was further improved based on the testing results to enhance the attractiveness of the use of Path2go.

The usability of the Trip2go web page was also tested thoroughly. Trip2go has newly incorporated traffic incident information with web-based trip planning so users can be provided similar planned trips when using either the Trip2go mobile application or the web page, and the trips planned on the web page can be transmitted to the phone for en-route updates/alerts. The project team has redesigned the web page to simplify the process for users to obtain information of interest with fewer clicks and with synchronized personal favorites and trips recorded with the Path2go mobile application.

Quality testing was rigorously performed for the integrated system to ensure the application was ready to be released for field testing. Integrated system was tested internally with an emulated trip/GPS updates and real-time multimodal information to identify issues that could affect field testing and any such issues were corrected promptly. The collection of user related data and data archiving, and process tools that allow regenerating trips based on recorded user inputs and archived transit/traffic data were verified through testing. Through the testing, major problems with integrated the Trip2go were identified and corrected. Remaining issues were continuously worked out through Beta testing.

3. Field Test of Trip2go

3.1   An Analysis of the Test Site

Los Angeles is one of the most congested metropolitan regions in the United States. An analysis was performed prior to the selection of Los Angeles County as the test site for the STC field operational tests. The analysis focused on whether mode shift to transit or to travel at off peak periods within each peak hour would help alleviate recurrent traffic congestion. The preliminary analysis suggested that removing vehicles from the highway during congested periods, either by mode shift or shifting time of travel, can result in congestion relief on the highways, thus reducing trip time for all travelers and resulting in cost savings for travelers. Mode shifts can also contribute to significant energy savings and emission reductions. A mode shift from single occupancy vehicles to transit buses would reduce the total number of vehicles on the road, significantly reducing fuel consumption and emissions. The congestion relief also provides fuel savings and emission reductions for the vehicles remaining on the highways.

We used the 20 mile travel distance between Long Beach and Los Angeles Downtown as an example. Two potential driving routes through I-710 N and I-110 N are possible. The driving time is about 25 minutes without congestion. However, I-110 and I-710 are highly congested during the morning and evening peak hours, causing the travel speed to often be as low as 15 mph. Consequently, the driving time can be as long as 100 minutes. If passengers take the Metro Blue Line, the travel time is 30 minutes. Shifting from either freeway would save substantial amount of time during the peak hours. Mode shift from single occupancy vehicles to transit would reduce the total number of vehicles on the road, and at the same time significantly reduce fuel consumption and emissions for the vehicles whose drivers make the mode shift. Based on an assumption for the number of drivers who make the mode shift, the estimated energy savings and emission reduction due to people changing from single occupancy vehicles to transit is summarized in Table 3-1[2].

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[2] (1) based on TTI report, the congestion cost = 15.47$ per hour. (2) Based on PeMS data, peak hours are generally from 7AM to 8:30AM and from 4:45PM to 6:15PM everyday; on average 3 hours are peak hours; (3) miles per gallon when speed is 15 mph is assumed equal to 15 (www.mpgforspeed.com); (4) CO_2 emissions from a gallon of gasoline = 19.4 pounds/gallon (www.epa.gov/oms/climate/420f05001.htm)

Table 3-1 Savings from Mode-Shift Based on Peak hours

(travel time saving 70 min; congestion cost saving per person: 18:04$; round trip saving: 36.08$)

Total drivers who make mode shift	Daily congestion costs – Saving (round trip)	Annual congestion costs - Saving	Daily Energy Consumption –Saving (Weekday)	Annual Energy Consumption –Saving (265 work days)	Daily Emission Reduction (Weekday)	Annual Emission Reduction (265 work days)
500	18K	4.8M	1330 Gallons Gas	0.35 M Gallons Gas	25.8K lbs CO_2	6.8M lbs CO_2
1000	36K	9.6M	2660 Gallons Gas	0.70M Gallons Gas	51.6K lbs CO_2	13.7M lbs CO_2
1500	54K	14.3M	3990 Gallons Gas	1.06M Gallons Gas	77.4K lbs CO_2	20.5M lbs CO_2
2000	72K	19.1M	5320 Gallons Gas	1.41 M Gallons Gas	103.2K lbs CO_2	27.3M lbs CO_2

3.2   Condition of the City and County of Los Angeles

Los Angeles County covers 4,061 square miles and has a population of 9,818,605 (2010 U.S. Census Data), which is the largest county in the United States by population. Figure 3-1shows a map of Los Angeles County.

Figure 3-1 Los Angeles County Map

There are 88 cities within the county and approximately 65% of the county is unincorporated. The central city of the county is the City of Los Angeles, the second largest city in the United States by population. It covers 469 square miles and has a population of approximately 3.8 million (2006 U.S. Census Data).

In recent years, the Los Angeles Metropolitan area was ranked by the Urban Mobility Report[3] as one of the top three most congested urban areas in the United States by all three measures: annual delay per traveler, travel time index and wasted fuel per traveler. According to the study, the average traveler in Los Angeles area experienced 70 hours of traffic delay per year, spent 49% more time on the road in peak period than under free-flow conditions and wasted 53 gallons of fuel per traveler per year.

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[3] Urban Mobility Report 2015. Texas Transportation Institute, 2009-2015.

3.2.1 Major Roadways

Caltrans District 7 operates and maintains 527 center-line miles of freeways in Los Angeles County, as well as an additional 382 conventional highway miles. These roadways are listed in Table 3-2 Caltrans District 7 Roadways.

Table 3-2 Caltrans District 7 Roadways

Freeways	Conventional Highways
US 101	State Route 1 (SR 1)
Interstate 5 (I-5)	SR 2
I-10	SR 19
I-105	SR 39
I-110	SR 42
I-210	SR 72
I-405	SR 90
I-605	SR 138
I-710	SR 126
State Route 2 (SR 2)	SR 107
SR 14	
SR 57	
SR 60	
SR 90	
SR 110	
SR 118	

The freeways are equipped with Vehicle Detection Stations (VDS), Closed-Circuit Television (CCTV) cameras, Changeable Message Signs (CMS), and Ramp Meters Stations (RMS) at entrance ramps, and Highway Advisory Radio (HAR). These ITS field elements are connected to the Caltrans District 7 Transportation Management Center (TMC), located in downtown Los Angeles[4].

The Los Angeles Department of Transportation (LADOT) operates and maintains 1,400 miles of major and secondary arterials in the City of Los Angeles, with about 4,300 signalized intersections.

3.2.2 Transit Services

The primary and largest regional public transportation agency is the Los Angeles County Metropolitan Transportation Authority (LACMTA or Metro), which provides bus, light rail and subway services throughout Los Angeles county and averages 1.6 million transit trips per week day. Metro operates 183 bus routes with a total 2,228 fleet buses that covers a 1,433 square mile service area and has 2,000 peak hour buses on the street on any giving business day. Metro also operates 79.1 miles of Metro Rail service. The Metro Rail system is composed of the Metro Red Line and Purple Line subway system, and the Metro Blue/Green/Gold Line light rail system. The

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[4] Los Angeles County Regional ITS Architecture. November 2004.

average weekday daily boardings for May 2011 are 1,141,389 on the Metro Bus System and 301,501 on the Metro Rail System.

LADOT operates its own Commuter Express bus service with nearly 400 vehicles to outlying suburbs in the city and the popular DASH (Downtown Area Short Hop) mini-bus service in downtown Los Angeles and to other neighborhoods in the city.

Other large operators include Long Beach transit (LBT), Santa Monica Big Blue Bus (SMBBB), Foothill Transit and Torrance Transit.

3.2.3 Parking

LADOT operates approximately 37,000 on-street metered spaces in 71 Parking Meter Zones and an additional 3,000 spaces in 60 off-street lots and garages. Through the ExpressPark Pilot program, 5,500 on-street meters and 7,500 off-street parking facilities are being equipped with smart sensors to provide travelers real-time parking availability and pricing information. The information is currently provided through the private company Streetline Inc. for Hollywood and Studio City, and has been released to the public for the whole ExpressPark program in the Fall of 2012. Significantly more off-street parking spaces are owned and operated by private entities. However, there are no accurate statistics about the private parking facilities in Los Angeles and the majority of these parking facilities are not instrumented with real-time parking availability information.

3.2.4 Commute Profile

According to 2009 U.S. Census data, of 4,388,488 workers over 16 who did not work at home in Los Angeles County, 72.2% commuted to work driving alone, 11.1% commuted by carpooling and 7.3% commuted on public transportation (excluding taxicab). The average travel time by mode is 27.1 minutes for driving alone, 30.9 minutes by carpooling and 47.1 minutes by public transit, with an average of 28.6 minutes across modes. However, a 2006 survey study[5] conducted by SCAG (Southern California Association of Governments) revealed a different commute profile. According to the 2012 State of Commute Report, 72% of LA County workers commuted to work driving alone, 13% by carpooling and 9% by public transit. The mode of commute is consistent with the 2009 U.S. Census data. The average one-way commute distance is 18.4 miles and the average commute time to work is 43 minutes, considerably higher than the 2009 U.S. Census data. In addition, 88% of LA County commuters' work place are also located in LA County, 62% of commutes used freeways, and 8% of commutes have to pay for parking. The 2009 US Census data and 2006 Survey study conducted by SCAG were the two most updated studies at the time the STC project was implemented. Note also that traffic declined during the economic downturn in the late 2000s and early 2010s and has increased dramatically when the STC study was carried out.

3.2.5 RIITS Data and Contains

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[5] State of Commute Report 2006. SCAG. December 2006.

RIITS stands for Regional Integration of Intelligent Transportation Systems. It is a communication network that supports the real-time exchange of information to help manage the regional transportation system. Metro sponsors RIITS with vital support from relevant Caltrans Districts, LADOT, the California Highway Patrol (CHP), Long Beach Transit (LBT), Foothill Transit (FHT), all of which contributing information collected through their own Intelligent Transportation Systems to the RIITS network using the Los Angeles County Regional ITS Architecture and Notional ITS Standards. The RIITS Network covers the entire Southern California region but focuses primarily on Los Angeles County. Figure 3-2 The RIITS Network: Data Providing Agencies and Output summarizes the current data that agencies provide and output from the RIITS Network.
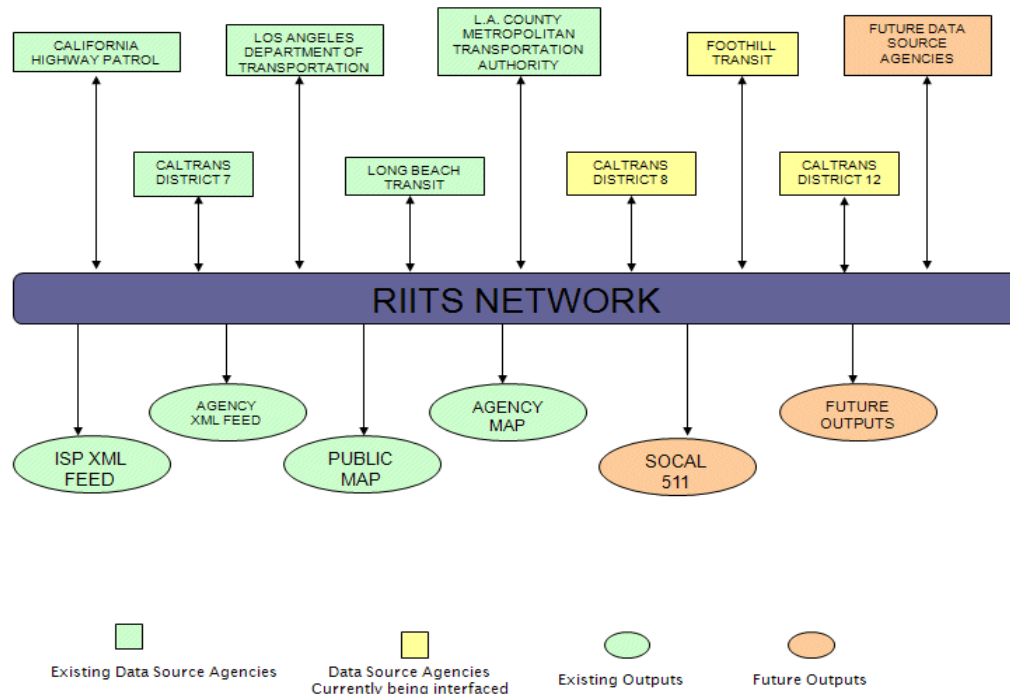
Figure 3-2 The RIITS Network: Data Providing Agencies and Outputs

Current baseline data from the RIITS Network includes information concerning:
- 1200 freeway vehicle detectors (Caltrans District 7);
- 100 freeway video surveillance systems (District 7);
- 100 changeable message signs (District 7);
- 3500 arterial traffic signals (LADOT) ;
- 2800 Metro Buses and 150 LBT buses;
- Metro light rail and heavy rail;
- CHP incident reports; and
- Caltrans freeway closure data

RIITS data are free to public agencies involved in transportation upon agreement with the RIITS Network. PATH has obtained the agreement to query real-time data from the RIITS Network. Data from RIITS network are in two categories: Inventory data and real-time data. Inventory

data are static freeway, arterial, and transit network configuration data, such as freeway/arterial loop locations, transit routes, stops, fares, and schedules, etc., while real-time data include the dynamic attributes that describe freeway, traffic and transit conditions. The inventory and real-time data sets are provided by different agencies, with various updating rates, as summarized in the table below.

Table 3-3 Data Provided by R/ITS

Category	Description	Agency	Attributes	Update Rate
Travel Time – Inventory	Static link configuration	Caltrans D7 (Freeway)	LinkID, route, direction, linkType (freeway/arterial), beginNode (ID, lat&lon) , endNode (ID, lat&lon), linkLength	Midnight
Travel Time – Real time	Dynamic link speed	Caltrans D7 (Freeway)	LinkID, linkSpeed, linkTravelTime	1 minute
Congestion – Inventory	Static detector configuration	D7 (Freeway) LADOT (Arterial)	LinkID, streetName, direction, lat&lon, # of lanes, laneType (freeway/arterial)	Midnight
Congestion – Real time	Dynamic detector info	D7 (Freeway) LADOT (Arterial)	LinkID, occupancy, volume, speed	1 minute
Event	Dynamic event info	D7 CHP	eventID, location, eventType (incidents, closures , planned closures, and special events), severity (none, minor, major, and natural disaster), affectedLanes, startTime, endTime	1 minute
Transit – Inventory	Static transit (bus/rail) data	MTA Metro	Configuration of routes, stops and schedules	Quarterly
Transit – Real time	Dynamic transit (bus/rail) AVL data	MTA Metro	vehID, lineID, routeID, direction, lat&lon, scheduleDeviation, nextTimepoint, timepointTime	(bus) 2 minutes (rail) 1 minute

3.3   Selection of Field Test Corridors

The project team worked with Caltrans District 7 and LAMTA to select two test corridors in LA. The selection criteria of test areas focused on the FOT objectives and evaluation needs. Of particular interest would be a corridor where users would have competitive travel times during commute hours across highway and transit modes, and convenient connections among modes. METRO ridership profiles were used to identify appropriate locations for these tests. Recognizing the work locations of most potential volunteers, we identified two downtown-oriented corridors as candidates for the study. Each features frequent transit service with convenient park-and-ride lots for commuters to switch modes mid-route. Since the purpose of the application was to inform travelers with real-time highway and transit trip information, including updates on incidents, these corridors were deemed ideal for testing how additional real time information affects commuting behavior. An additional benefit is that most of the commuter transit service is provided by only a few transit agencies, which streamlines data collection for the evaluation study and places only a smaller burden on available servers than would be the case for a region-wide trial.

Corridor #1: Long Beach to Downtown Los Angeles

This corridor connects two Los Angeles subregions--the Gateway Cities and Southbay Cities subregions--with downtown Los Angeles. At the end of the corridor, Long Beach is the second largest city in Los Angeles County.

Transit Service: The two main express transit lines that serve this corridor include LA Metro's Blue Rail Line and Silver BRT Line (shown in Figure 3-3). The Blue Line runs between the 110 and the 710 freeways, originating in downtown Long Beach. Roughly parallel to the 710 in Long Beach, it veers northwest toward the 110 and downtown Los Angeles midway through the route. The Silver Line begins at the Harbor Gateway Transit Center in Gardena and runs along the 110 freeway to downtown. In addition to these two primary transit lines, LACMTA also operates additional express routes. Line 450 is a Metro Express route, which runs from San Pedro to downtown Los Angeles.

LADOT operates its Commuter Express 448 from Rancho Palos Verdes to downtown Los Angeles, with six buses in the peak direction at 20-minute headways. Beginning in Palos Verdes, it runs east and jumps on the 110 for the remainder of the route. Torrance Transit runs a weekday express service to downtown Los Angeles. Going from Torrance to downtown via the I-110 Express Lanes, Line 4 consists of four morning buses and four evening buses. Although a number of additional municipal transit agencies run transit service throughout the corridor area, these agencies provide only local service bus routes, and none were identified as having regional service from Long Beach to downtown Los Angeles.

Park-and-Ride Lots: Given the many park-and-ride facilities along the Blue and Silver Lines, there is many opportunities for mode shifts throughout the corridor. Also, since the vast majority of the park-and-ride facilities are free, there would be no additional cost for parking.

Seven stations along the Blue Line have free park-and-ride lots. The stations with free park-and-ride lots include: Florence (103 Spaces), 103rd St/ Watts Towers (63 spaces), Willowbrook (335 spaces), Artesia (247 spaces), Del Amo (332 spaces), Wardlow (114 spaces), and Willow St. (863 spaces). In addition to the free park-and-ride lots listed, there are also additional private lots near most of the Blue Line Stations.

Five stations on the Silver Line south of downtown Los Angeles have free park-and-ride lots. These stations include Slauson (151 spaces), Manchester (247 spaces), Harbor Freeway (253 spaces), Rosecrans (338 spaces), and Harbor Transit Gateway Center (980 spaces).

Corridor #2: Pasadena to Downtown Los Angeles

From Pasadena, the two freeways toward downtown include the Arroyo Seco Parkway-110 and the SR-2 (via the SR-134). We selected the second corridor to include travel between and directly surrounding these major thoroughfares, which connects downtown Los Angeles to the communities of Glendale, Eagle Rock and Pasadena, shown in Figure 3-4.

Transit Service: The primary transit line serving this corridor is the Gold Line, currently running from the Sierra Madre Villa station in Pasadena to Union Station in downtown Los Angeles. The route roughly parallels the 110, which would make it easy for a commuter to exit the 110 and transfer to the Gold Line. Also, LADOT operates Commuter Express 409 along SR-2 from Glendale and Eagle Rock to downtown Los Angeles. In addition to the commuter express services, Metro operates Local Lines 81 and 84 from Eagle Rock to downtown Los Angeles with 15-minute headways in the morning. No additional transit agencies were found to have downtown-oriented services.

