OneBusAway:
Improving the Usability of Public Transit

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This is to certify that I have examined this copy of a doctoral dissertation by

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Abstract

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Public transit systems play an important role in providing transportation mobility to a significant portion of the community, while at the same time combating traffic congestion, reducing carbon emissions, and promoting compact, sustainable urban communities. We can help existing riders and encourage new riders by enhancing the usability of public transit through good transit traveler information systems. I describe OneBusAway, a set of transit tools focused on providing real-time information to transit riders in the Puget Sound region of Washington State. I present our design investigations into the barriers to wider use of public transit and describe a principled framework for prioritization of future enhancements of OneBusAway. I present a number of specific enhancements, including work in the area of intelligent, real-time trip planning and service alerts in the mobile domain, as well as crowd-sourcing the validation of public transit data, both describing the motivation for these tools and their evaluation. Finally, I present evaluations of OneBusAway that demonstrate the value of the system across a variety of measures. I specifically show how OneBusAway improves satisfaction with public transit, reduces wait times, increases transit usage, encourages walking, and improves perception of safety among riders.

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Chapter 1
INTRODUCTION

Public transit systems play an increasingly important role in the way people move around their communities. We consider some of the benefits of public transit, the challenges facing its widespread adoption, and the role transit traveler information systems can play in meeting those challenges.

1.1 The Case for Public Transit

The benefits of public transportation are numerous, both to riders and to society at large.

For individuals, public transit provides mobility to those who cannot or prefer not to drive, including access to jobs, education, and medical services. For example, public transit has been shown to provide important access to health-care for poor and elderly riders [91]. Analysis also suggests that improved access to public transit is a significant factor in determining averages rates of labor participation [93]. In general, transport mobility - the ability for people to move around their community - is a strong indicator for employment, with studies showing, for example, a direct connection between car ownership and employment [101]. However, trying to provide everyone with a car is not necessarily the best solution. Attempts to increase access to cars for excluded populations can actually increase social exclusion for those still lacking access to automobile transportation [47]. In fact, social exclusion - the barrier to access of opportunities, social networks, goods and services - is linked to transport mobility in a number of ways [52]. To be clear, transportation mobility is a national problem. Nationally, almost 15 million people in this country have difficulties getting the transportation they need. Of these, about 6 million are people with disabilities. More than 3.5 million people in this country never leave their homes. Of these, 1.9 million are people with disabilities. About 560,000 disabled people indicate they never leave home because of transportation difficulties [72]. Public transit can help remove these barriers and help these populations in ways that automobiles cannot.

Moving from individuals to society at large, the case for public transit can be made in a number of ways. From an economic standpoint, transportation projects and investments can drive economic growth [107] [23]. Public transit reduces congestion, gasoline consumption and the nation's carbon footprint [1]. In 2007, public transit saved 646 million hours of delay and 398 million gallons fuel in the U.S., at an estimated savings of $13.7 billion, when compared with equivalent travel by private automobile [94].

These economic and productivity gains are not limited to just the developed world. In the developing world, transport mobility has been identified as a key factor in achieving a number of the United Nations Millennium Development Goals through improved access to education, health services, and employment [82]. In addition to economic development, transport mobility provides access to important social networks and social capital [7]. Social capital as used in [7] includes the social resources people utilize to pursue their livelihoods and well-being: friends, family, and social interactions, and is undermined by social exclusion. Explorations of transportation policy and global poverty [43] provide specific advice about providing adequate transport to places of employment, eliminating impediments to non-motorized transport, and eliminating gender bias in transport provision.

While the economic benefits of public transit in both the developing and developed world are notable, the environmental impacts are increasingly important as well. Use of public transportation reduced U.S. CO_2 emissions by 6.9 million metric tons in 2005 [18]. Communities that invest in public transit reduce the nation's carbon emissions by 37 million metric tons annually. One person switching to public transit can reduce daily carbon emissions by 20 pounds, or more than 4,800 pounds in a year [1]. While hybrid and electric vehicle technologies can reduce the carbon-footprint of single-occupancy vehicles, they cannot compete with public transit in reduction of traffic and promotion of compact, sustainable communities, rather than low-density sprawl. By helping travelers move from single-occupancy vehicles to public transit systems, communities can reduce traffic congestion and the environmental impact of transportation.

1.2 The Challenge of Public Transit

While the case can be made for public transit, the challenges facing wide-spread adoption of public transit are numerous. Transit agencies across the country periodically survey residents of their region, both riders and non-riders alike, to identify these challenges [70] [14] [103] [15] [8] [12] [108] [24]. What follows is a brief summary of some the concerns most often identified by riders, in order of decreasing importance:

- Wait time when transferring
- On-time performance
- Cleanliness of shelters
- Personal safety on bus after dark
- Travel time by bus
- Ability to get parking at park-n-ride lots
- Frequency of service (especially at night)
- Availability of seating
- Where routes go
- Inside cleanliness
- Driver operates vehicle in safe / competent manner
- Personal safety waiting after dark
- Driver courtesy

Summarizing some of these findings, the battle of user satisfaction with public transit is often not only won on the bus itself, but also off it. Frequent, reliable service in an environment of personal safety at transit stops is critical to rider satisfaction [99] [100].

Additionally, the surveys mentioned previously catalog a number of barriers to using public transit faced by non-riders. These were characteristics that non-riders would not only like to see improved, such as those listed above, but instead were things that literally prevented them from choosing public transportation. This list included:

- I like my car
- Planning around bus schedules
- Have to transfer
- Need car for emergencies

- Need car for errands / kids
- Need to transport stuff
- No stop near work / home
- Not knowing how to use the system

These issues facing riders and non-riders map directly to issues faced by members of our own community. A 2006 survey of King County Metro riders [24] identified key areas of dissatisfaction, including the top two: 26% of riders were dissatisfied with their wait time when transferring, while 19% were dissatisfied with personal safety when waiting for the bus after dark. In addition, 42% of riders said they had experienced problems with on-time bus performance in the past 3 months. Another survey of King County residents [33] found similar reasons for choosing a car over public transit: 45% of respondents reported that not driving would take too much time, 51% said that public transportation was unavailable or impractical, and 57% said that they needed the car to carry things.

In this chapter, I have outlined the ways public transit can benefit both riders and society at large. I have also outlined the challenges facing wider adoption of public transit. In the next chapter, I will present my proposal for meeting some of these challenges, describe the contributions of this research, and give an overview of the remainder of the dissertation.

Chapter 2
THESIS

While the challenges facing the wide-spread adoption of public transit can be addressed in a number of ways, I believe one area of study deserves particular attention. Specifically, real-time transit traveler information systems present a number of opportunities for research, especially given the rapid progress in information communication technology over the past decades, particularly in the area of mobile devices. In general, transit traveler information systems refer to technologies that communicate information about a public transit system to riders. Real-time systems specifically communicate dynamic information to riders, such as predicted vehicle arrival times or service alert information. It has been shown that transit traveler information can generally result in a mode-shift to public transportation [69]. This stems from the riders' ability to feel more in control of their trip, including factors such as their time spent waiting and their perception of safety. Real-time arrival information can help in both of these areas. We specifically focus on real-time information, which has been shown to have a number of benefits. For example, real-time arrival information can shorten a rider's perception of time spent waiting [21] and increase a rider's feelings of safety [111]. For these reason and more, I ultimately believe that pushing the boundaries of how real-time transit information is provided to transit riders can have profound impacts on the way people perceive and use public transit.

For my dissertation, I will demonstrate the following thesis:

> **A real-time transit traveler information system can improve the usability of public transit, ultimately positively changing a rider's use of and satisfaction with their transit system.**

2.1 Research Approach

At the core of of my approach is the OneBusAway transit traveler information system. The system, which began as side-project in my spare time with a simple goal of making it easier for me to ride