Figure 3-3 LA Metro Blue and Silver Lines

Park-and-Ride Lots: There are several free park-and-ride lots along the Gold Line. Stations with
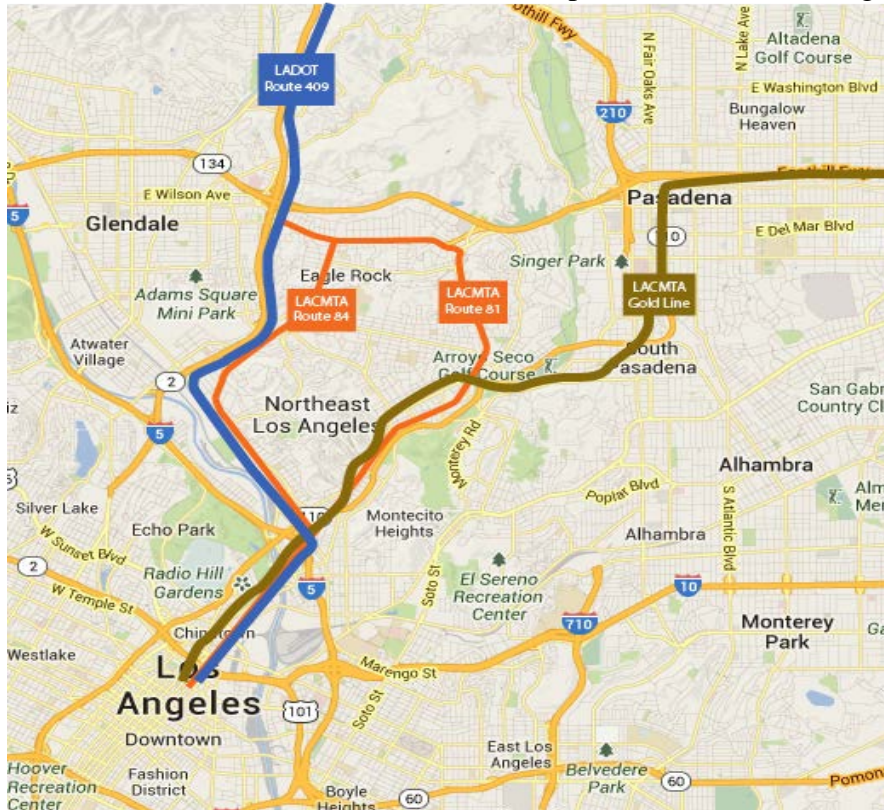
free park-and-ride lots include Sierra Madre Village (877 spaces), Fillmore (130 spaces), South Pasadena (120 spaces), Heritage Square (123 spaces), and Lincoln/Cypress (84 spaces). Stations with paid reserved parking include Sierra Madre Village (88 spaces), Lake (50 spaces), Del Mar (610 spaces), Fillmore (30 spaces), Heritage Square (six spaces), and Lincoln/Cypress (10 spaces).

Figure 3-4 Transit Lines between Downtown LA and Northeast LA

The characteristics of the two corridors are provided in Table 3-4.

Table 3-4 Summary of the two corridors

	Corridor #1: Long Beach to Downtown Los Angeles	Corridor #2: Pasadena to Downtown Los Angeles
Driving distance	21 miles	11 miles
Driving time	26 (38) minutes	19 (27) minutes
Alternative routes	I-110 / I-710	HW101 / HW134
Alternative mode	Metro Blue Line 6-minute headway 86,485 weekday boardings 44 minutes (183%) Metro Silver Line 6-minute headway 12,311 weekday boardings 32 minutes (172%)	Metro Gold Line 6-minute headway 44,116 weekday boardings 26 minutes (136%)
Parking	At selected Blue & Silver Line stations	At selected Gold Line stations

3.4 Beta Testing

As the Trip2go application nears readiness for deployment, thorough testing of the app for its effectiveness was conducted. The purpose of this phase of the study was to (1) find any yet unidentified errors in the programming of the application (2) test further the usability of the application and (3) identify specific problems faced by certain groups, as identified in the survey questionnaire.

PATH staff performed initial testing to debug the basic functionality and design of the application. Also, testing was conducted using the web interfaces for trip planning functions to fine tune the user interfaces

An independent test team then performed Beta testing to provide and objective, independent and heuristic evaluation of the Trip2go system. The task for the Beta test participants was to use the Trip2go app for random trips to test if trip plans were reasonable, the trajectory tracking was accurate, the transfer and arrival alerts given at various stage of the trips were correct, and the overall performance of Trip2go was acceptable. To form the test team, a workshop was organized with students of the University of California at Los Angeles. Workshop participants were introduced to the Trip2Go Application and instructed to download it on their smartphones. Feedback was obtained at the workshop and interest was gathered for the participating independent Trip2go evaluation. Subsequently, four students were chosen for the Beta tests.

Test participants conducted multiple trips per day for several months. When taking each trip, the test participants plan their trip, confirm the trip option and then take the trip following trip instruction(s) and alert(s). They verified that the information about traffic and travel times for both driving and transit is correct and provided in a timely manner. Detailed notes are taken as to how trip information and instructions are compared with actual situations. Test participants then discussed with PATH staff any problems encountered and recommendations for possible improvements. During the course of the tests, technical issues associated with the trip planner, localization and association of passenger/bus, and arrival prediction were debugged.
Upon completing the trial testing, Caltrans project managers and PATH staff conducted an evaluation test and made a judgement according to generally agreed-upon usability principles to proceed with the field operational test.

The project initially planned a Pilot Test phase to introduce the application to a wider group of people who would test the application as part of their daily commute. However, the project schedule did not allow the Pilot test due to project delays in the technical development phase. As the number of possible tests for even simple software components is extremely large, the project team felt that the trial testing had helped to resolve major software errors and the app was ready for the actual Field Operational Test. During the FOT, participants reported issues and difficulties.. However, once understood, the participants were mostly able to use the app independently.

3.5 Data Collected Through Field Operational Tests of Trip2go

A key feature of Trip2go, compared with off-the-shelf trip planning tools, is the data gathering capability. Trip2go collects and archives a large amount of data to support the evaluation study. Three types of data are collected and saved by the Trip2go system, as summarized in Table 3-5. Table 3-6, Table 3-7 and Table 3-8 further describe the user survey data, usage data and transit/traffic data. Various database tables to store and manage the collected data for future analysis were also developed. These tables include storing searches and trip planning data for different modes, data capturing the trips that users select and data capturing the conditions of the multimodal networks at the time when trips are planned and then made (if travel data are available). Furthermore, tools for associating different types of data (and database tables) were also developed to support the relationship analysis between mode selection and current conditions of the multimodal network, captured in relevant database tables.

Table 3-5 Overview of data

Type	Description
User Survey	Surveys (voluntary or invited) hosted on project website. We had both anonymous surveys (main survey held by independent evaluator) and surveys that are linked to a user.
Usage data	User clicks on the web site, user inputs to the trip planner and other API calls to the server that are originated by the users have also been recorded.
Transit / traffic data	Static transit data: schedules, transit routes; Real-time transit data: Real-time arrival information at bus stops are archived.

Table 3-6 Survey Data

Type	Description
Post-account creation survey	Voluntary: detailed user information, including home zip code, household income, industry, commute distance, commute time, mode and major source of traveler information Had about 300 survey responses
Project survey by independent evaluator`	1. Anonymous survey 2. Many questions asked, mainly on the user feedback / satisfaction ; 3. 100+ survey responses
En route feedback	1. Associated with a user id; 2. Can be associated with a trip after some extra processing; 3. A simple question (usefulness of information) was asked. 4. On mobile phone only.

Table 3-7 Usage Data

Type	Description
Trip planning	1. Origin and destination (Latitude and longitude) 2. Date and time 3. mode 4. User id (anonymized, but can be associated with trips from same user)
Check trip information (associated with a trip planning result)	1. User checking for trip update after planning a trip 2. Is associated with user id and a trip 3. Some requests come with location 4. Date and time
Check real-time information (web / mobile)	1. User checking for real-time arrival information 2. Can be associated with user id 3. Date and time
Check real-time arrival information without trip planning	1. Can be associated with user id 2. Route and stop 3. Date and time

Table 3-8 Transit / Traffic Data

Type	Description
Transit static data	1. Transit schedules for all bus routes operated within LA county 2. Route GIS information (location of stops, stop name, stop sequence etc);
Transit real-time data	1. Predicted arrival time of a bus / train at downstream stops / stations for MTA buses;

While a rich set of data was collected and saved by the Trip2go system, data gaps still existed. Most notably, in addition to LACMTA, LA County is also served by a number of transit agencies for adjacent cities. However, real-time GPS data is not always available for some transit buses. Trip2go would have to apply schedule-based data instead, for which the prediction time accuracy for such bus trips would be negatively impacted.

3.5   *Preparation for the Field Operational Test*

In order to ensure that the field operational test is successful, the project developed plans for FOT testing and support, user recruitment and outreach. An evaluation plan was also developed. The plans defined the objectives, hypotheses, measures of effectiveness (MOEs), approaches and data sources that the evaluation team identified for evaluation purposes, and methods to extract MOEs from the data that were collected during the FOT.

As a critical FOT step, the project team devoted substantial effort in preparing for soliciting participation of volunteer travelers. The project team sought people who were able to use multiple modes of travel for their commutes between home and work. The plan identified volunteer recruitment instruments in collaboration with Caltrans and METRO and recruiting messages were developed to explain the benefits of Trip2go. When recruited, potential participants were informed that they would be responsible for completing structured survey instruments and that they would be invited to participate in focus groups based upon their experience.

The recruitment plan targeted participants who were willing to participate from among smart phone users who commute within the designated test corridors. The participants were to be a "random" sample of commuters, and were recruited using a variety of blogs, website recruitment announcements and employer e-mail network announcements. Incentives also were planned as a part of the recruitment process. The initial plan was to win an Android pad or iPad Mini as a thank-you for their participation. The recruitment process was carried out by a UCLA graduate student under the direction of Professor Emeritus Martin Wachs. A great deal of interaction was anticipated, by e-mail and telephone, between the recruitment staff and potential participants.

User survey questions were designed for collecting feedback from participants to capture the following four main elements.

- The first element was to obtain baseline information about the participants – their demographic, geographic, and commuting fundamentals.
- Their assessment of the technical characteristics of the tool that they have been using – the effectiveness and clarity of the user interface and of the quality of the information that they have been provided.
- How often they used Trip2Go, for what purposes, and whether or not it influenced their travel choices or decision-making. This would provide an early indication of whether or not it would be possible to subsequently model the impacts of the experiment on travel behavior, probably with a larger sample.
- A stated preference experiment to gather travel choice decisions from the users based on hypothetical settings. This behavioral response data was combined with real world data to develop detailed travel choice models.

The recruitment process and surveys were submitted to the campus Committee for Protection of Human Subjects (CPHS or IRB) for review and the project team received approval.

After system debugging, the Trip2go system was prepared for data collection. Sample data on Trip2go usage, including searching activities and travel behavior data, were collected on the PATH data server and have been evaluated by the evaluation team.

Trip2go was set up on Google Play where people can register as participants, after which their qualifications would be assessed.

3.6   Field Test

Field testing of Trip2go was conducted between Feb 2015 and September 2015. During the FOT, the project team worked with stakeholders to solicit participants. Also, the Trip2go system was continuously maintained throughout the FOT period.

3.6.1 Recruitment Methods and Experience

The project team recruited participants according to the user recruitment plan. The goal was to engage with at least fifty Los Angeles commuterswith access to Trip2go via the Android smart phone and travel along the test corridor to generate 500 trips.

The initial outreach effort was to recruit test participants among constituencies who were considered to be familiar with transportation operations and sympathetic to the development of this application. Under consideration for recruitment as participants were:

> Employees of Los Angeles County Metro
> Employees of Caltrans, District 7
> UCLA graduate students and staff
> Members of FAST (Fixing Angelinos Stuck in Traffic)
> Subscribers to transportation related blogs and newsletters, for example LA Streetsblog

The project team worked with LACMTA and Caltrans D7 to develop messages for the outreach efforts.

> "*Volunteers needed for travel app testing*
>
> *Are you interested in helping test a new application for travel conditions, transportation options and efficiency? Do you live in Pasadena or Long Beach and work in downtown Los Angeles? Do you have an Android smartphone? You may be just the person we're looking for.*
> *The Partners for Transit and Highways (PATH) Program at the University of California is testing a new computer application in the LA Area. Similar to how WAZE and Google provide you traffic conditions, this app provides highway and transit options based on real-time traffic and transit data. Users can set up alerts for current incidents, and then get information about transit and park & ride options instantaneously so they can switch to an alternate mode of travel on short notice.*

Volunteers are needed to try the app and to help improve it by responding to online questions. Volunteers may also be invited to attend focus group discussions. As the testing continues, we would also like to know whether and how volunteers use it in daily commuting.

Participants will be eligible for a monthly prize drawing with new and different prizes to be announced each month. The participant group will most likely be small, so the probability of winning a prize will be favorable.

If you are interested, please send an e-mail message containing your contact information to: Trip2go@gmail.com"

Recruitment took place by using e-mail blasts distributed to the chosen categories of commuters, employing e-mail lists provided by the parent organizations. Candidates were informed that participation is entirely voluntary and would not affect their employment. Once a user who signed up for the study is reviewed through the entry survey based on initial selection criteria, he/she is sent detailed instructions on how to employ Trip2go in planning their daily travel and how to manage both trip planning information and en-route alerts. The participants were also informed on how to seek further instruction and how to ask clarifying questions of the project technical staff. Interaction was typically not necessary at this phase of the test for a majority of participants.

This initial recruitment effort resulted in a list of two dozens of volunteers. While the project team anticipated a fairly high dropout rate, very few participants actually tested Trip2go and only two participants completed 10 trips.

The PATH team evaluated the situation and determined that the outreach message placed more emphasis on testing the Trip2go app instead of evaluating the impact of the information. With this understanding in mind, participants likely would try the app and determine that it is not as user friendly as other commercially off-the-shelf trip planning products such as Google and WAZE and give up. The second possible factor for low motivation might be the incentive method. Recent studies have shown that a lottery is much more effective than a cash equivalent bonus for attracting participants in studies of this kind.

Although Trip2go has more complete real-time information about the region and added functionalities, given the constraints of developing Trip2go, the user interface and system usability are immature as compared with other commercial products. Since the goal of Trip2go project was to evaluate the impact of information on travelers' trip decision-making, not to conduct a product evaluation, the outreach message wasmodified to better reflect the intent of the project.

"PARTICIPATE IN TRANSPORTATION RESEARCH PROJECT

Volunteers are needed to participate in research about daily travel in the Los Angeles area. Participation will be fun and easy, and participants will receive gift cards worth up to $100. You are eligible to participate if you have an Android Smart Phone and live

and work in the travel corridor that runs from Pasadena through downtown Los Angeles to Long Beach.

Trip2GO is a trip planning app that supports research assessing how real-time information informs travelers making daily travel decisions. The trip planning tool provides side-by-side comparisons of transit, driving, driving to transit, and transit-only modes, sorted by travel time, cost or environmental impact. Trip2GO also provides driving directions, real-time updates on traffic condition, park and ride options, and real time arrivals for bus, train, and transfer connections. Trip2GO covers the driving routes for the entire L.A. region and transit routes served by Metro, Foothill Transit, and Long Beach Transit.

Participants will complete a couple of questionnaires on line about their households and travel choices, and can earn more rewards by filling out fewer than a dozen shorter questionnaires about daily trips. The research team will analyze the data and use the results hopefully to improve travel forecasting and planning.

If you live and work in the research corridor and have an Android smart phone, you may click "here" for more detailed information about the app, the research, and the rewards for participating."

In this round of outreach, we also changed the incentive method by providing two $50 gift card rewards at two milestones of the FOT. The changed messages, as well as the incentive method, were resubmitted to CPHS for review and the project team again received approval.

The new outreach message, instead of asking the volunteers to help to develop a new product, we asked participants to help the region's transportation planning and forecasting by volunteering their time in the role of evaluators. We also determined that MTA's BLOG had the largest number of readers and was more effective in drawing interest from potential participants. In the follow-on outreach efforts, MTA's BLOG was the primary means for delivering our outreach message. Additional outreach via posts on Twitter and Craigslist was also performed to increase awareness of the environmental- and commuter-friendly research by Caltrans and UC Berkeley/ITS/PATH.

The new outreach message and incentive method have drawn significantly more volunteers. The project team also devoted significant efforts interacting with participants via e-mail and phone calls. The recruitment of participants continued until at least 50 participants were registered.

3.6.2 Interaction with FOT Participants

The project team continuously tracked how participants used Trip2go, particularly how often users returned to use Trip2go. Daily surveys were sent at 8pm each evening to participants who completed trips during that day. Project team members evaluated Trip2go's usage level and reminded those who signed up but had not yet used Trip2go. Participants were given an e-mail address and telephone number to contact project staff with questions about using Trip2go and to which they could convey observations about system performance while they were using the app.

3.6.3 FOT Support

The project team provided continuous support on the use of Trip2go during the FOT. PATH staff performed regular system maintenance, including server maintenance, data backup, periodically removing the large amount of data to a secondary data server to save space, monitoring the program reliability, automated email reporting and prompt handling of potential exceptions. Transit schedules were seasonally updated to support the FOT.

3.6.1 Summary of FOT

Between February 2015 and September 2015, we conducted four rounds of recruitment, in which 316 people signed up to volunteer for the field testing. A total of 83 volunteers were deemed qualified for the Trip2go FOT. Among these volunteers, 65 people participated in the entry survey and were invited to participate in the FOT. Thirty-seven active users finished at least one daily survey. Eighteen completed at least 10 trips. Among all participants, Trip2go was used 1135 times for trip planning and 334 times for trip advisory. Because some users may make trip plans and then follow the trip plan without keeping Trip2go active, we deem some of the planned trips real trips as well.

User daily activities for August and September 2015, including the number of daily surveys, daily planned trips and daily completed trips, are summarized in Figure 18. It is noted that our sample involves more people using trains and buses on more days than using private automobiles.
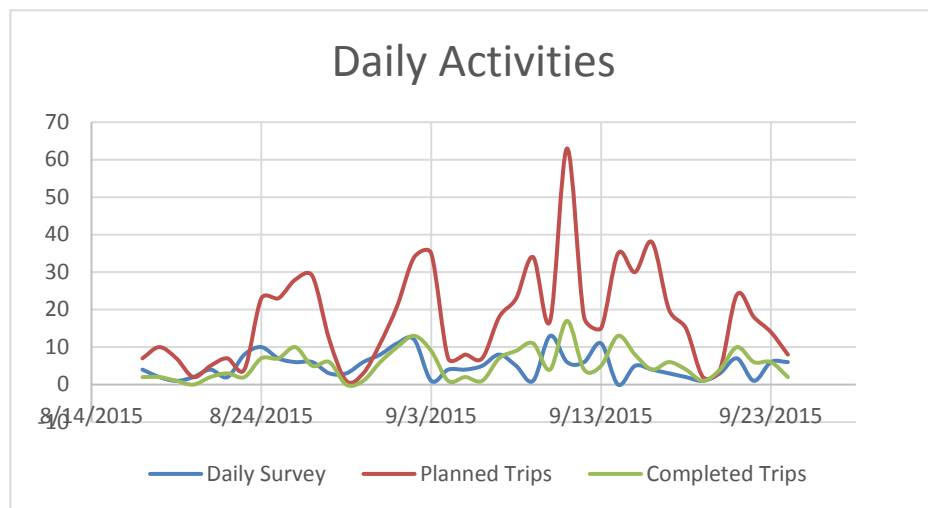
Figure 5 Daily activities

4.0 FOT Evaluation

The focus of the evaluation was to test the hypotheses that real-time multimodal information may potentially influence trip decisions for some travelers who have commute options and that their travel patterns including route changes, modal shifts and changes in the frequency of trip making may be adjusted based on recommendations from Trip2go or other trip advisory tools. The hypotheses were tested through three means, including (1) surveys of travelers' past trip behavior and their reflections of the trips taken based on recommendations by Trip2go, (2) development of statistical models of mode choice from the trip data, and (3) focus groups in which FOT participants were invited to share their impressions and evaluations of the performance of the system.