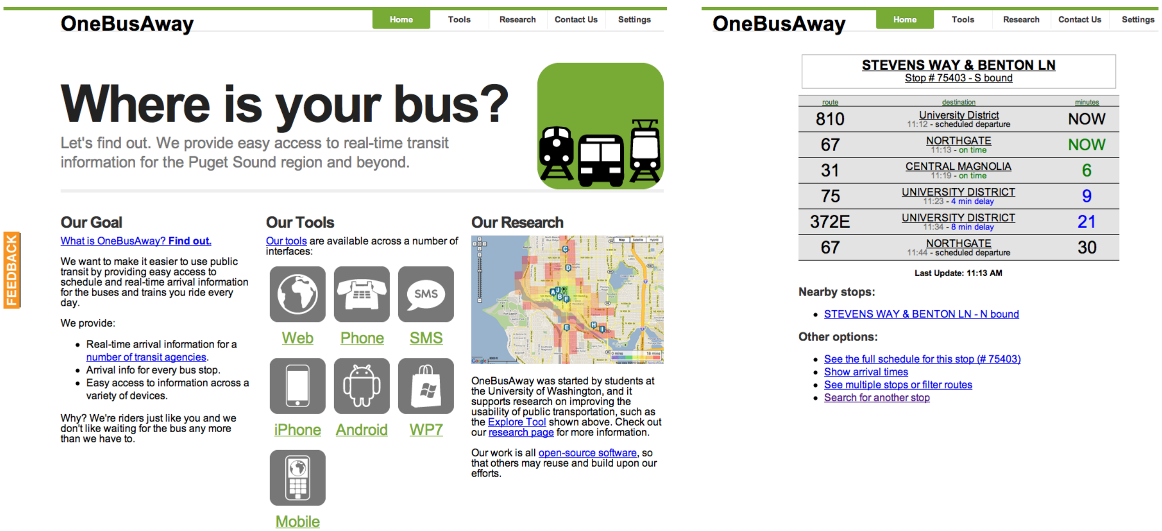

Figure 2.1: The OneBusAway website, on the web at http://onebusaway.org, showing real-time arrival info at a stop.

the bus, is now in regular use by more than 50,000 unique riders each week in the Puget Sound region. The system has grown into a comprehensive suite of tools across a variety of interfaces: web (Figure 2.1), interactive voice response (IVR) phone, SMS, and mobile apps (Figure 2.2). The system is completely open-source, and has an active community of developers both contributing improvements to the system itself and using our public APIs to create new and innovative uses for OneBusAway data on mobile devices and other platforms. The code that powers OneBusAway is currently in use in a pilot project to provide an open-source vehicle tracking solution for New York City MTA buses, and we are actively exploring how other agencies might use OneBusAway for their own transit systems. I will discuss the functionality of the OneBusAway system and artifacts in Chapter 4.

As I have explored in further detail the issues and challenges facing users of public transit, I have generated a number of ideas for new applications and improvements to OneBusAway that I believe might benefit transit riders. However, our developer resources are limited and the number of hours in a day is finite, so I must make hard decisions about which improvements to pursue. There are a number of trade-offs to consider when making such a decision: who does a new feature benefit?

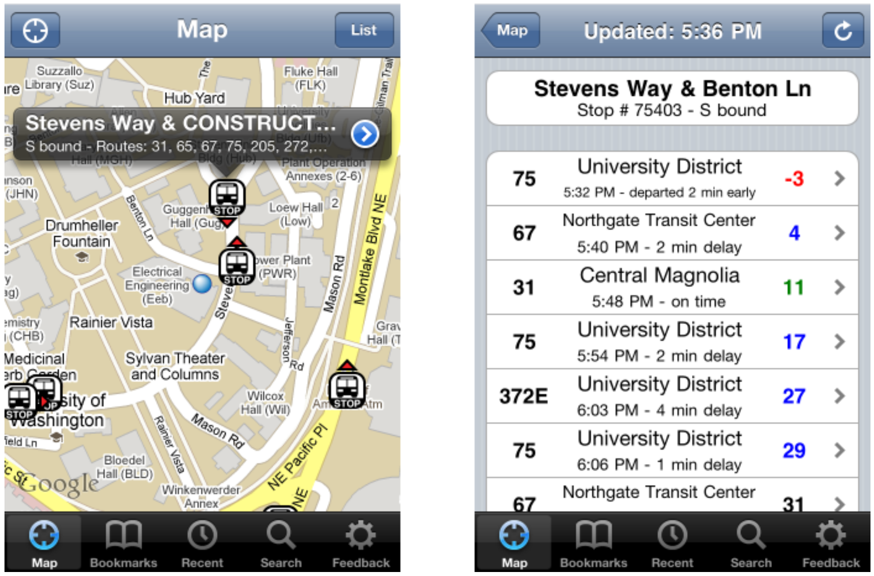

Figure 2.2: The OneBusAway iPhone app, showing real-time arrival information at a stop.