4.1 Surveys

The following flowchart shows the basic experiment setup and survey sending procedure.
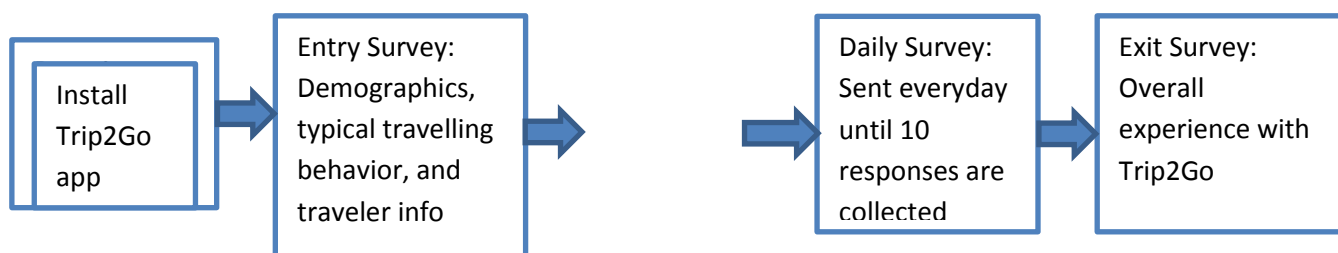
Questionnaire surveys of participants were conducted with each individual participant at three stages of the FOT. Detailed information is shown as follows (Appendix B, C, D documents the survey questionnaires):

- **Entry surveys** conducted after the initial sign-ups to collect information about the demographics, typical trip profiles, and current traveler information use of the volunteers. There were 65 users who have completed the entry survey that included 47 questions. All of the 65 users are employed and 85% of them are full-time wage earners.
- **Daily surveys** on the days that the Trip2Go app was used to obtain self-reported travel behavior changes and feedback on the quality of the traveler information. We have collected 359 daily surveys in total.
- **Exit surveys** were conducted to obtain information on their overall assessment of their experience with Trip2go after using the app for at least 10 days,

The responses to the structured questionnaire study results are summarized in the following sections. While responses to questions about Trip2go's technical aspects are certainly provided, additional focus is placed on the influence that the experiment has had on participants' travel choices and behavior as obtained from the daily surveys and the exit survey questions.

4.2 Survey Summary and Descriptive Statistics about Behavioral Change

In this section, we initially provide a brief summary of the surveys, and then present a statistical analysis about the users' travel behavioral change. Detailed summary for entry/daily/exit surveys can be found in Appendix E.

From the entry survey results, we know that 90% of the participants work five days a week and about 75% of them travel during morning and evening peak hours in a typical week. For the typical travel pattern, the users were asked to choose their transportation modes from the following options: drive (alone/carpool), transit (rail/bus), park-and-ride (drive to bus or rail), and other (walk/bicycle/telecommute). The following figure shows the distributions of different travel modes.
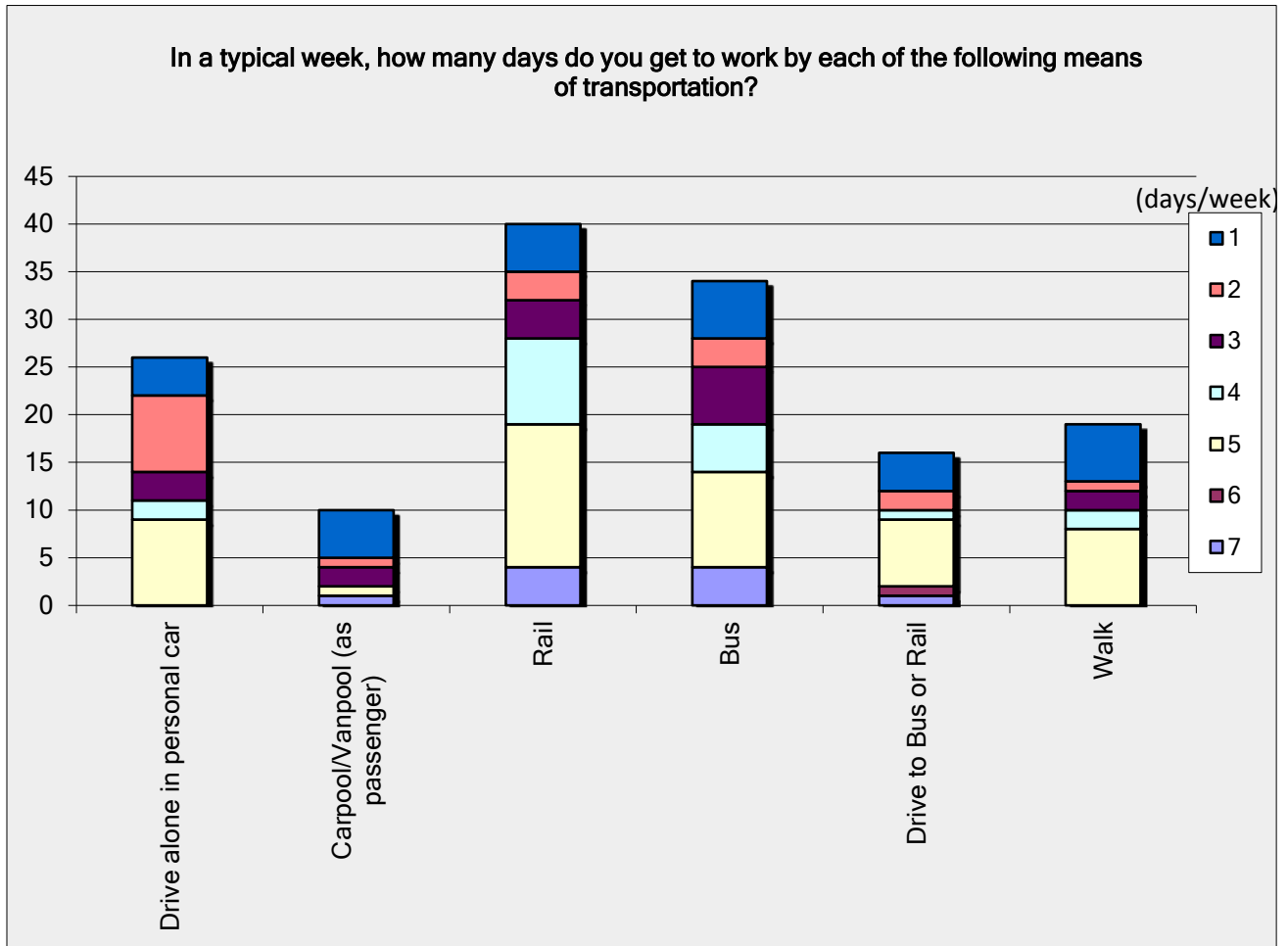
Figure 6 Typical travelling pattern reported in the entry survey (Source: Entry Survey)

Approximately seventy-five percent of the trips recorded in the daily surveys were commute trips to and/or from work. The distribution of transportation modes is similar as that in the entry survey, including drive alone, carpool, rail, bus, park-and-ride (drive to bus or rail) and others (walk or bicycle). For the real-time information sources for both commute and non-commute trips, nearly half of the users only use Trip2Go, the rest of them mainly use Google Maps, Go Metro or other apps. Compared to the commute trips, fewer people use Trip2Go and more people use Google maps for their non-commute trips. For the satisfaction rate, about half of the users are

satisfied with the performance of Trip2Go. The exit survey results show that nearly 25% of users used real-time information more than before participating in this experiment. Fifty percent of users say they are still using Trip2Go for their commute information and 20% of users use it for either non-commute information or en-route alerts. Users think that Trip2Go was useful in determining how to reduce emissions, what bus or train to take, what mode to use, etc.

From the survey results, we can see that most of the users are transit takers while driving or walking capture only a small share. We also want to know if the real-time information changes users' travel behavior, such as changing intended travel route, mode or departure time. However, the results show that only a small number of people changed their intended travel behavior due to the real-time information. The reasons would be that many users are transit takers and some of them do not have a car, thus they do not consider driving as an option, thus their transportation mode cannot be changed; if they have a car, they may not consider transit as a feasible alternative unless traffic is bad. From the daily surveys, we know that 75% of trips are commute trips, and that users' travel behavior changes are different for commute and non-commute trips. The following two figures show whether and how real-time information change users' intended commute or non-commute trips.
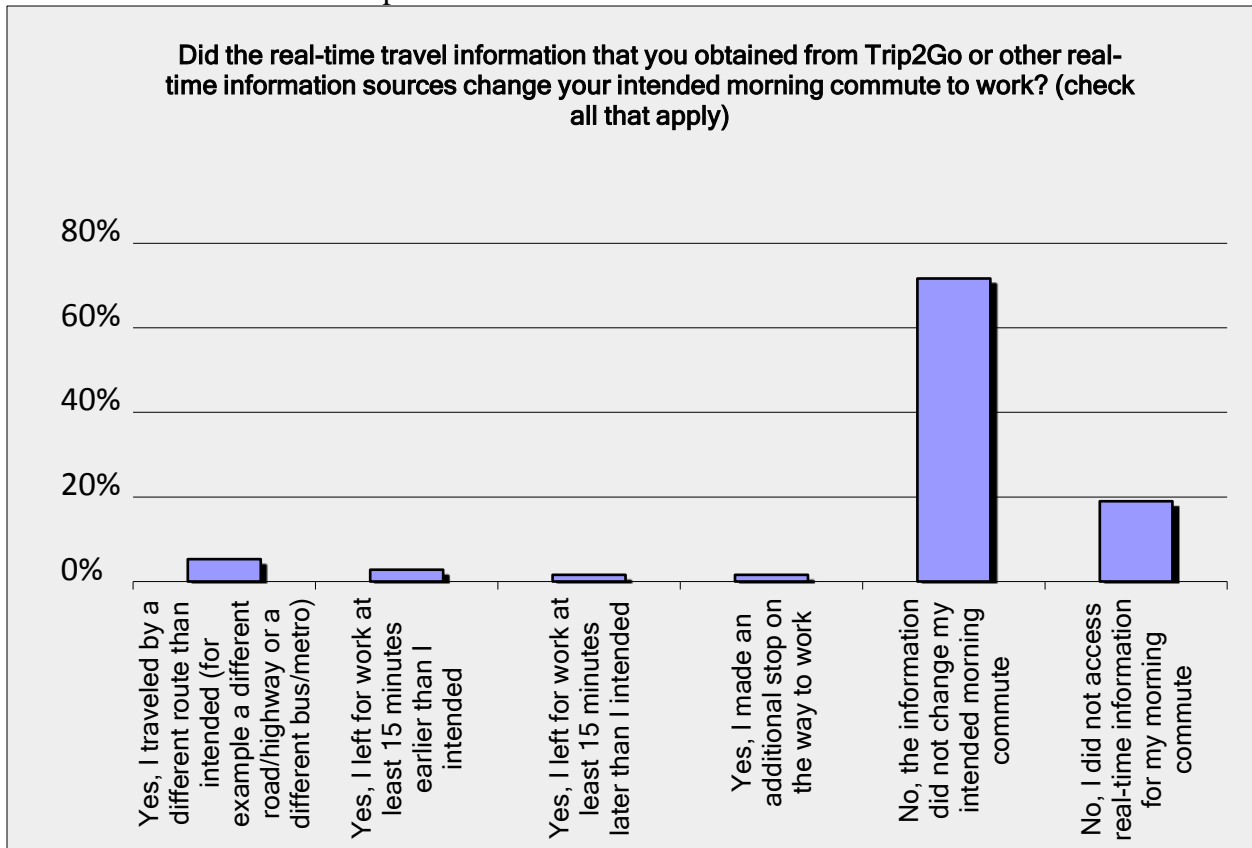
Figure 7 Real-time information on travel behavior change for commute trips (Source: Daily Survey)
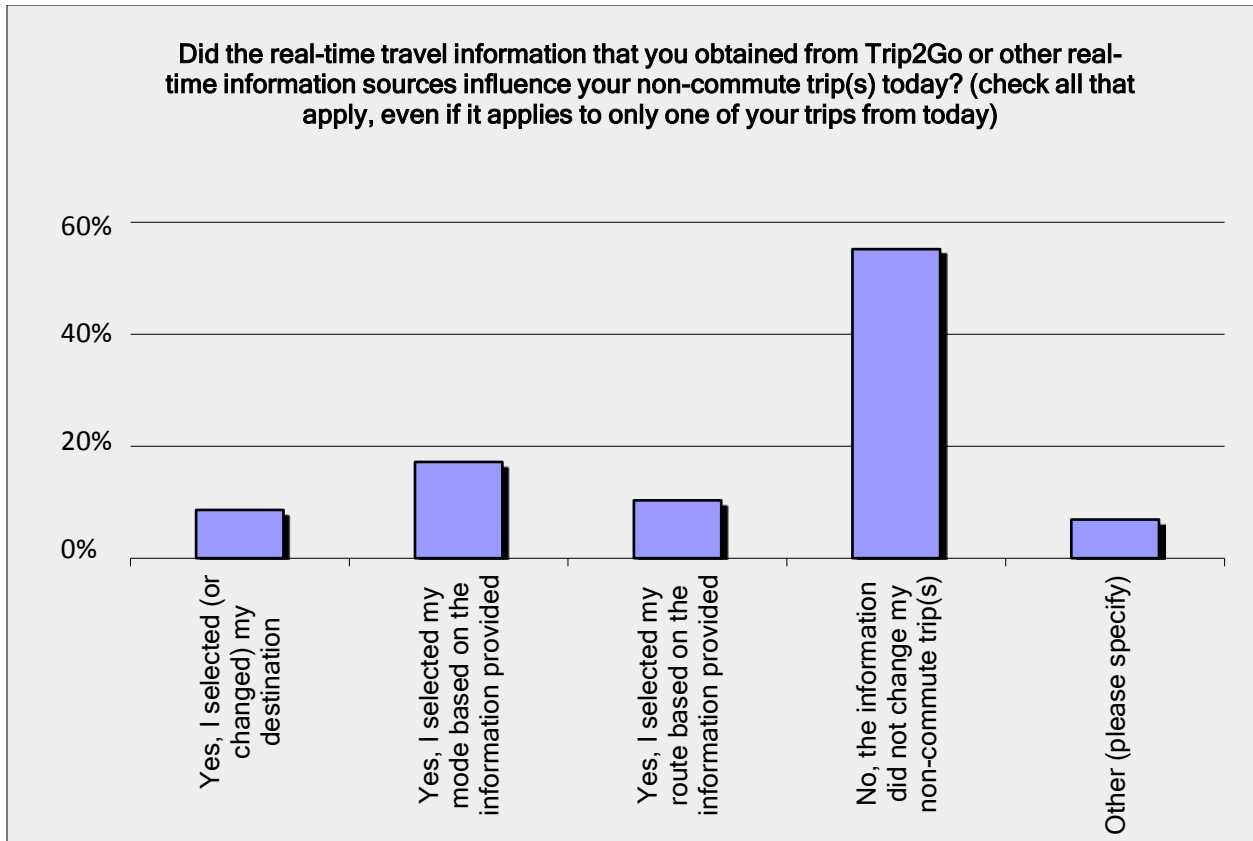
Figure 8 Real-time information on reported travel behavior change for non-commute trips (Source: Daily Survey)

We can see that less than 20% of the trips changed because of the real-time information for morning commute trips. (Evening commute trips are similar) The reason is that the origin and destination of these commute trips are always the same, and users are familiar with the typical travel conditions at that time of day, so they tend not to change their travel behavior for such trips. However, for non-commute trips, nearly 40% of them do change due to the real-time information and 50% of the changed trips are for a different travel mode.

We have 196 observations for morning commute trips, 199 observations for evening commute trips, and 64 observations for non-commute trips. Only four of 327 trips changed mode: one on the way to work and three on the way home from work (two switched to drive and two switched to rail); Of those changing route (road or bus/train): 91% driving, 9% carpool, 0% other; Of those changing time (earlier or later by at least 15 minutes): 37% driving, 15% carpool, 42% transit. For the travel modes in changed commute trips, 20% of them are driving, 11% are carpool and 50% are transit; for the changed non-commute trips, there are 25% driving, 7% carpool, and 40% transit.

For commute trips, we see that the real-time information has a larger influence on route and departure time decisions for driving travelers while it only affects the departure time for transit riders. The policy implication is that real-time information may influence drivers to avoid congestion and other undesirable traffic conditions for their commute trips, and this behavior change can improve the total performance of the network. The following figure shows behavior changes after participating in this experiment.
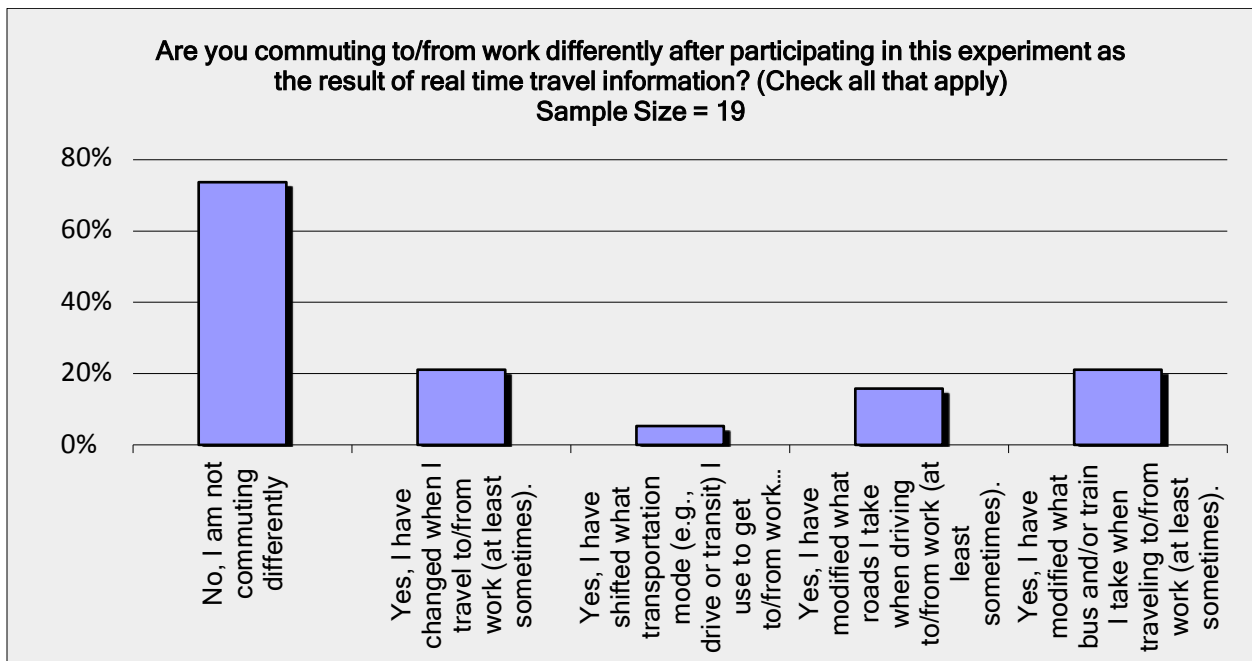
Figure 9 Travel behavior change for commute trips (Source: Daily Survey)

Because of the real-time travel information, approximately 30% of users changed their travel behavior, such as different transportation mode, route or departure time. However, since the sample size is small (only 19 users), only one user changed her transportation mode.

4.3 Mode Choice Model Development

This project presents a unique opportunity to study behavioral response to information in a real-world setting. While there is a large body of literature that aims to quantify the impact of traveler information, almost all of it is based on data collected in laboratory and/or hypothetical settings. The few field tests of information systems analyze the response at an aggregate or descriptive statistical level, not making use of the detailed models of individual behavior that populate the studies conducted in the laboratory. One of the issues with developing models from real response data (called revealed preferences) is that the attributes of the alternatives (time, cost, and emissions) are highly correlated with one another and this multiple co-linearity makes it difficult to estimate the behavioral models.

Currently, travelers have become more informed with real-time traffic information resulting from the development of advanced traveler information systems (ATIS). ATIS help travelers to avoid congestion, lower travel cost and become more efficient in making decisions. Research has been performed in various kinds of ATIS, such as variable message signs (Emmerink, Nijkamp et al. 1996, Lee, Choi et al. 2004), radio (Emmerink, Nijkamp et al. 1996), and telephone (Bratt, Dowding et al. 1995). ATIS basically provides static information, or pre-trip information (Polak and Jones 1993), such as schedules, properties of network, and fares. ATIS also gives travelers dynamic information, or en-route information (Van Berkum and Van der Mede 1998), such as congestion, accident, and real-time traffic conditions. There are three types of data for behavioral analysis in ATIS: simulated, stated preference (SP), and revealed preference (RP) data (Chorus 2007). For simulated data, travelers are often assumed to have a certain type of travel pattern, and simulated data is generated base on real-world traffic scenarios. This type of data is always used to validate feasibility of models (Ettema, Tamminga et al. 2005). SP data is obtained by offering respondents hypothetical choice alternatives, always by means of SP surveys (Fujii and Gärling 2003). However, SP data has its own limitations since it approximatesfor real world situations. We get RP data by observing what travelers behave in actual travelling activity. But RP data is sometimes hard to obtain because transportation information services are not available (Chorus 2007). In this case, SP data can only be used to analyze traveler behavior. However, combining SP and RP data is a good approach to fully understand traveler response in both pre-trip (Khattak, Polydoropoulou et al. 1996) and en-route (Polydoropoulou, Ben-Akiva et al. 1996) to ATIS.

Information from ATIS would influence route choice behavior and departure time decisions (Liu and Mahmassani 1998, Mahmassani and Liu 1999). (Owens 1980) did research in drivers' route-choosing behavior in response to two different kinds of pre-trip messages. In (Abdel-Aty, Kitamura et al. 1997), binary choice model is estimated by SP data for understanding effect of ATIS on commuters' route choice. Also, (Abdel-Aty and Abdalla 2006) use simulated data to estimate five different models to address drivers' route choice. A multinomial probit model is used to understand commuters' route choice decisions (Mahmassani and Liu 1999). Discrete choice models are always applied in analyzing and predicting travel behavior (Ben-Akiva and Bierlaire 2003). Departure times and route changing in ATIS of both pre-trip and en-route decisions are discussed in (Khattak, Schofer et al. 1995). (Jou 2001) uses probit model to analyze impact of pre-trip information on commuters' choice behavior in departure times and route choice. Moreover, there are also literatures discussing mode choice impact of ATIS (Khattak, Polydoropoulou et al. 1996, Polydoropoulou, Ben-Akiva et al. 1996). (Abdel-Aty and Abdalla 2006) addresses the significance of model correlation in mode-choice data considering the ATIS effect. Mode choice change is also reported in (Yim and Miller 2000) by giving different information to travelers from ATIS.

Based on the data collected in this project, including survey data, behavioral response models were used to analyze travelers' behavioral responses to traffic. The objective of such modeling was to quantify both the value of information and the impact that information (and different aspects of information such as parking) has on travel choices. The models explain the travel choices made (mode, route, time of day) as a function of the attributes of the alternatives, the

information acquired, the purpose of the trip, and the socio-demographics of the traveler. This study focused on traveler's mode choice when using Trip2Go to plan their daily commute or non-commute trips.

After the stated preference experiment was conducted, choice models were developed of the behavioral response to traffic information in hypothetical settings. The mode choice data obtained from the Trip2go application was processed after the FOT users used the application for 10 days/trips. Suchdata was used to develop choice models of behavioral response to information.

4.3.1 Modeling framework

For the mode choice model, the alternatives are three modes that are shown to users in the Trip2Go app; the independent variables are the factors influencing users' decision making process, such as travel time and travel cost for a certain mode. Detailed model description and specifications are summarized as follows:

<u>Alternative:</u>

Transit (T), Park-and-Ride (PR), Driving (D);

<u>Variables:</u>

DrivingCost: travel cost for driving;

TransitCost: travel cost for transit (bus or rail);

AccessTime: the time you spend from origin to bus stop or rail station;

DownTime: the time when you are on the bus or train;

DummyDriving: '1' when the user's typical traveling mode is driving, and '0' otherwise.

The definition of DummyTransit and DummyParkRide are similar to Dummy Driving.

<u>Model:</u>

Multinomial logit.

<u>Utility specifications (for individual n):</u>

$U_{Tn} = Asc_{Transit} + 3 * \beta_{D_T} * \text{TransitCost}_n + \beta_{D_T} * \text{DownTime} + \beta_{A_T} * \text{AccessTime} + \beta_{DD} * DummyDriving$

$U_{PRn} = Asc_{Driving} + 3 * \beta_{DrT} * \text{DrivingCost}_n + \beta_{DrT} * \text{DrivingTime} + \beta_{DD} * DummyDriving$

$$U_{Dn} = 3 * \beta_{DrT} * \text{TransitCost}_n + 3 * \beta_{D_T} * \text{DrivingCost}_n + \beta_{DrT} * \text{DrivingTime} + \beta_{D_T}$$
$$* \text{DownTime} + \beta_{A_T} * \text{AccessTime} + \beta_{DD} * DummyParkRide$$

Typically, we need to have another parameter for travel cost, however, we cannot get the right sign for it due to the high co-linearity between variables. Alternatively, in this specification, we set the parameter for travel cost to be three times the parameter for travel time, which means we restrict the value of time to be $\frac{\beta_{time}}{\beta_{cost}} = \frac{1}{3}$ $/mins = $20/hour (consistent with the literature in the United States (Belenky, 2001)), which guarantees that the sign of travel time/cost will be negative.

4.3.2 Data Description and Estimation Results

The data used to estimate the mode choice model are from surveys and the Trip2Go database. Appendix F provides an example of one single data point of a trip made on April 22, 2015.

We then use PythonBiogeme to estimate this mode choice model based on the data by maximizing the likelihood function. The following estimation results were obtained.

Estimation Results

Number of estimated parameters:	**9**
Sample size:	666
Init log-likelihood:	-688.121
Final log-likelihood:	-451.116
Likelihood ratio test for the init. model:	474.01
Rho for the init. model:	0.344
Rho bar for the init. model:	0.331

Estimated parameters:

Name ▼	Value	Std err	t-test	p-value
ASC_Driving	0.325	0.294	1.11	0.27
ASC_Transit	1.75	0.14	12.47	0
Access Time (mins)	-0.019	0.0109	-1.75	0.08
Down Time (mins)	-0.0542	0.00818	-6.63	0
Driving Travel time (mins)	-0.177	0.0316	-5.6	0
Dummy Driving Pattern	4.23	0.636	6.66	0
Dummy ParkRide Pattern	2.23	0.878	2.54	0.01
Dummy Transit Pattern	2.37	0.615	3.86	0

Down time in the table indicates the time when the system is unavailable. From this estimation result, we can see that all the parameters have the expected signs and are highly significant. The three dummy variables indicate that the users tend to choose their typical travel mode. Higher travel time results in a lower probability of choosing a certain mode.

5.0 Conclusions

Trip2go was successfully tested in Los Angeles County between February 2015 and September 2015. A total of three hundred sixteen people signed up to volunteer in the FOT. The survey results show that the majority of the volunteers were recruited through LA Metro Blogs. Using predetermined selection criteria, eighty-three volunteers were qualified for the Trip2go field testing. Among these volunteers, sixty-five travelers participated in the entry survey and were invited to participate in the FOT. Thirty-seven users finished at least one daily survey. Eighteen volunteers completed at least ten trips. Among all participants, 1,135 full trip activities were recorded. Additionally, Trip2go was used 334 times for trip advisory purposes. As some users may make trip plans and then follow the trip plans without keeping Trip2go active, we determined that some of the planned trips were real trips as well. Throughout the FOT, high quality travel behavior data (origin, destination, and mode of travel) was collected, processed and used to evaluate how travelers use multimodal traveler information and the effectiveness of such information on travel behavior change.

Statistical and quantitative evaluations were conducted to assess the usability and performance of the Trip2go system, and to determine the effectiveness of real-time multimodal information on travelers' behavior for improvement of travelers' perception of transit service and the likelihood of such information to encourage mode shift. Daily surveys were also conducted with each volunteer during the FOT, together with more comprehensive surveys at the beginning and the conclusion of the field test.

Feedback from users indicated that they positively value the information provided in comparison with some of the well-established trip planning apps. Around 50% of users are satisfied with the performance of Trip2Go. The exit survey results show nearly 25% of users used real-time information more than before participating in this experiment. Fifty percent of users say they were still using Trip2Go for their commute information at the time when they completed their exit surveys, among which 20% of users use it for non-commute information and en-route alerts. The users think that Trip2Go was useful in determining how to reduce emissions, which bus or train route to take and what mode to use. While Tri2go offered more real-time information, as a research tool, it has some limitations and shortcomings. The research team made every effort to incorporate real-time information for transit services in the test site. However, schedule information is used for some routes because not all transit agencies offer real-time information. As a result, trips plans involving schedule information are considered inaccurate by the users. As Trip2go is released for limited public use, the users tend to compare the functionalities and user interface design with other publically available trip planners and have provided constructive suggestions for improvements. However, due to the limited resources and time, some of the suggested improvements cannot be implemented.

The results show that information provided to users by Trip2go has influenced their trip decisions. Particularly, nearly 40% of travelers changed their plans for non-commute trips after consulting with Trip2go, among which 50% of the changed trips involved a different travel mode. For commute trips, we found that real-time information has a larger influence on driving

travelers adjusting their routes and departure time, and has more influence on the departure time for transit users. Survey results show that less than 20% of commuter trips are likely influenced by real-time information and most of the changes involve time and route adjustments as opposed to mode change. Only four of 327 trips changed mode from transit to driving. Of those involving time change (earlier or later by at least 15 minutes), 37% driving, 15% carpool, and 42% transit. As most of the subscribers of LA Metro Blogs are transit users, a majority of the volunteers use transit only. Some of the transit riders do not have cars. Thus, changing mode may not be an option for some of these volunteers. Driving trips for commuting was a small portion of the total trips collected. Only 20% of the 69 participants are drivers, however, if the data is interpreted proportionally, there can be a higher percentage of behavior change for drivers.

Based on the data collected through this project, behavioral response models from surveys and the Trip2go database were used to analyze travelers' behavioral response to traffic in order to quantify the value of information and quantify the impact that information has on travel choices. After the stated preference experiment was conducted, choice models were developed of the behavioral response to traffic information in hypothetical settings. The trip data obtained from the users who made more than 10 trips were processed to develop choice models of behavioral response to information. The models explain the travel choice made (mode, route, and time of day) as a function of the attributes of the alternatives, the information acquired, the purpose of the trip, and the socio-demographics of the traveler. Modeling results show that the travelers tend to choose their typical travel mode, which is consistent with the fact that only a small portion of users change their intended mode. The model also indicated that longer travel time would result in a lower probability of choosing a certain mode. Alternatively, shorter travel times could trigger travelers to choose an alternative mode. From the analysis of survey responses and model estimations, we may draw the conclusion that real-time information may change travelers' travel behavior by advising them to avoid incidental traffic congestion, subsequently helping to improve overall traffic flow conditions.

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Appendix A. Trip2GO Test Corridor Zip Codes

Test Corridors Zip Codes

Legend
- Corridor Transit Lines
- Selected Zip Codes
- LA County

N

0 2 4 8 Miles
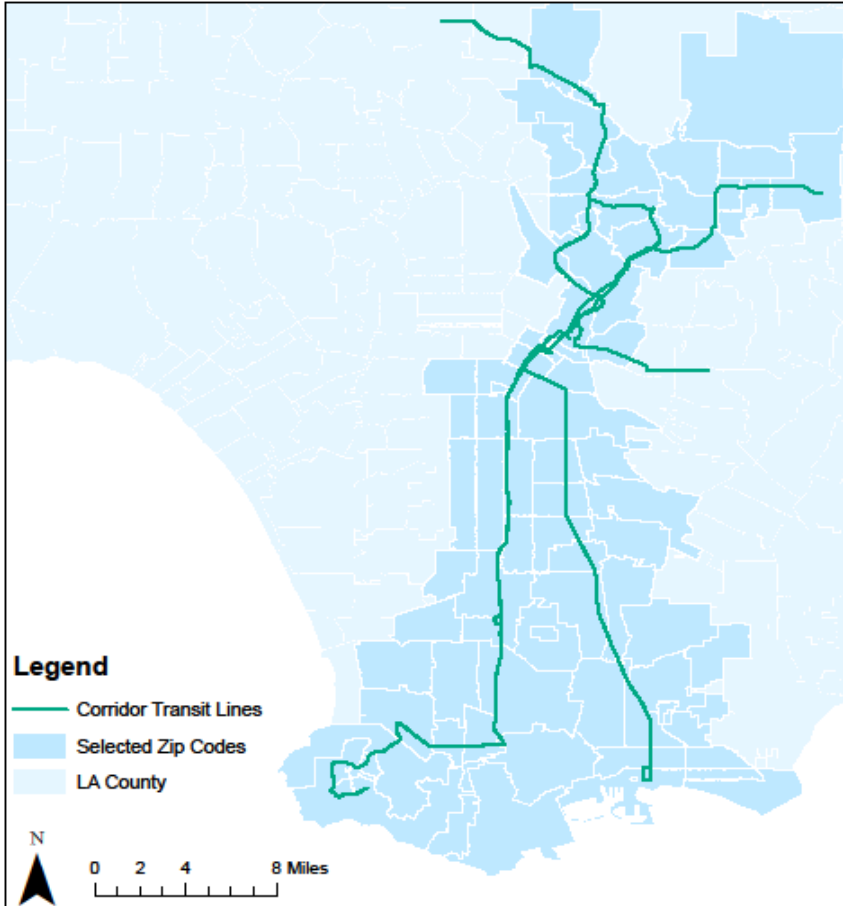
Zip Codes			
90001	90058	90502	90810
90002	90059	90503	90813
90003	90061	90504	90814
90007	90062	90505	90831
90011	90065	90710	91001
90012	90071	90712	91020
90013	90089	90717	91030
90014	90089	90731	91046
90015	90220	90732	91101
90017	90221	90744	91103
90018	90222	90745	91104
90021	90247	90746	91105
90031	90248	90747	91106
90033	90249	90755	91107
90037	90255	90802	91205
90039	90262	90803	91206
90041	90274	90804	91207
90042	90275	90805	91208
90044	90280	90806	91214
90047	90501	90807	

Appendix B. Trip2go User Survey

Entry user survey. Conduct once through Survey Monkey when participants are invited to join to test Trip2go app for their commutes.

List of User Survey Questions (double click it to show the whole pdf file):

Welcome to Trip2Go!

`|■                                                    | 3% |`

As part of the Trip2Go research project, we'd like to ask you some general questions about your commute, your current use of traveler information, and aspects of your household and work situation that researchers have found to have an influence on travel patterns.

The survey will take approximately 10 minutes, and we very much appreciate you taking the time to assist our research. All of your responses will be kept completely confidential and only used for research purposes.

[Next]

`|■                                                    | 7% |`

1. Before you were sent this survey, you were asked to download and register for the Trip2Go mobile app. What is the username that you are registered under?

[   ]

[Prev] [Next]

`|■                                                    | 10% |`

In the first part of the survey, we'd like to get information about your typical commute from home to work. For each of the following questions, think about a typical week (Monday through Sunday). If you do not have a "typical" workweek, then answer the questions based on your commute last week.

Appendix C. Trip2go Daily Survey

Conduct daily to selected users through Survey Monkey.

List of Dailey Survey Questions:

We detect that you used Trip2Go today, please tell us about your trip(s) by answering a two minute survey.

This is a "daily" survey, so you may have answered these questions for a different day. We apologize for the trouble, but it is important that we obtain information on a number of your trips.

Note that the word "**today**" in the questions is the day when you received our survey link in your email. We send the email out in the evening; if you opened it the next morning then we are asking about yesterday's trips.

For what types of trips did you use Trip2Go today?

○ Only for commute trips to and/or from work

○ Only for non-commute trips

○ For both commute and non-commute trips

○ I was exploring the functionality of the app and not planning for an actual trip

1. **Only for commute trips to and/or from work:**

Now that we know what types of trips you used Trip2Go for, we'd like to get more detail on these specific trips as well as your experience with Trip2Go. In this page, we are going to ask several questions about your _commute_ trips.

How did you get to work from home today?

○ Drive alone in personal car

○ Carpool/Vanpool (as driver)

○ Carpool/Vanpool (as passenger)

○ Taxi, Car Share, Ride Share (Zipcar, City Car Share, Uber, Lyft, SideCar, etc.)

○ Motorcycle

○ Rail

○ Bus

○ Drive to Bus or Rail

○ Bicycle

○ Walk

○ Telecommute

○ Other (please specify)

[   ]

How did you get home from work today?

○ Drive alone in personal car

○ Carpool/Vanpool (as driver)

○ Carpool/Vanpool (as passenger)

○ Taxi, Car Share, Ride Share (Zipcar, City Car Share, Uber, Lyft, SideCar, etc.)

○ Motorcycle

○ Rail

○ Bus

○ Drive to Bus or Rail

○ Bicycle

○ Walk

○ Telecommute

○ Other (please specify)

[   ]

In addition to Trip2Go, did you use any other source to obtain real-time travel information <u>for your commute this morning or evening</u>? (check all that apply)

☐ No, I did not use any other travel information source today for my morning or evening commute today

☐ Yes, I used Google Maps

☐ Yes, I used Apple Maps

☐ Yes, I used Waze

☐ Yes, I used 511.org

☐ Yes, I used Go Metro

☐ Yes, I used Other app or website with real-time bus or rail arrival times

☐ Yes, I used Radio

☐ Yes, I used TV

☐ Other (please specify)

[   ]

Did the real-time travel information that you obtained from Trip2Go or other real-time information sources <u>change your intended</u> morning *commute to work? (check all that apply)*

☐ Yes, I traveled by a different mode than intended (for example switched from driving a car to bus or vice versa)

☐ Yes, I traveled by a different route than intended (for example a different road/highway or a different bus/metro)

☐ Yes, I left for work at least 15 minutes earlier than I intended

☐ Yes, I left for work at least 15 minutes later than I intended

☐ Yes, I made an additional stop on the way to work

☐ Yes, I decided not to make a stop that I intended to make

☐ Yes, I worked from home rather than going to the office

☐ No, the information did not change my intended morning commute

☐ No, I did not access real-time information for my morning commute

☐ Other (please specify)

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│                             │
└─────────────────────────────┘
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Did the real-time travel information that you obtained from Trip2Go or other real-time information sources change your <u>intended</u> evening <u>commute</u>? (check all that apply)

☐ Yes, I traveled by a different mode (for example switched from driving a car to bus or vice versa) than intended

☐ Yes, I traveled by a different route (for example a different road/highway or a different bus/metro) than intended

☐ Yes, I left work at least 15 minutes earlier than I intended

☐ Yes, I left work at least 15 minutes later than I intended

☐ Yes, I made an additional stop on the way home from work

☐ Yes, I decided not to make a stop that I intended to make

☐ No, the information did not change my intended commute in the evening

☐ No, I did not access real-time information for my commute this evening

☐ Other (please specify)

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┌─────────────────────────────┐
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└─────────────────────────────┘
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Which of the following information sources influenced your travel decisions (check all that apply)?