What are the implementation costs? What stakeholder values are impacted by our decision? To address these questions, I present a Value Sensitive Design (VSD) approach to exploring the impacts of new features and outline a framework for prioritizing new features in a principled way. Details of the framework and the VSD analysis are covered in Chapter 6.

As result of that principled prioritization, I will discuss how our exploration has led us in the direction of real-time trip planning and service alerts. While trip planning - the task of providing a rider with directions from point A to point B using public transit - is a critical component of any transit traveler information system, most existing systems function primarily around scheduled data. Of course, the reality is that schedules do not always hold: transit vehicles can be delayed, detoured, or cancelled completely for any number of reasons. I want to communicate this information to riders when they need it most: when they are in the active process of using public transit. There are a number of challenges both technical, practical, and human in achieving this goal. I will discuss these challenges and my initial work on a solution in Chapter 7.

As a real-time transit traveler information system, OneBusAway is only as good as the data that powers it. Open data from our regional transit agencies - providing the locations of stops, route maps, bus schedules, and real-time arrival information - are critical to the system's function, and the accuracy of that data is critical to maintaining the trust of our users. As might be expected with a large, complex data set, there can be errors. Our large user base provides an opportunity to crowd-source the identification and correction of those errors. I present tools that allow users to quickly identify errors, and discuss plans for evaluation of the success of this feature, in Chapter 8.

The success of the OneBusAway ecosystem provides a unique opportunity to explore and evaluate the potential set of designs, features, and issues surrounding a real-time transit traveler information system. While our large user base suggests that we are probably doing something right, I also wanted to explore the effects that real-time transit tools have on riders: their perceptions of public transit, their use of public transit, and their use of transportation in general. I will present specific criteria that I wish to evaluate and present evaluations of these criteria given our user base. Specifically, I present a survey evaluation in Chapter 9, a large-scale user study in Chapter 10, and additional evaluations in Chapter 11.

2.2 Contributions

I present my core contributions below. It is important to note that much of the work on OneBusAway has been done in partnership with my colleague Kari Watkins, a PhD student in UW Civil and Environmental Engineering. As appropriate, I detail contributions that are joint work between Kari and myself.

- OneBusAway, an open-source public transit traveler information suite operating across a number of user interfaces.

- A framework for prioritizing future development of OneBusAway, using the Value Sensitive Design theory and methods, that triangulates among the aspects of stakeholder values, impacted stakeholder dependence on transit, and pragmatics of implementation. (Joint with Kari)

- Implementation and initial evaluation of real-time trip planning and service alerts, with a focus on intelligent mobile interfaces.

- A method for crowd-sourcing the validation of public transit data, with empirical evaluations of the impact on riders and agency staff.

- Evaluation results demonstrating the effects of OneBusAway on transit riders:

  - A survey evaluation of OneBusAway users (Joint with Kari);
  - A field study evaluating frequency of transit use between OneBusAway users and non-users; and
  - A field study evaluating perception of wait time and actual wait times for OneBusAway users and non-users (Joint work with Kari).

Chapter 3

RELATED WORK

3.1 Transit Traveler Information Systems

Transit traveler information systems have come a long way from their humble beginnings as posted paper schedules, route maps, and fixed signage. Even in the earliest days of the web, transit agencies were exploring ways to put transit traveler information online [37]. Most transit agencies these days provide fully featured websites that provide timetables, interactive route maps, trip planners, and service alert subscriptions over email. Some even provide mobile phone optimized webpages or apps with similar information.

In addition to tools provided by agencies themselves, commercial software companies provide a variety of options as well. One of the most popular examples is Google Transit. Started as a Google Labs project in December 2005, Google Transit is now directly integrated into the Google Maps product on the web, and provides transit trip planning for more than 400 cities around the world [39]. Interfaces to Google Transit exist on a variety of mobile devices, making use of location sensors such as GPS and WiFi localization on the device to determine a starting location for trip planning.

While Google Transit has been useful to transit riders around the world, it is also significant for establishing a *de facto* standard for exchanging transit schedule data: the General Transit Feed Specification (GTFS) [38]. Many of the transit agencies participating in the Google Transit program have also released their transit scheduling data in the GTFS format used by third-party developers. Development ecosystems have grown out of the public availability of this data, with many so-called "transit hackers" working on innovative uses of transit data. For example, the Portland TriMet third-party applications page [104] lists over 20 applications using Portland's transit data, many targeted at providing transit data on mobile devices and many of which use localization capabilities of these devices to return location-relevant results. Similar ecosystems exist in San Francisco, Chicago, and other major cities.

Though Google Transit has proven pivotal in encouraging the availability of open transit data, the Google Transit trip planning engine is not available as an API for other tools to use. As such, projects like OneBusAway must look elsewhere for their trip planning needs. While a variety of papers have discussed aspects of implementing a transit trip planning engine [85] [109], OneBusAway is currently using the OpenTripPlanner project [81]. The project aims to provide an open-source multi-modal trip planner for use by developers and transit agencies alike. OneBusAway was involved with the initial founding of OpenTripPlanner and recent work has focused on tighter integration between the two projects.

3.2 Real-Time Arrival Information

While static schedules and timetables are an important base for rider information, the reality is that transit vehicles do not always run on time. Traffic congestion, weather, accidents, passenger incidents: there are any number of reasons why a transit vehicle might not meet its schedule. As such, many recent transit traveler information system improvements have focused on providing real-time arrival information. Increasingly in use by U.S transit agencies [10], real-time arrival information using fixed signage is a relatively accepted means to increase ridership by reducing rider anxiety, increasing the perception of reliability and presenting an image of a modern transit system [83].

While we will discuss additional rider benefits from real-time arrival information below, many transit agencies adopt real-time arrival prediction and vehicle tracking systems primarily to improve the agency's own management of its transit fleet. Real-time vehicle tracking can lead to more efficient operations and also enhanced sense of safety for transit operators [83] [68]. In terms of efficiency, studies have found that agencies must build a fair amount of slack time into their schedules to allow for delayed buses. Slack time is the padding agencies add to their schedule above and beyond the minimal travel time for a route. The ratio of slack time in the schedule versus scheduled travel time can be as high as 25% [19]. However, with real-time tracking, agencies can adopt a headway based approach. Supervisors use real time transit data to maintain a certain amount of time between buses, rather than attempting to maintain a schedule, thereby allowing free running time and saving slack time [112]. This savings in running time can allow an agency to provide the same level of service on a transit route at reduced cost, or provide higher frequency at the same cost.

While real-time arrival systems have most often focused on fixed displays at transit stations and stops, that need not be the case. The investment in website and phone-based real time transit information can potentially save an agency substantially in deployment costs. As an example, Portland deployed their Transit Tracker program in 2001 with information displays at transit stops, a webpage, and, more, recently a phone system. The transit tracker signs at light rail stations and 13 bus stops in Portland cost $950,000 including message signs and conduit. The cost for computer servers and webpage development was much less expensive at $125,000 [13]. Given the widespread availability of mobile phones and web access, providing real time transit information via a service such as OneBusAway could yield a substantial savings for an agency over constructing real-time arrival display signs. At the same time, consideration must be given in order not to unfairly disadvantage people who do not have access to such technology.

3.3 Effects of Real-time Arrival Information on Riders

While analytical modeling and surveying have hinted that providing real-time arrival information could lead to improvement in rider measures such as travel time [44] or encourage a mode-shift for ad-hoc trips [88], only recently have enough real-time systems been deployed such that thorough evaluations of the effects of real-time on riders could be conducted. One study showed a 20% reduction in perceived wait time with the addition of fixed real-time arrival signage at a tram station [21]. Other work has more generally demonstrated real-time arrival information's positive impact on rider perceived wait time, feelings of security, and public transit ease of use [22] [111]. However, surprisingly, those results were not confirmed in an initial Seattle deployment over seven years ago, where no increase in rider satisfaction was found [95].