☐ Trip2Go

☐ Other real-time app or web site (such as Google, Waze, 511.org, and Go Metro)

☐ TV and/or Radio

☐ No information influenced my travel decisions

☐ Other (please specify)

[   ]

How satisfied were you with the quality of the real-time information provided by <u>Trip2Go</u> *today?*

○ Very dissatisfied

○ Dissatisfied

○ Neither satisfied or dissatisfied

○ Satisfied

○ Very satisfied

How satisfied were you with the quality of the real-time information provided by the <u>other sources</u> *today?*

○ Very dissatisfied

○ Dissatisfied

○ Neither satisfied or dissatisfied

○ Satisfied

○ Very satisfied

○ Not applicable; I did not obtain information from other sources

2. Only for non-commute trips:

Now that we know what types of trip(s) you used Trip2Go for, we would like to get more detail on these specific trip(s) as well as your experience with Trip2Go. In this page, we are going to ask several questions about your non-commute trip(s).

In addition to Trip2Go, did you use any other source to obtain real-time travel information for your non-commute trip(s) today? (check all that apply)

☐ No, I did not use any other travel information source today for my non-commute trip(s) today

☐ Yes, I used Google Maps

☐ Yes, I used Apple Maps

☐ Yes, I used Waze

☐ Yes, I used 511.org

☐ Yes, I used Go Metro

☐ Yes, I used Other app or website with real-time bus or rail arrival times

☐ Yes, I used Radio

☐ Yes, I used TV

☐ Other (please specify)

[   ]

Did the real-time travel information that you obtained from Trip2Go or other real-time information sources influence your non-commute trip(s) today? (check all that apply, even if it applies to only one of your trips from today)

☐ Yes, I selected (or changed) my destination

☐ Yes, I selected my mode based on the information provided

☐ Yes, I traveled by a different mode than intended (for example switched from driving a car to bus or vice versa)

☐ Yes, I selected my route based on the information provided

☐ Yes, I traveled by a different route than intended (for example a different road/highway or a different bus/metro)

☐ Yes, I decided not to make a trip

☐ No, the information did not change my non-commute trip(s)

☐ Other (please specify)

[   ]

Which of the following information sources influenced your travel decisions (check all that apply)?

☐ Trip2Go

☐ Other real-time app or web site (such as Google, Waze, 511.org, and Go Metro)

☐ TV and/or Radio

☐ No information influenced my travel decisions

☐ Other (please specify)

How satisfied were you with the quality of the real-time information provided by <u>Trip2Go</u> *today?*

○ Very dissatisfied

○ Dissatisfied

○ Neither satisfied or dissatisfied

○ Satisfied

○ Very satisfied

How satisfied were you with the quality of the real-time information provided by the <u>other sources</u> *today?*

○ Very dissatisfied

○ Dissatisfied

○ Neither satisfied or dissatisfied

○ Satisfied

○ Very satisfied

○ Not applicable; I did not obtain information from other sources

3. For "both commute and non-commute trips":

Now that we know what types of trips you used Trip2Go for, we would like to get more detail on these specific trips as well as your experience with

Trip2Go. In this page, we are going to ask several questions about your commute and non-commute trips.

Please answer the following questions based on your _commute_ trips:

How did you get <u>to work</u> from home today?

○ Drive alone in personal car

○ Carpool/Vanpool (as driver)

○ Carpool/Vanpool (as passenger)

○ Taxi, Car Share, Ride Share (Zipcar, City Car Share, Uber, Lyft, SideCar, etc.)

○ Motorcycle

○ Rail

○ Bus

○ Drive to Bus or Rail

○ Bicycle

○ Walk

○ Telecommute

○ Other (please specify)

[   ]

How did you get <u>home</u> from work today?

○ Drive alone in personal car

○ Carpool/Vanpool (as driver)

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○ Carpool/Vanpool (as passenger)

○ Taxi, Car Share, Ride Share (Zipcar, City Car Share, Uber, Lyft, SideCar, etc.)

○ Motorcycle

○ Rail

○ Bus

○ Drive to Bus or Rail

○ Bicycle

○ Walk

○ Telecommute

○ Other (please specify)

[   ]

In addition to Trip2Go, did you use any other source to obtain real-time travel information for your <u>commute</u> *this morning or evening? (check all that apply)*

☐ No, I did not use any other travel information source today for my morning or evening commute today

☐ Yes, I used Google Maps

☐ Yes, I used Apple Maps

☐ Yes, I used Waze

☐ Yes, I used 511.org

☐ Yes, I used Go Metro

☐ Yes, I used Other app or website with real-time bus or rail arrival times

☐ Yes, I used Radio

☐ Yes, I used TV

☐ Other (please specify)

[   ]

Did the real-time travel information that you obtained from Trip2Go or other real-time information sources change your intended <u>morning commute</u>*? (check all that apply)*

☐ Yes, I traveled by a different mode than intended (for example switched from driving a car to bus or vice versa) in the morning

☐ Yes, I traveled by a different route than intended (for example a different road/highway or a different bus/metro) in the morning

☐ Yes, I left for work at least 15 minutes earlier than I intended

☐ Yes, I left for work at least 15 minutes later than I intended

☐ Yes, I worked from home rather than going to the office

☐ No, the information did not change my intended commute in the morning

☐ No, I did not access real-time information for my commute this morning

☐ Other (please specify)

[   ]

Did the real-time travel information that you obtained from Trip2Go or other real-time information sources change your intended <u>evening commute</u>*? (check all that apply)*

☐ Yes, I traveled by a different mode than intended (for example switched from driving a car to bus or vice versa) in the evening

☐ Yes, I traveled by a different route than intended (for example a different road/highway or a different bus/metro) in the evening

☐ Yes, I left work at least 15 minutes earlier than I intended

☐ Yes, I left work at least 15 minutes later than I intended

☐ No, the information did not change my intended commute in the evening

☐ No, I did not access real-time information for my commute this evening

☐ Other (please specify)

[   ]

Which of the following information sources influenced your commute decisions (check all that apply)?

☐ Trip2Go

☐ Other real-time app or web-site (such as Google, Waze, 511.org, and Go Metro)

☐ TV and/or Radio

☐ No information influenced my travel decisions

☐ Other (please specify)

[   ]

Please answer the following questions based on your _non-commute_ trips:

In addition to Trip2Go, did you use any other source to obtain real-time travel information for your <u>non-commute</u> *trip(s) today? (check all that apply)*

☐ No, I did not use any other travel information source today for my non-commute trip(s) today

☐ Yes, I used Google Maps

☐ Yes, I used Apple Maps

☐ Yes, I used Waze

☐ Yes, I used 511.org

☐ Yes, I used Go Metro

☐ Yes, I used Other app or website with real-time bus or rail arrival times

☐ Yes, I used Radio

☐ Yes, I used TV

☐ Other (please specify)

[   ]

Did the real-time travel information that you obtained from Trip2Go or other real-time information sources change your intended <u>non-commute</u> *trip(s) today? (check all that apply)*

☐ Yes, I selected (or changed) my destination

☐ Yes, I selected my mode based on the information provided

☐ Yes, I traveled by a different mode than intended (for example switched from driving a car to bus or vice versa)

☐ Yes, I selected my route based on the information provided

☐ Yes, I traveled by a different route than intended (for example a different road/highway or a different bus/metro)

☐ Yes, I decided not to make a trip

☐ No, the information did not change my non-commute trip(s)

☐ Other (please specify)

[   ]

Which of the following information sources influenced your non-commute decisions (check all that apply)?

☐ Trip2Go

☐ Other real-time app or web site (such as Google, Waze, 511.org, and Go Metro)

☐ TV and/or Radio

☐ No information influenced my travel decisions

☐ Other (please specify)

[   ]

Please answer the following questions based on your *commute and non-commute* trips:

How satisfied were you with the quality of the real-time information provided by Trip2Go today for your <u>commute and non-commute</u> *trips today?*
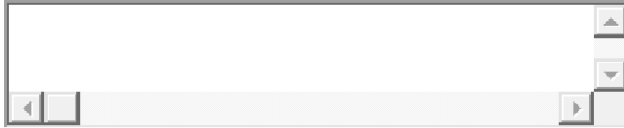
○ Very dissatisfied

○ Dissatisfied

○ Neither satisfied or dissatisfied

○ Satisfied

○ Very satisfied

How satisfied were you with the quality of the real-time information provided by the other sources for your <u>commute and non-commute</u> *trips today?*

○ Very dissatisfied

○ Dissatisfied

○ Neither satisfied or dissatisfied

○ Satisfied

○ Very satisfied

○ Not applicable; I did not obtain information from other sources

Do you have any other comments, questions, or concerns?

```
[                    ▲]
[                     ]
[                    ▼]
[◄         ►         ]
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Appendix D. Trip2go Exit survey

As part of the Trip2Go research project, this is the last survey of the study, and it's really important. Some questions will be similar to the first online survey you took, whereas others will be different.

The survey will take approximately 10 minutes, and we very much appreciate you taking the time to assist our research. All of your responses will be kept completely confidential and only used for research purposes.

For each of the following questions, think about a typical week (Monday through Sunday). If you do not have a "typical" workweek, then answer the questions based on your commute last week.

1. In a typical week, on how many days do you obtain real-time information about transportation conditions (such as current traffic conditions or bus/rail arrival times) for your morning commute <u>before leaving your house</u>? (Either from Trip2Go and/or other sources)

[▼]

2. In a typical week, on how many days do you obtain real-time information on your smartphone about transportation conditions (such as current traffic conditions or bus/rail arrival times) for your morning commute <u>while en-route</u> to work? (Either from Trip2Go and/or other sources)

[▼]

3. Compared to your behavior before participating in this experiment, would you say you are using real-time travel information (either Trip2Go or other traveler information sources):

○ Significantly less than before

○ Somewhat less than before

○ The same as before

○ Somewhat more than before

○ Significantly more than before

4. Are you still using Trip2Go? (check all that apply)

☐ No

☐ Yes, to get information on my work commute before I leave

☐ Yes, to get information on non-work trips before I leave

☐ Yes, for the en-route alerts

5. *For your <u>commute</u> to or from work, <u>Trip2Go</u> was useful in determining:*

6.	Not at all useful	Not useful	Useful	Very Useful	Extremely useful
whether to go to work or telecommute	○ whether to go to work or telecommute Not at all useful	○ whether to go to work or telecommute Not useful	○ whether to go to work or telecommute Useful	○ whether to go to work or telecommute Very Useful	○ whether to go to work or telecommute Extremely useful
when to go to work or leave from work	○ when to go to work or leave from work Not at all useful	○ when to go to work or leave from work Not useful	○ when to go to work or leave from work Useful	○ when to go to work or leave from work Very Useful	○ when to go to work or leave from work Extremely useful
what mode to use (e.g., drive or transit)	○ what mode to use (e.g., drive or transit) Not at all useful	○ what mode to use (e.g., drive or transit) Not useful	○ what mode to use (e.g., drive or transit) Useful	○ what mode to use (e.g., drive or transit) Very Useful	○ what mode to use (e.g., drive or transit) Extremely useful
what road to take when driving	○ what road to take when driving Not at all useful	○ what road to take when driving Not useful	○ what road to take when driving Useful	○ what road to take when driving Very Useful	○ what road to take when driving Extremely useful
what bus or train to take	○ what bus or train to	○ what bus or train to	○ what bus or train to take Useful	○ what bus or train to take Very Useful	○ what bus or train to take Extremely useful

6.	Not at all useful	Not useful	Useful	Very Useful	Extremely useful
	take Not at all useful	take Not useful			
how to save time	○ how to save time Not at all useful	○ how to save time Not useful	○ how to save time Useful	○ how to save time Very Useful	○ how to save time Extremely useful
how to save money	○ how to save money Not at all useful	○ how to save money Not useful	○ how to save money Useful	○ how to save money Very Useful	○ how to save money Extremely useful
how to reduce emissions	○ how to reduce emissions Not at all useful	○ how to reduce emissions Not useful	○ how to reduce emissions Useful	○ how to reduce emissions Very Useful	○ how to reduce emissions Extremely useful
how to get more physical activity	○ how to get more physical activity Not at all useful	○ how to get more physical activity Not useful	○ how to get more physical activity Useful	○ how to get more physical activity Very Useful	○ how to get more physical activity Extremely useful

7. *For your trips that were <u>NOT commuting</u> to or from work, <u>Trip2Go</u> was useful in determining:*

	Not at all useful	Not useful	Useful	Very useful	Extremely useful
whether to make a trip	○ whether to make a trip Not at all useful	○ whether to make a trip Not useful	○ whether to make a trip Useful	○ whether to make a trip Very useful	○ whether to make a trip Extremely useful
where to go	○ where to go Not at all useful	○ where to go Not useful	○ where to go Useful	○ where to go Very useful	○ where to go Extremely useful
when to go	○ when to go Not at all useful	○ when to go Not useful	○ when to go Useful	○ when to go Very useful	○ when to go Extremely useful
what mode to use (e.g., drive or transit)	○ what mode to use (e.g., drive or transit) Not at all useful	○ what mode to use (e.g., drive or transit) Not useful	○ what mode to use (e.g., drive or transit) Useful	○ what mode to use (e.g., drive or transit) Very useful	○ what mode to use (e.g., drive or transit) Extremely useful
what road to take when driving	○ what road to take when driving Not at all useful	○ what road to take when driving Not useful	○ what road to take when driving Useful	○ what road to take when driving Very useful	○ what road to take when driving Extremely useful
what bus or train to take	○ what bus or train to take Not at all useful	○ what bus or train to take Not useful	○ what bus or train to take Useful	○ what bus or train to take Very useful	○ what bus or train to take Extremely useful
how to save time	○ how to save time Not at all useful	○ how to save time Not useful	○ how to save time Useful	○ how to save time Very useful	○ how to save time Extremely useful
how to save money	○ how to save money Not at all useful	○ how to save money Not useful	○ how to save money Useful	○ how to save money Very useful	○ how to save money Extremely useful
how to reduce emissions	○ how to reduce emissions Not at all useful	○ how to reduce	○ how to reduce emissions Useful	○ how to reduce emissions Very useful	○ how to reduce emissions Extremely useful

	Not at all useful	Not useful	Useful	Very useful	Extremely useful
		emissions Not useful			
how to get more physical activity	○ how to get more physical activity Not at all useful	○ how to get more physical activity Not useful	○ how to get more physical activity Useful	○ how to get more physical activity Very useful	○ how to get more physical activity Extremely useful

7. *In general, travel information sources (Trip2Go as well as other sources) are useful in determining*

	Not at all useful	Not useful	Useful	Very useful	Extremely useful
whether to make a trip	○ whether to make a trip Not at all useful	○ whether to make a trip Not useful	○ whether to make a trip Useful	○ whether to make a trip Very useful	○ whether to make a trip Extremely useful
where to go	○ where to go Not at all useful	○ where to go Not useful	○ where to go Useful	○ where to go Very useful	○ where to go Extremely useful
when to go	○ when to go Not at all useful	○ when to go Not useful	○ when to go Useful	○ when to go Very useful	○ when to go Extremely useful
what mode to use (e.g., drive, transit, or walk)	○ what mode to use (e.g., drive, transit, or walk) Not at all useful	○ what mode to use (e.g., drive, transit, or walk) Not useful	○ what mode to use (e.g., drive, transit, or walk) Useful	○ what mode to use (e.g., drive, transit, or walk) Very useful	○ what mode to use (e.g., drive, transit, or walk) Extremely useful

	Not at all useful	Not useful	Useful	Very useful	Extremely useful
what road to take when driving	○ what road to take when driving Not at all useful	○ what road to take when driving Not useful	○ what road to take when driving Useful	○ what road to take when driving Very useful	○ what road to take when driving Extremely useful
what bus or train to take	○ what bus or train to take Not at all useful	○ what bus or train to take Not useful	○ what bus or train to take Useful	○ what bus or train to take Very useful	○ what bus or train to take Extremely useful
how to save time	○ how to save time Not at all useful	○ how to save time Not useful	○ how to save time Useful	○ how to save time Very useful	○ how to save time Extremely useful