In the transit service planning industry, 10 minutes has long been considered the barrier between schedule-based and headway-based service. A recent study found that at 11 minutes, passengers begin to coordinate their arrivals rather than arriving randomly [83]. This is consistent with earlier studies documenting random versus coordinated arrivals. Therefore, at a time between buses greater than 10 minutes, passengers want a schedule to coordinate their arrival times. However, with the introduction of real-time arrival information systems, such as OneBusAway, we have shown that users more frequently refer to real time information than to schedules to determine when to wait at the bus stop. Building on our previous discussion of headway-based scheduling, there is a potential opportunity to move routes from scheduled-based to headway-based operation at longer frequency intervals, providing potential opportunities for reductions in operating costs for agencies.

3.4 Real-time Vehicle Tracking and Prediction

The task of physically tracking the location of transit vehicles and predicting their arrival at a transit stop is largely a solved problem at this point, with commercial systems available to transit agencies to perform the task. However, it is worthwhile to review the research origins of these systems, note situations where commercial systems are not always appropriate, and discuss potential alternatives. Early work in the field focused on physically tracking transit vehicles using various positioning technologies [20] or synchronizing a timed transfer between two routes [19]. One of the first online bus tracking and arrival prediction systems, BusView, was developed by Daniel Dailey and others at the University of Washington [63]. The system used a Kalman Filter based approach and worked with vehicle odometry and radio beacon sensor data. The system has since been extended to work with GPS data; some combination of GPS and dead-reckoning is the preferred method for most modern systems.

More recent work in the field has focused on more robust prediction [48], and incorporating historical data in a variety of ways to improve real-time arrival prediction accuracy [50] [17] [57]. While these, and other commercial systems deployed by modern transit agencies, work quite well in practice, they are expensive to deploy and require a large amount of structured schedule and GIS to function properly. That can be a prohibitively high barrier to entry for some transit systems, especially in the developing world, where research has focused on the deployment of cheap GPS and SMS devices that can be used ad-hoc public transit vehicle tracking [2] [86]. Even in the developed world, finding the financial resources to install a vehicle-tracking system can be difficult. Here, researchers and developers have looked to take advantage of the proliferation of GPS-enabled smart phones to build crowd-sourced vehicle tracking systems [102]. While many have argued the value of such crowd-source systems to give riders a more active role in their transit system [98] [62], and the technical algorithms to power such systems have been explored in detail, the real challenge lies in encouraging enough users to provide crowd-sourced information to make the system useful while avoiding bad data from bad actors [110].

3.5 Mobile Applications

With the proliferation of smart phones in recent years, the number of mobile applications for public transit has exploded [104]. That said, a number of researchers have looked more systematically at how mobile applications can improve the usability of public transit, both for the general rider (e.g., [55] - TramMate tool, various notifications), and for targeted groups such as those with cognitive impairments [9] including participatory design approaches [29]. As examples of the latter sort of application, the Travel Assistance Device (TAD) [4] uses GPS on a mobile device to detect the current location of a bus rider so as to prompt the rider with context specific prompts, such as notification of an upcoming stop. Another example is Mobility Agents [90], which provides a mobile device interface for users with cognitive impairments and a web interface for caregivers that allowed them to receive status updates about the progress of their charges.

Both the Travel Assistance Device and Mobility Agents require some amount of involvement from a care-giver in both initial setup and active monitoring during a trip. Other systems have attempted to reduce the burden on the care-giver. The Opportunity Knocks system, briefly mentioned in [61] and elaborated further in [84], provides a mobile, location-aware application to provide cognitive assistance to transit riders. Unlike the TAD and Mobility Agents tools, the Opportunity Knocks system automatically detects the user's current mode of transportation from GPS traces and learns the important places a user travels to, such as home and workplace, without manual labeling. Based on these learned models, the application can automatically predict where a user is headed given only a small amount of tracking data, and can detect when the user does something unexpected, such as forgetting to get off the bus at a regular stop or getting on a wrong bus.

Another class of applications targeting general riders are persuasive applications: tools designed primarily to encourage the use of public transit or other social goals. A prime example is the UbiGreen application [33], a mobile app that encourages the use of non-single-occupancy-vehicle travel by rewarding the user with a progressively revealed cute graphic featuring polar bears and penguins every time the user makes an alternative transportation choice. The application makes use of some sensing on the phone to determine transportation mode transition points and has a number of game-like qualities that encourage user participation. Another application tries the carrot and stick approach, providing bus schedule and transportation pollution information for riders on a mobile phone [89]. The authors note, however, that riders responded more positively to the utility of the schedule information than the pollution information. As a final example of persuasive transit tools, consider [66], which considers a variety of persuasive displays in a subway station to encourage healthier activity (e.g. take the stairs) and social interaction around public transit.