how to save money	○ how to save money Not at all useful	○ how to save money Not useful	○ how to save money Useful	○ how to save money Very useful	○ how to save money Extremely useful
how to reduce emissions	○ how to reduce emissions Not at all useful	○ how to reduce emissions Not useful	○ how to reduce emissions Useful	○ how to reduce emissions Very useful	○ how to reduce emissions Extremely useful
how to get more physical activity	● how to get more physical activity Not at all useful	○ how to get more physical activity Not useful	○ how to get more physical activity Useful	○ how to get more physical activity Very useful	○ how to get more physical activity Extremely useful

8. Are you <u>commuting</u> to/from work differently after participating in this experiment

as the result of real time travel information? (Check all that apply)
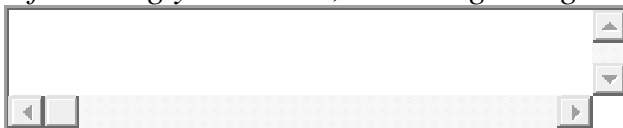
☐ No, I am not commuting differently

☐ Yes, I am telecommuting more than before.

☐ Yes, I am telecommuting less than before.

☐ Yes, I have changed when I travel to/from work (at least sometimes).

☐ Yes, I have shifted what transportation mode (e.g., drive or transit) I use to get to/from work (at least sometimes).

☐ Yes, I have modified what roads I take when driving to/from work (at least sometimes).

☐ Yes, I have modified what bus and/or train I take when traveling to/from work (at least sometimes).

9. Are you traveling for your <u>NON-commute</u> trips differently after participating in this experiment? (Check all that apply)

☐ No, I am not traveling differently for my NON-commute trips.

☐ Yes, I am traveling more than before.

☐ Yes, I am traveling less than before.

☐ Yes, I have changed when I travel (at least sometimes).

☐ Yes, I have shifted what transportation mode (e.g., drive, transit, or walk) I use (at least sometimes).

☐ Yes, I have modified what roads I take when driving (at least sometimes).

☐ Yes, I have modified what bus and/or train I take when traveling (at least sometimes).

10. Tell us any other thoughts you have on whether or not traveler information is influencing your travel, including thoughts on how and why (or why not).

11. When using the Trip2Go App, did you find it easy to understand and the functions easy to follow?

○ The app was <u>more</u> difficult and complicated to use than other travel apps I have used

○ The app was <u>no more</u> difficult to use than other travel apps I have used

○ The app was reasonably <u>easy</u> to understand and simple to use

○ The app was <u>hard</u> to understand and difficult to use

12. Please rate the Trip2Go app in terms of the several factors listed below

	Was not at all adequate	Fell short of expectations but worked	Neither good nor bad	Pretty good	Fully met my expectations
The readability of the screen	○ The readability of the screen Was not at all adequate	○ The readability of the screen Fell short of expectations but worked	○ The readability of the screen Neither good nor bad	○ The readability of the screen Pretty good	○ The readability of the screen Fully met my expectations
The level of detail of the information that was provided for each trip	○ The level of detail of the information that was provided for each trip Was not at all adequate	○ The level of detail of the information that was provided for each trip Fell short of expectations but worked	○ The level of detail of the information that was provided for each trip Neither good nor bad	○ The level of detail of the information that was provided for each trip Pretty good	○ The level of detail of the information that was provided for each trip Fully met my expectations
The accuracy of the information that was provided	○ The accuracy of the information that was provided Was not at all adequate	○ The accuracy of the information that was provided Fell short of expectations but worked	○ The accuracy of the information that was provided Neither good nor bad	○ The accuracy of the information that was provided Pretty good	○ The accuracy of the information that was provided Fully met my expectations

	Was not at all adequate	Fell short of expectations but worked	Neither good nor bad	Pretty good	Fully met my expectations
The speed of the app in providing what I wanted	○ The speed of the app in providing what I wanted Was not at all adequate	○ The speed of the app in providing what I wanted Fell short of expectations but worked	○ The speed of the app in providing what I wanted Neither good nor bad	○ The speed of the app in providing what I wanted Pretty good	○ The speed of the app in providing what I wanted Fully met my expectations
The ability of the app to alert me to changes in travel conditions	○ The ability of the app to alert me to changes in travel conditions Was not at all adequate	○ The ability of the app to alert me to changes in travel conditions Fell short of expectations but worked	○ The ability of the app to alert me to changes in travel conditions Neither good nor bad	○ The ability of the app to alert me to changes in travel conditions Pretty good	○ The ability of the app to alert me to changes in travel conditions Fully met my expectations

If applicable, please explain what did not perform well, was not adequate, and how you would improve

the app.

13. Last question! Tell us anything else you'd like about your experience participating

in this experiment.

Appendix E

In this section, we show detailed summary of three different surveys (entry/daily/exit surveys):

1. Employment status of participants:

Which of the following best describes your employment status?

Legend:
- Full-time paid employment (minimum 40 hours per week)
- Part-time paid employment (fewer than 40 hours per week)
- Unpaid Internship/Volunteer Work
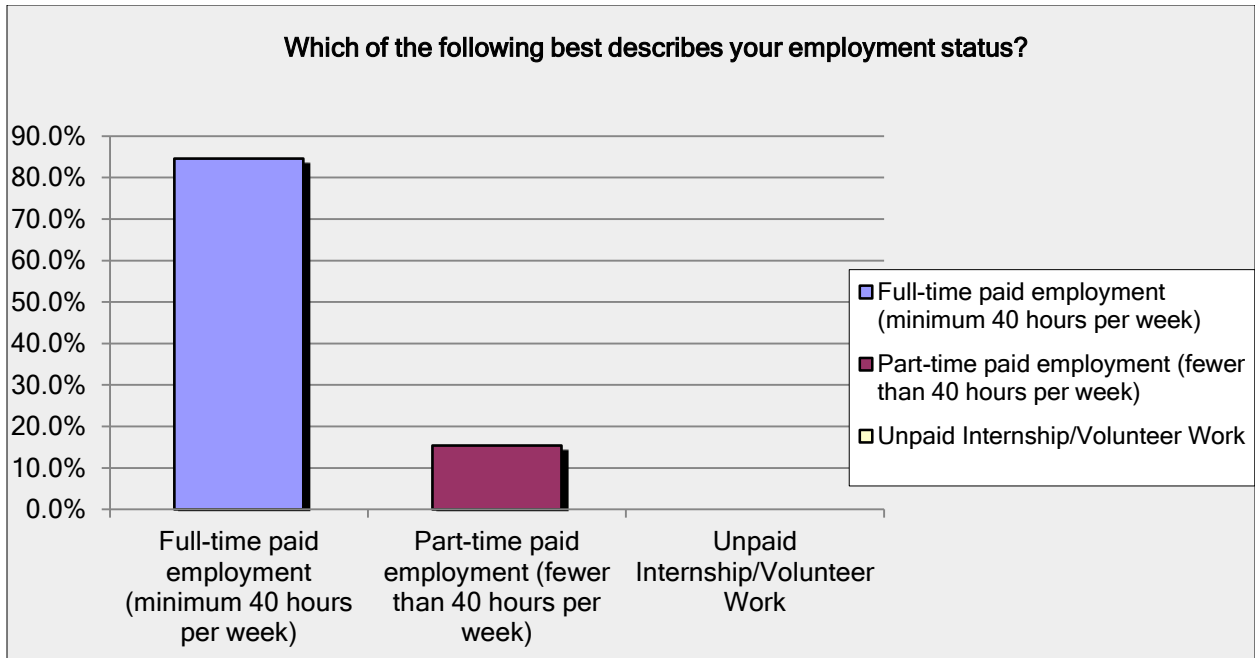
All employed, 85% are part-time paid employment.

2. Number of working days:

In a typical week, how many days do you work?

Legend: 1, 2, 3, 4, 5, 6, 7
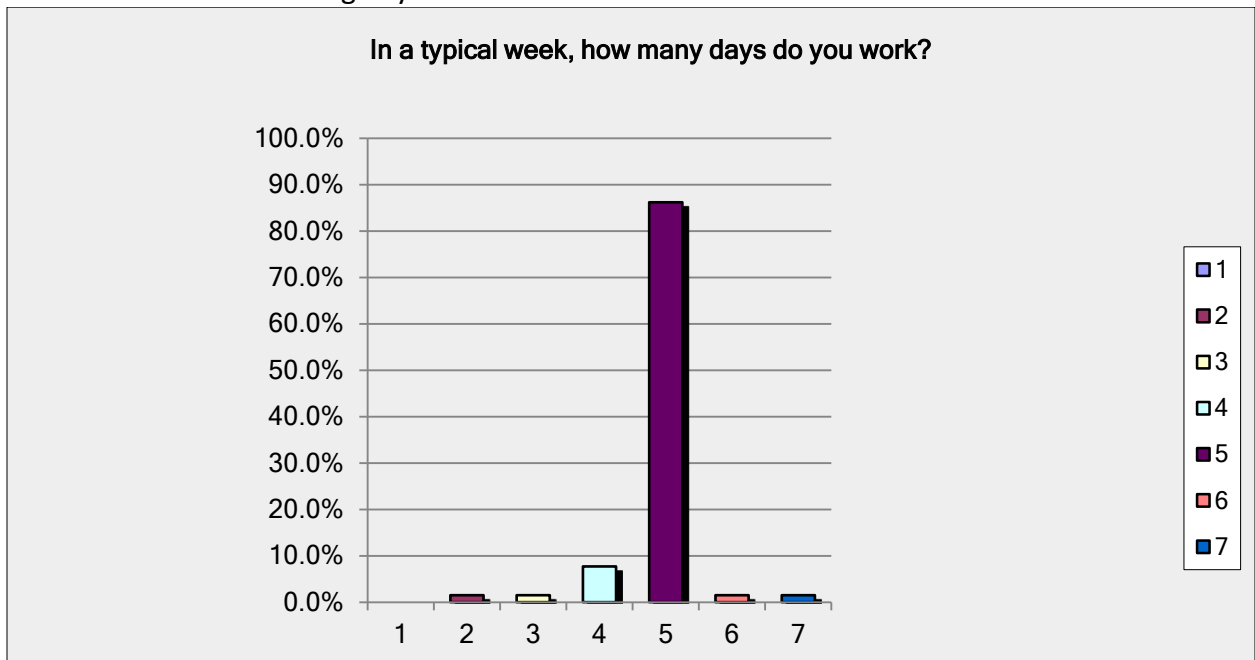
In a typical week, how many times do you travel to work in the morning peak period (Monday-Friday between 6:00 and 10:00 AM)?
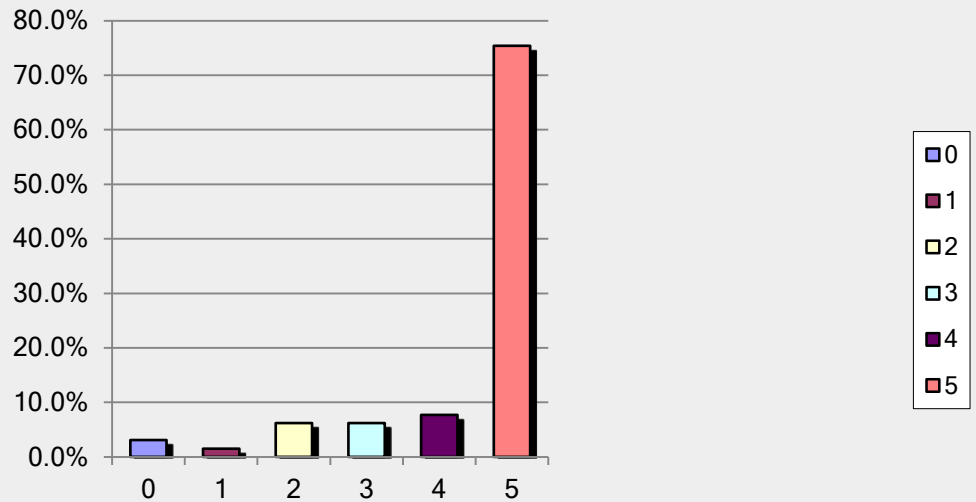
In a typical week, how many times do you travel from work to home in the evening peak period (Monday-Friday between 3:00 and 7:00 PM)?
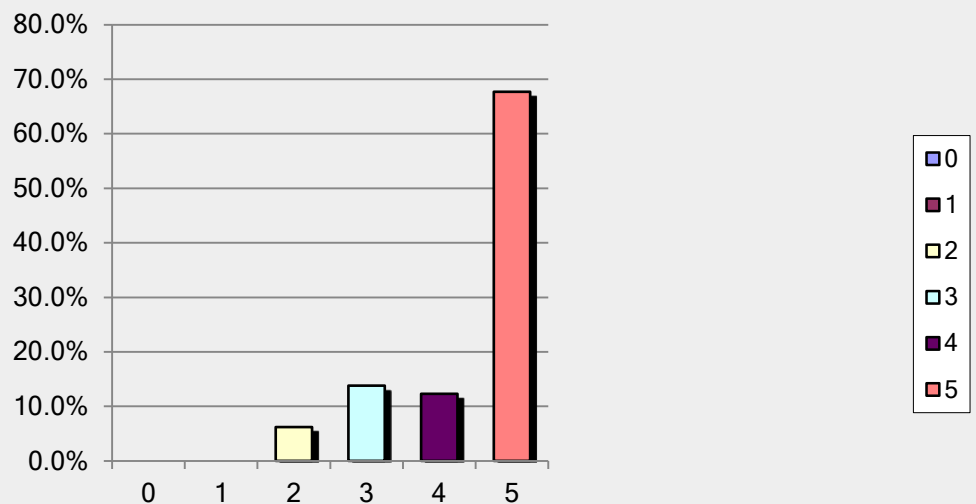
We can see that most of the users work five days per week and most of their trips happen during morning/evening peak periods.

3. Participant's typical travel pattern:

In a typical week, how many days do you get to work by each of the following means of transportation?
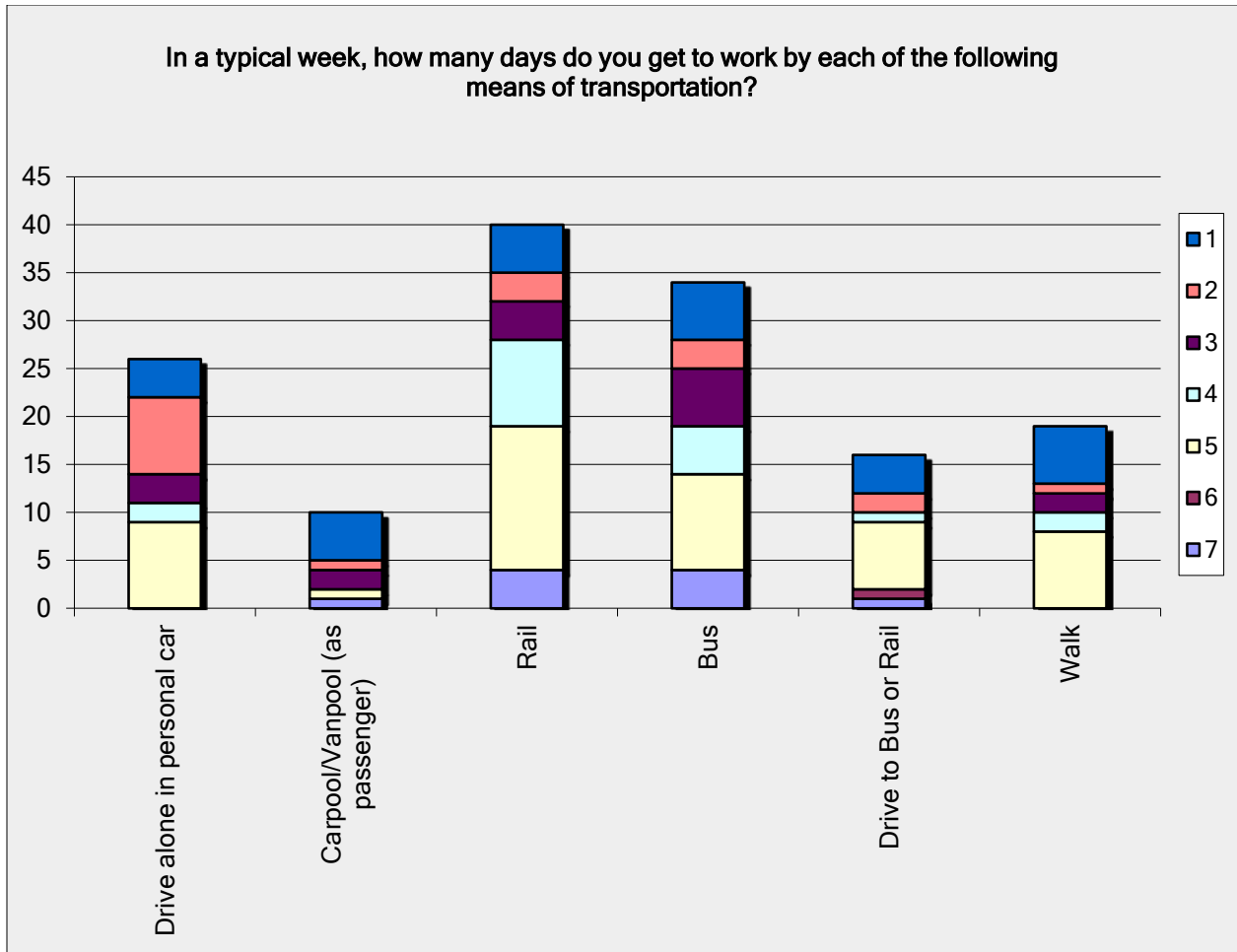
The main travel patterns include drive (alone/carpool), transit (rail/bus), park-and-ride (drive to bus or rail), and other (walk/bicycle).

4. Changing transportation mode due to real-time information:

How often does this real-time information make you change your intended means of transportation? (For example switching from driving your car to taking a bus or vice versa.)

Legend:
- Never
- Rarely (between 1 and 2 times per month)
- Occasionally (between 3 and 4 times per month; about once a week)
- Often (between 5 and 8 times per month)
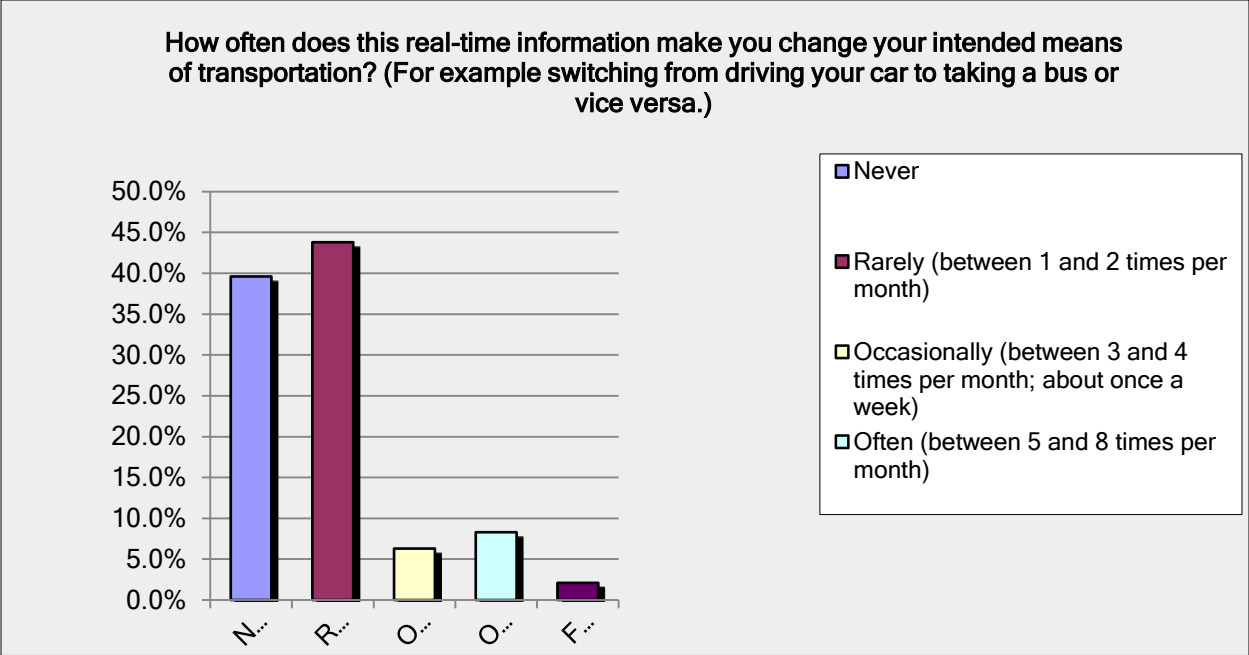
The real-time information does not have much influence on changing intended means of transportation.

5. Changing transportation route due to real-time information:

How often does this real-time information make you change your intended route? For example to a different bus line or a different roadway.

Legend:
- Never
- Rarely (between 1 and 2 times per month)
- Occasionally (between 3 and 4 times per month; about once a week)
- Often (between 5 and 8 times per month)
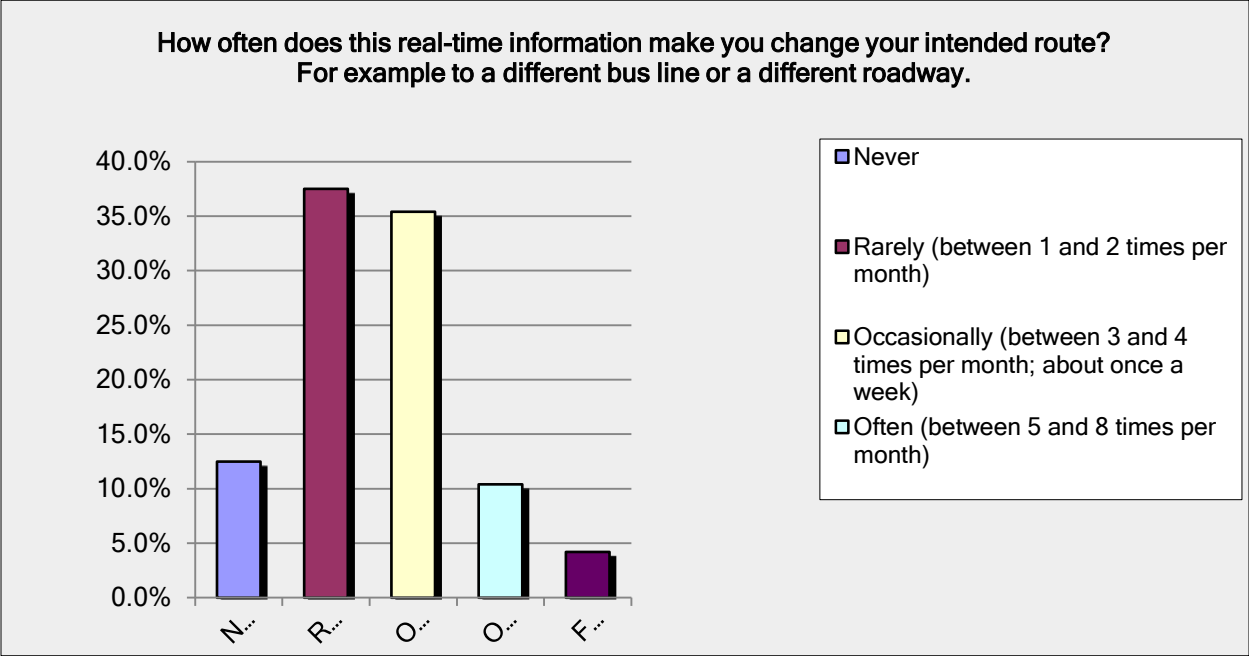
The real-time information has a larger influence on changing route than mode.

6. Reasons for not taking bus or rail:

When you do not take bus or rail, which of the following reasons apply?
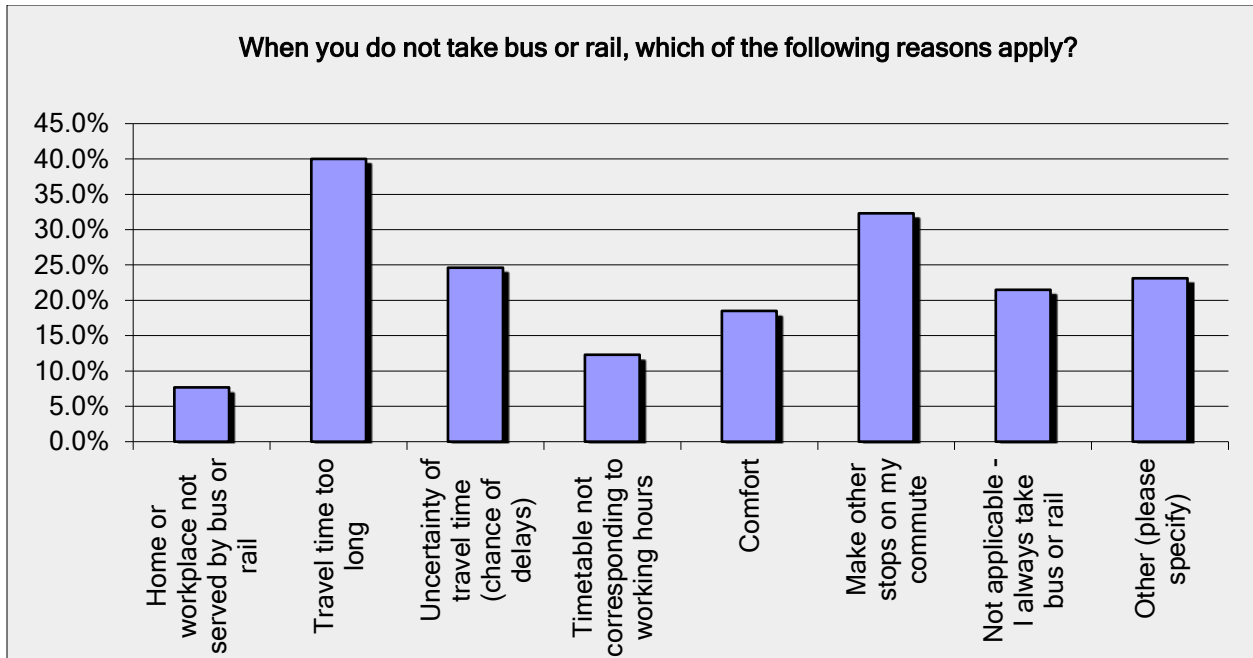
The main reasons for not taking bus or rail are 1) travel time is too long; 2) make other stops.

4.2.2 Daily Survey

1. Distributions for commute and non-commute trips:

For what types of trips did you use Trip2Go today?

- Only for commute trips to and/or from work
- Only for non-commute trips
- For both commute and non-commute trips
- I was exploring the functionality of the app and not planning for an actual trip
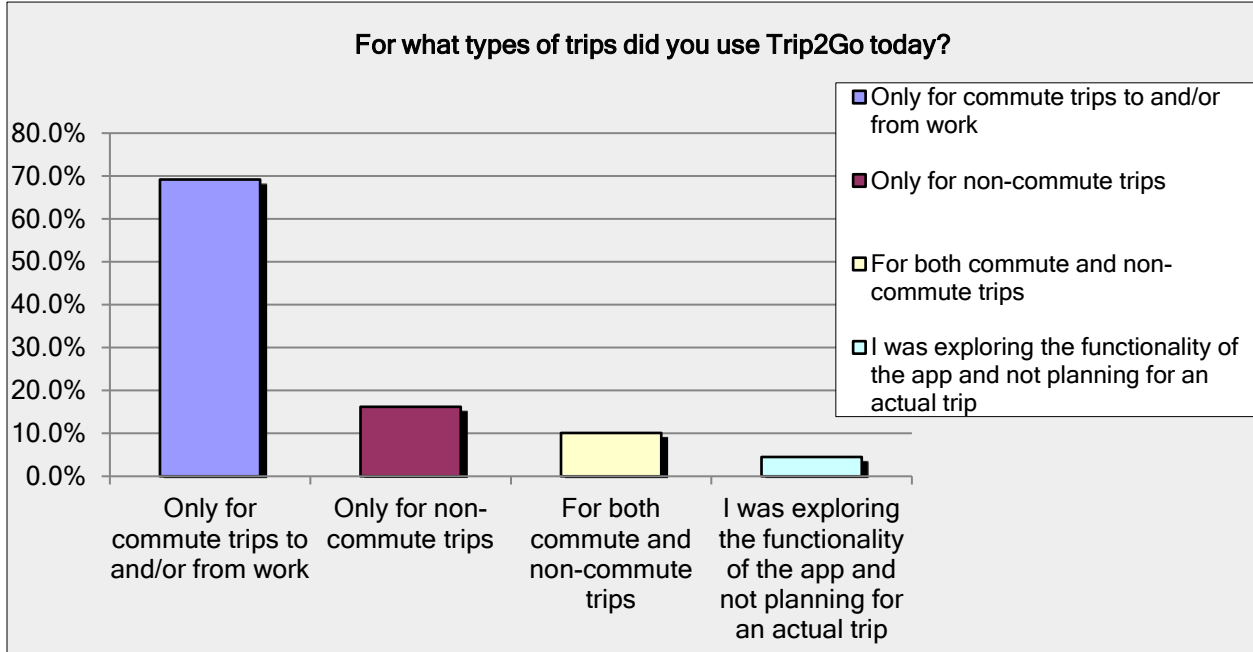
From this, we can see that most trips are only for commute trips.

2. Transportation mode:

How did you get to work from home today?

Legend:
- Drive alone in personal car
- Carpool/Vanpool (as passenger)
- Rail
- Bus
- Drive to Bus or Rail
- Other (please specify)
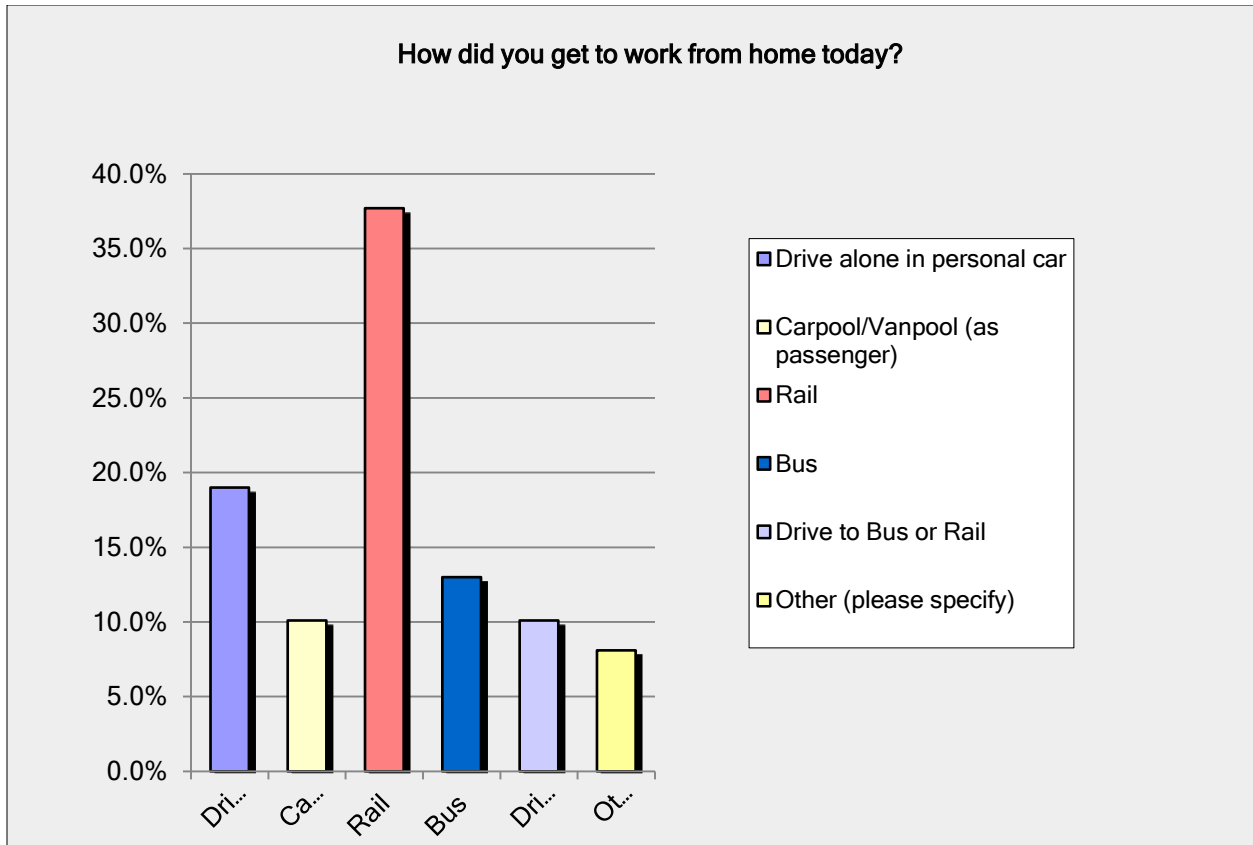
The distribution over different modes is similar to that in the entry survey.

3. Other real-time information sources for commute trips:

In addition to Trip2Go, did you use any other source to obtain real-time travel information for your commute this morning or evening? (check all that apply)
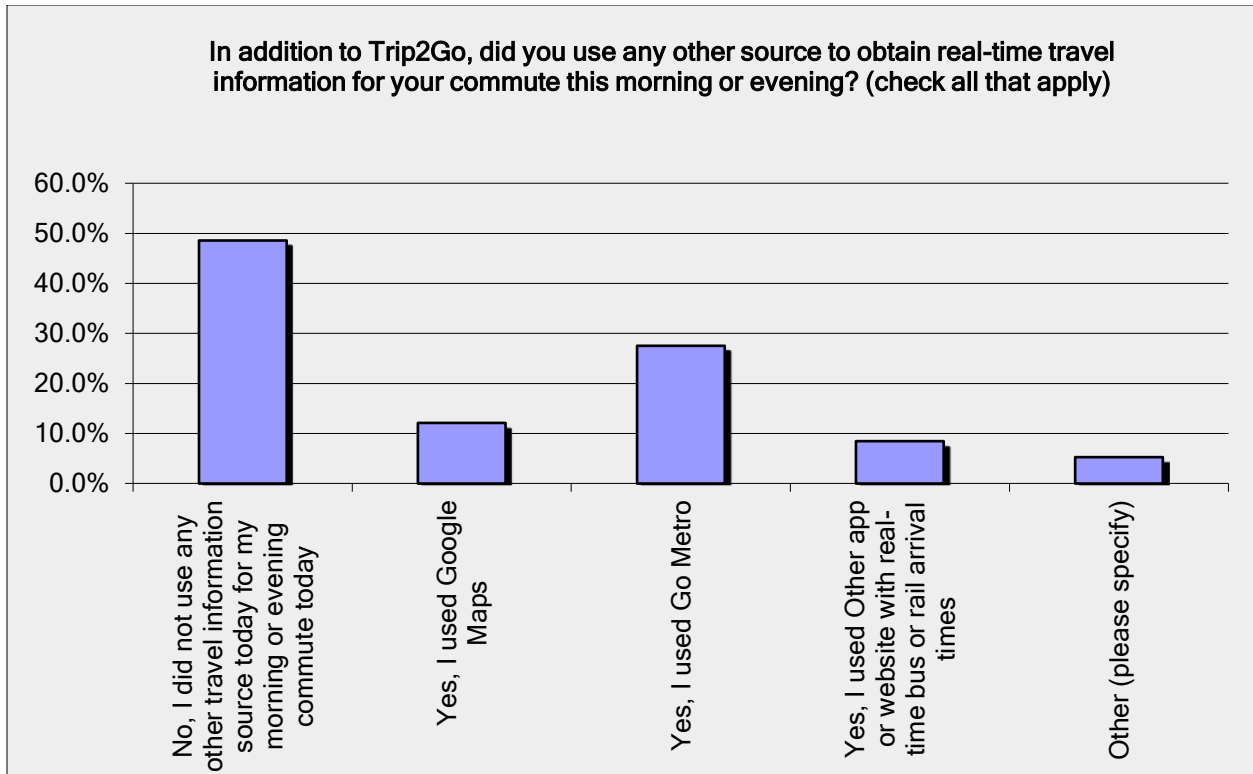
Nearly 50% of the users only use Trip2Go to get real-time information for commute trips.

4. Other real-time information sources for non-commute trips:

In addition to Trip2Go, did you use any other source to obtain real-time travel information for your non-commute trip(s) today? (check all that apply)
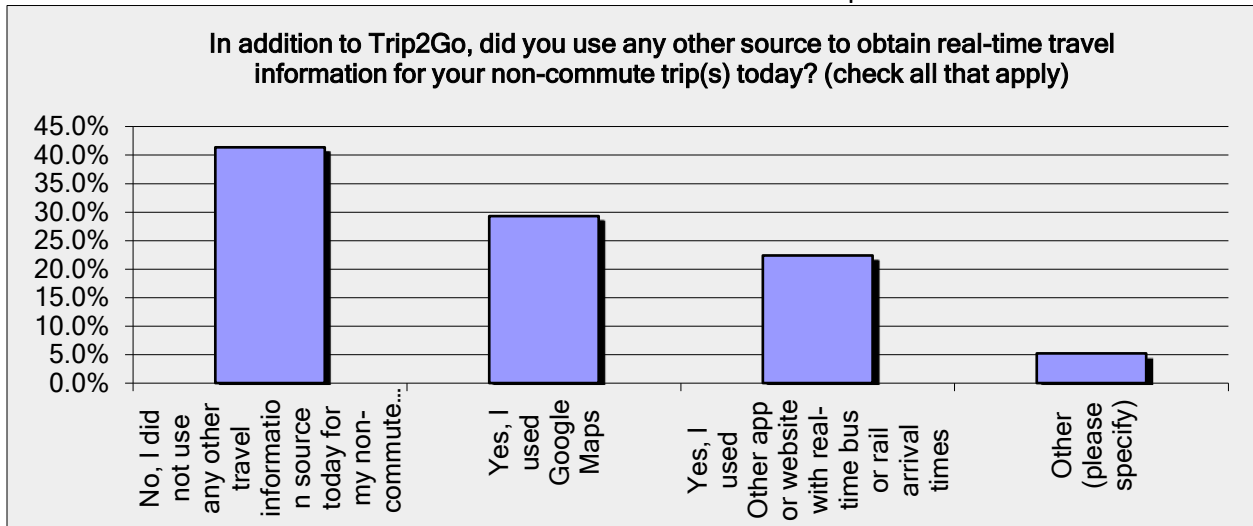
Compared non-commute trips, less people use Trip2Go and more people use Google maps.

5. Real-time information on travel behavior change for commute trips:

Did the real-time travel information that you obtained from Trip2Go or other real-time information sources change your intended morning commute to work? (check all that apply)
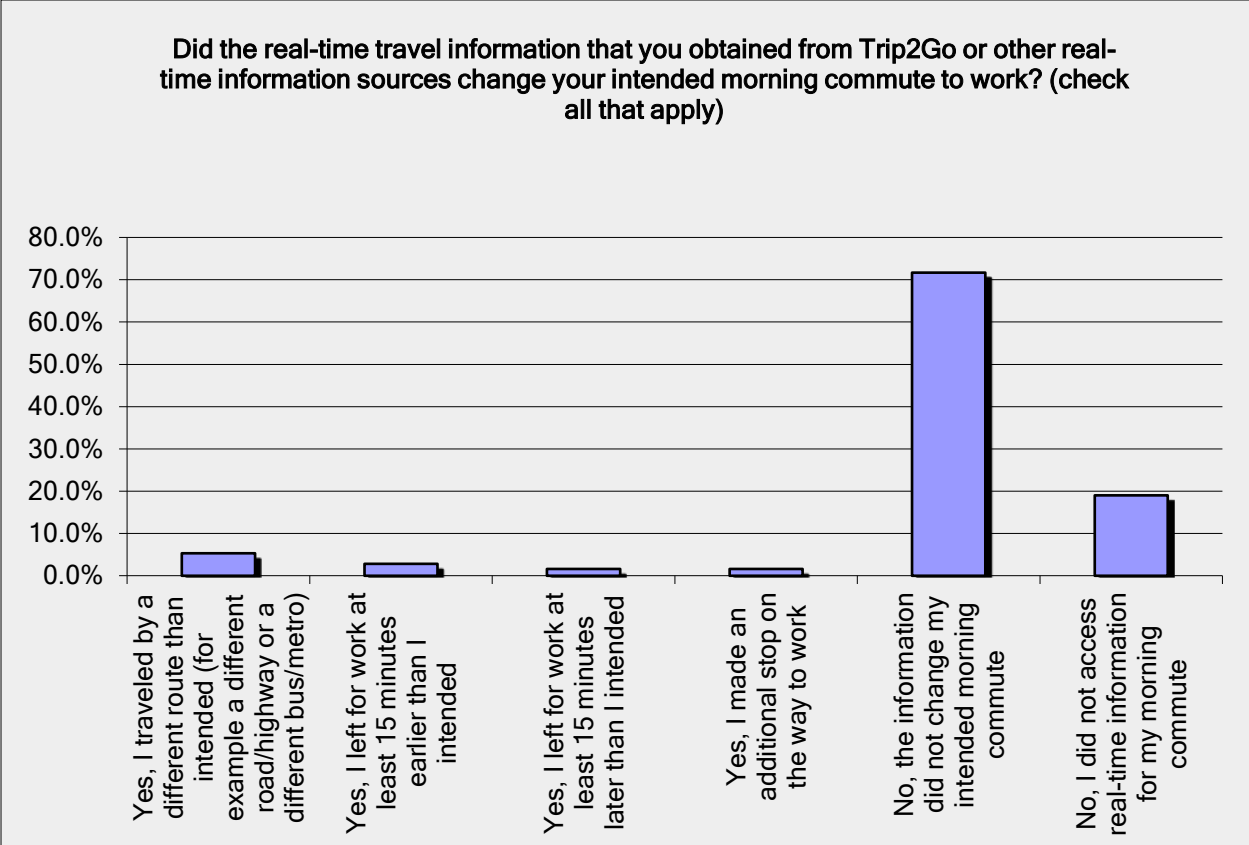
Less than 10% of trips are changed because of the real-time information for morning commute trips. (Evening commute trips are similar)

6. Real-time information on travel behavior change for non-commute trips:

Did the real-time travel information that you obtained from Trip2Go or other real-time information sources influence your non-commute trip(s) today? (check all that apply, even if it applies to only one of your trips from today)
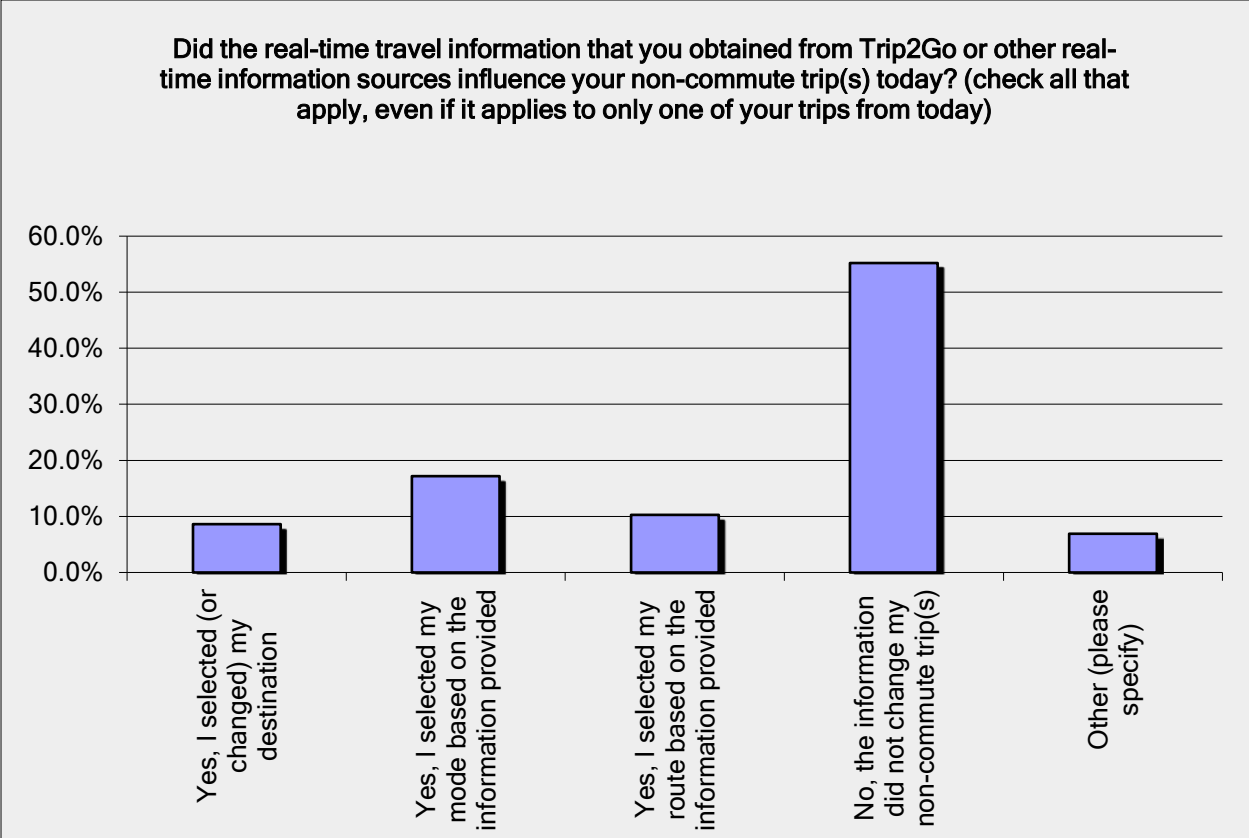
Compared to commute trips, more non-commute trips are changed due to real-time information.

7. Satisfaction rate of the quality of Trip2Go's real-time information:

How satisfied were you with the quality of the real-time information provided by Trip2Go today?

- Very dissatisfied
- Dissatisfied
- Neither satisfied or dissatisfied
- Satisfied
- Very satisfied
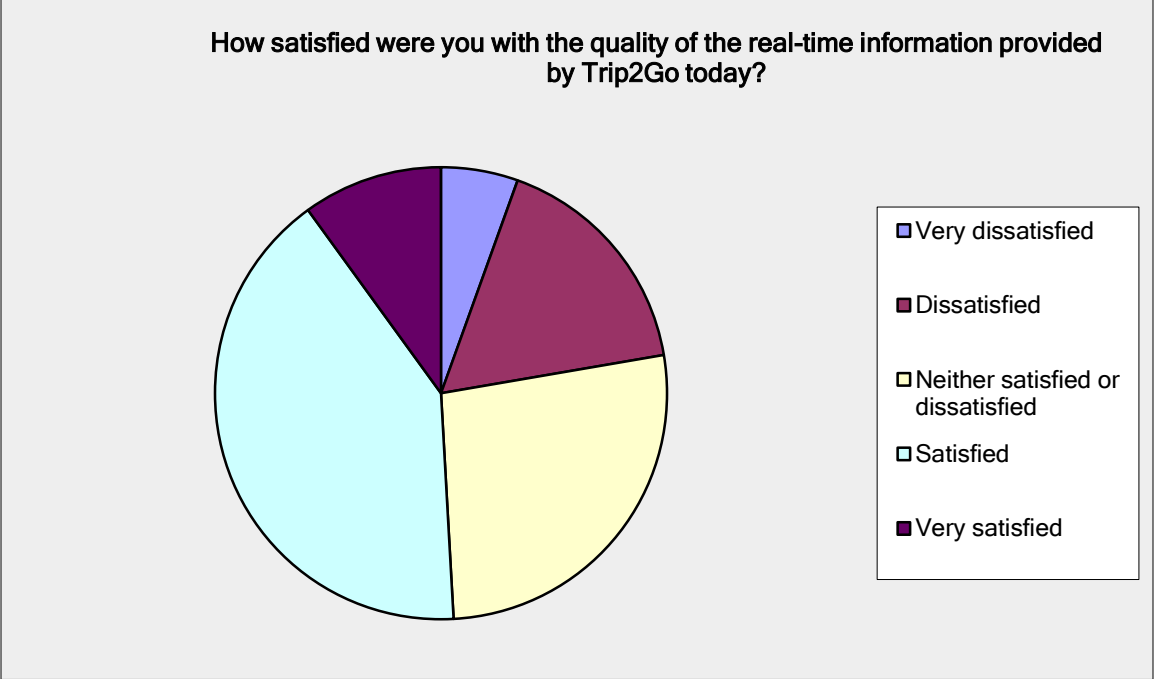
4.2.3 Exit survey

1. Behavior change in terms of using real-time information:

Compared to your behavior before participating in this experiment, would you say you are using real-time travel information (either Trip2Go or other traveler information sources):

Legend:
- ☐ Significantly less than before
- ◼ Somewhat less than before
- ☐ The same as before
- ☐ Somewhat more than before
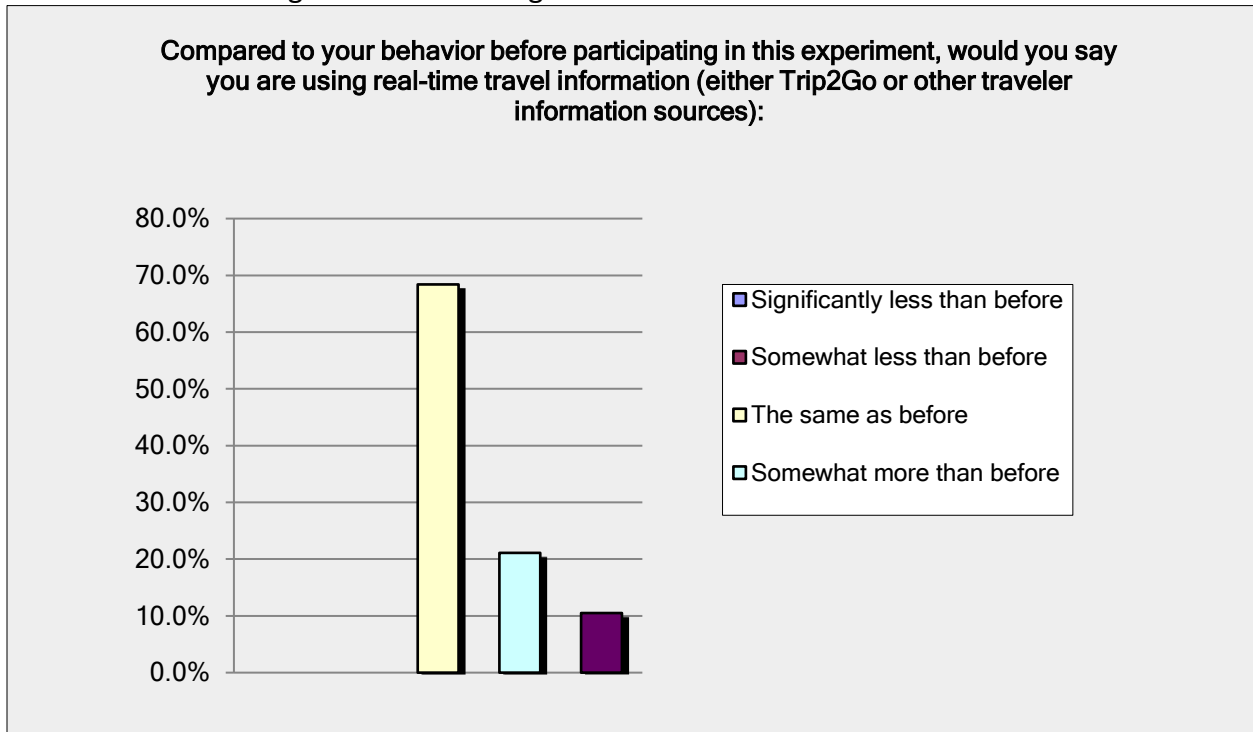
2. Whether to continue to use Trip2Go:

Are you still using Trip2Go? (check all that apply)

3. Usefulness of Trip2Go:

For your commute to or from work, Trip2Go was useful in determining:

Category	Value (approx.)
how to get more physical activity	2.45
how to reduce emissions	2.90
how to save money	2.45
how to save time	2.70
what bus or train to take	2.25
what road to take when driving	2.30
what mode to use (e.g., drive or…)	2.25
when to go to work or leave from…	2.70
whether to go to work or…	1.75

4. Travel behavior change for commute trips:

Are you commuting to/from work differently after participating in this experiment as the result of real time travel information? (Check all that apply)

Response	Percentage (approx.)
No, I am not commuting differently	74.0%
Yes, I have changed when I travel to/from work (at least sometimes).	21.0%
Yes, I have shifted what transportation mode (e.g., drive or transit) I use to get to/from work…	5.0%
Yes, I have modified what roads I take when driving to/from work (at least sometimes).	16.0%
Yes, I have modified what bus and/or train I take when traveling to/from work (at least sometimes).	21.0%

Appendix F

In this section, we present a detailed description of the data we used to estimate the mode choice model.

1. Data on the planning app (presented to users):

|	Driving	Transit	Park-and-Ride
Trip Start Time	15:41:00	15:42:49	15:47:54
Trip End Time	16:05:33	16:14:33	16:29:33
Driving Distance (meters)	29612	0	0
Walking Distance (meters)	0	40	40
Trip Cost ($)	11.040054	1.75	1.7796
Transit Cost ($)	0	1.75	1.75
Parking Cost ($)	0	0	0
Trip Emissions ($)	7.783238	0	0.068864
Travel Time (minutes:second)	24:33	31:44	41:39
Travel Cost ($)	11.040054	1.75	1.7796
Downtime (minutes:second)	0	30:00	30:00
Driving Time (minutes:second)	24:33	0	1:05
Walking Time (minutes:second)	0	1:43	0:33
Number Of Transfers	0	0	0
Transferring Time (minutes:second)	0	0	0
Number of Trip Segment	1	3	3
Historical Travel Time (minutes)	24	31	41
Saved Trip Cost ($)	0	9.290054	9.260454
Emission Less (lb)	0	7.783238	7.714374

Note:

a. "Number of Trip Segment": for example, the following trip contains 3 trip segments: walking -> transit -> walking;

b. Saved Trip Cost = Highest Trip Cost - Trip cost for Driving/Transit/ParkAndRide;

c. Emission Less = Highest Emission – Emission for Driving/Transit/ParkAndRide.

2. GPS trace (he turned on the app after choosing "Driving" in Trip2Go):
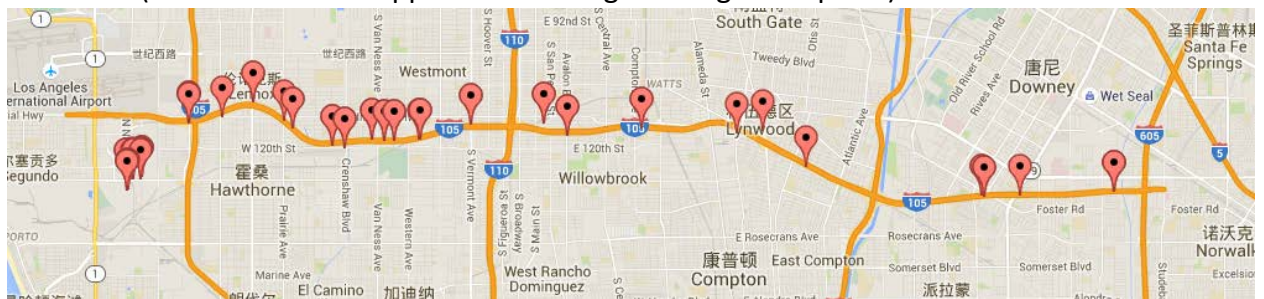
GPS data (Comes from TripGPS database):

Record Time	Current Latitude	Current Longitude	Latest Alert
15:41:48	33.9143	-118.387	ETA update
15:42:08	33.91411	-118.387	ETA update
15:42:29	33.91401	-118.387	ETA update
15:42:49	33.91426	-118.387	ETA update
15:43:29	33.91657	-118.388	ETA update
15:43:50	33.91657	-118.388	ETA update
15:44:10	33.9167	-118.386	ETA update
15:44:30	33.91678	-118.386	ETA update
15:44:51	33.9167	-118.386	ETA update
15:45:11	33.91669	-118.384	ETA update
15:45:32	33.91681	-118.383	ETA update
15:45:52	33.91686	-118.383	ETA update
15:46:13	33.91703	-118.383	ETA update
15:46:33	33.91704	-118.383	ETA update
15:46:53	33.91708	-118.383	ETA update
15:49:16	33.92961	-118.37	ETA update
15:49:37	33.92957	-118.37	ETA update
15:49:58	33.92954	-118.37	ETA update
15:50:21	33.92954	-118.37	ETA update
15:52:16	33.93096	-118.361	ETA update
15:53:52	33.93433	-118.352	ETA update
15:55:38	33.93433	-118.352	ETA update
15:57:54	33.93008	-118.344	ETA update
15:58:23	33.92825	-118.341	ETA update
15:58:46	33.92825	-118.341	ETA update
15:59:21	33.92425	-118.33	ETA update
15:59:51	33.92425	-118.33	ETA update
16:00:46	33.92365	-118.327	ETA update
16:01:11	33.92365	-118.327	ETA update
16:01:34	33.92561	-118.319	ETA update
16:01:54	33.92561	-118.319	ETA update
16:02:14	33.92531	-118.316	ETA update
16:02:35	33.92532	-118.316	ETA update
16:02:56	33.92538	-118.313	ETA update
16:03:16	33.92538	-118.313	ETA update
16:04:37	33.92575	-118.306	ETA update
16:04:57	33.92582	-118.306	ETA update
16:05:18	33.92582	-118.306	ETA update
16:06:29	33.92901	-118.292	ETA update

16:07:03	33.92901	-118.292	ETA update
16:14:57	33.92949	-118.272	ETA update
16:15:26	33.92949	-118.272	ETA update
16:16:25	33.92664	-118.265	ETA update
16:16:46	33.92664	-118.265	ETA update
16:21:48	33.92817	-118.244	ETA update
16:22:08	33.92817	-118.244	ETA update
16:24:26	33.92706	-118.218	ETA update
16:24:48	33.92776	-118.211	ETA update
16:26:08	33.91957	-118.199	ETA update
16:28:27	33.91266	-118.149	ETA update
16:28:48	33.91266	-118.149	ETA update
16:29:59	33.91301	-118.15	ETA update
16:30:27	33.91301	-118.15	ETA update
16:30:55	33.9128	-118.139	ETA update
16:31:48	33.91365	-118.113	ETA update
16:32:14	33.91365	-118.113	ETA update
16:34:43	33.91365	-118.113	ETA update

Alerts can be one of the following: ETA update, Close to Transfer, Your Stop Next, Your Bus/Train is coming, Construction ahead, Accident ahead.

3. Daily survey data of this user on April 22, 2015:

Q1: For what types of trips did you use Trip2Go today?
- Only for commute trips to and/or from work

Q2: How did you get to work from home today?
- Drive to Bus or Rail

Q3: How did you get home from work today?
- Carpool/Vanpool (as passenger)

Q4: In addition to Trip2Go, did you use any other source to obtain real-time travel information for your commute this morning or evening? (check all that apply)
- No, I did not use any other travel information source today for my morning or evening commute today

Q5: Did the real-time travel information that you obtained from Trip2Go or other real-time information sources change your intended morning commute to work? (check all that apply)
- No, I did not access real-time information for my morning commute

Q6: Did the real-time travel information that you obtained from Trip2Go or other real-time information sources change your intended evening commute? (check all that apply)
- No, the information did not change my intended commute in the evening

Q7: **Which of the following information sources influenced your travel decisions (check all that apply)?**

- No information influenced my travel decisions

Q8: **How satisfied were you with the quality of the real-time information provided by Trip2Go today?**

- Satisfied

Q9: **How satisfied were you with the quality of the real-time information provided by the other sources today?**

- Not applicable; I did not obtain information from other sources