These mobile applications for public transit have some common technical elements which we wish to explore further. Specifically, most rely on some form of transportation mode detection and a subset make use of some form of significant place detection.

3.6 Transportation Mode Detection

A key task in most real-time mobile public transit applications is the ability to detect the current transportation mode of the user: is the user stopped, walking, on a bus, in a car, or on a bike? A variety of techniques have been proposed in the literature to address this task. These techniques can be grouped by the sensors they use (GPS, accelerometers, WiFi localization), the underlying data sources they require (GIS street network, bus stop network), whether they run offline or online, and how much training data they require.

Liao and colleagues [61] present a technique for robustly tracking a user's location, mode of transportation, and likely destination from GPS traces. The system can additionally detect deviations from ordinary behavior, such as failing to get off a bus at a regular stop or getting on the wrong bus entirely. Their technique uses hierarchical Markov models, represented as a Dynamic Bayesian Network, along with Rao-Blackwellized particle filters to efficiently and compactly perform inference. The system learns likely transportation mode transition points, such as favorite bus stops or parking lots, as well as destination goals from GPS traces, but assumes access to data about the underlying street and transit networks, as well as a sufficient corpus of GPS traces for training.

A similar GPS-only method [113] presents an offline method for determining transportation mode from GPS traces. The method does not require access to street and transit network data, but instead assumes a large enough corpus of GPS data from multiple users to automatically learn road network and bus stop locations. The method applies a change-point-based segmentation procedure to trace data, followed by targeted feature extraction on segments, and finally decision tree classification on each segment to determine classification mode.

With the proliferation of mobile devices carrying not only GPS, but also WiFi-localization and accelerometer sensors, a variety of techniques have attempted to combine information from all three sources for transportation mode determination [59] [114] [87]. Because of the power consumption penalty for using GPS on a mobile device continuously, techniques are focusing more and more on using lower power sensors like the accelerometer or cell-tower ID to do the bulk of classification, only using the GPS when a user is in motion [102].

3.7 Significant Place Detection

As mobile applications for public transit attempt to reduce the amount of manual configuration required of the user and move towards a model of automatic discovery, significant place detection becomes a key building block for most intelligent transit applications. Significant place detection refers to the task of automatically detecting important places that a user visits repeatedly over the course of a day, week, or month. Simple examples include where a user lives, where they work, where they go to school, or where they shop for groceries.

Most standard techniques in this area focus on simply detecting when a location sensor, such as GPS or WiFi-localization, indicate that a user has stopped for some fixed minimum threshold of time [45] [49] [53]. Others use the lack of an accurate GPS lock to indicate that a user is indoors in a building [61]. Fundamentally, these techniques suffer from the fact that any fixed threshold method will fail in some instances, whether it be a false positive or true negative. As an example, it can be hard to distinguish between a lengthy traffic light that a user gets stuck at each day on their way to work versus quickly dropping off the kids at school each morning. The pause for the traffic light might appear longer than the pause for dropping off the kids.

Liao and colleagues address these limitations with significant place detection in [60]. The authors jointly model significant places and activities at those places to build a more accurate representation than what is possible with simple fixed-time-threshold place detection methods. By combining rich context data about a user - including GPS traces, transportation data, and an expanded activity model, with a hierarchical Conditional Random Field - they efficiently infer user activities and navigation patterns. Because the number of significant places is not known a-priori, an iterative refinement technique of inference, labeling, and clustering is used until the set of significant places converge. Other techniques have tried different approaches to this problem, including a non-temporal Dirichlet process clustering algorithm for place segmentation and clustering [71].

It is also worth mentioning the Predestination system [56], which is standard in the way it uses GPS to learn models of significant places and destinations, but novel in its attempts to better combine previous information from user with an open-world model that uses a general model to predict when a user is headed somewhere new. This may better handle the initial case where not enough information has yet been collected to build a sufficient model of a user's significant places.

Finally, it is worth mentioning that there are other sources of significant place labels for potential mining. Place check-in systems - such as Foursquare [30], Gowalla [41], and Facebook [25] - encourage users to check-in at the places they visit over the course of the day, sharing that information with their social network and earning potential rewards from each site.

3.8 Usability and Accessibility

Some work in the literature has looked at the general issue of usability and design when it comes to transit traveler information systems. For example, some work has shown a slight preference among riders for textual travel itineraries over graphical itineraries [65]. Other work has attempted to outline the general information requirements for a transit traveler information system at the various stages of the transit process [11] [42].

In terms of usability, accessibility issues are often of critical importance when considering the design of a transit traveler information system, as riders with visual, auditory, cognitive, or mobility impairments are often those most dependent on public transit. The public transit industry itself has put a lot of resources into identifying and addressing areas needing accessibility improvements for riders, especially in light of Americans with Disabilities Act (ADA) requirements. Transportation literature [46] has surveyed a variety of transit accessibility options, covering stop announcements (audio, visual), tactile maps, rider orientation and mobility training, agency sensitivity training, and other possibilities. Agencies, often faced with limited budges, hope to find solutions that improve the usability of public transit for all riders while specifically benefiting riders with impairments. Other specific challenges have been identified in the area of para-transit [73], where timeliness, service-denial, and cost are major factors limiting access to riders who need it most.

Agencies and research groups have increasingly looked to technology as a potentially cost-effective solution to some accessibility challenges. For blind users in particular, a number of options have been explored. One system uses infrared beacons to help blind users more easily identify bus stop locations [16]. Another provides discussion about transit accessibility issues [67], which specific design guidelines for mobile web accessibility. Tools the explore the use of Braille keyboards to communicate transit information for blind and deaf-blind riders have been explored in research [3] and in commercial systems as well [96].

3.9 Social Impact of Transit

We discussed how transport mobility relates to the ideas of social capital and social exclusion in the introduction. We described specifically how access to transportation; whether car, public transit, or other modes; can play a general role in issues of social capital and exclusion [47] [52] [7].

Studies have also looked at particular transit-dependent populations to see what specific issues are faced by those groups. Of particular relevance to our work is [92], where the authors present a design ethnography of transit-dependent riders in the Seattle area. The work identifies groups of transit-dependent riders, their technology use, and their transit priorities while examining innovative ways these riders overcome transit constraints by focusing on agency: their resourcefulness and resilience. There are some specific insights, such as the discovery that many transit-dependent riders in the White Center area of Seattle would use a system like OneBusAway, but they had simply not heard of it. The work proposes a number of specific design recommendations: smarter, more-flexible trip planning, better discoverability for existing tools, user ratings or recommendations for routes, improved facilitation of social connections for transit riders, and the ability to highlight valuable nearby services and destinations for riders. At the same time, any such system must avoid the need for advanced personal technology resources.

Similar work described in [58] highlights the impacts seemingly well-meaning changes can have. One agency's move to an electronic fare payment system had a negative impact on the poor: the system was harder to use, the account balance was less visible, and riders lost the ability to negotiate a fare closer to what they could afford to pay. Similar results were found in [92]. These instances highlight some of the general social justice and social exclusion issues in focusing resources on capturing non-transit-dependent riders when transit dependents are often a more important core constituency [35].

Chapter 4
THE ONEBUSAWAY SYSTEM

In this chapter, I will go into specific detail about the various OneBusAway system artifacts. Almost all the components that make up the OneBusAway system are open-source, with all code available on the web at our Google Code project page [76]. The system is composed of many pieces, tools, and interfaces:

- The `http://onebusaway.org/` website
- The phone interactive-voice-response (IVR) interface
- The SMS text-messaging interface
- The iPhone app
- The OneBusAway API
- The Explore tool
- The service alerts webapp
- The SIRI (Service Interface for Real Time Information) repeater

We will cover each piece individually in the remainder of this chapter, along with a brief summary of the relative usage statistics for each interface.

4.1 The Website

The OneBusAway website, at `http://onebusaway.org/`, is the main entry point for most riders when using OneBusAway for the first time. The homepage, as shown in Figure 4.1, has a

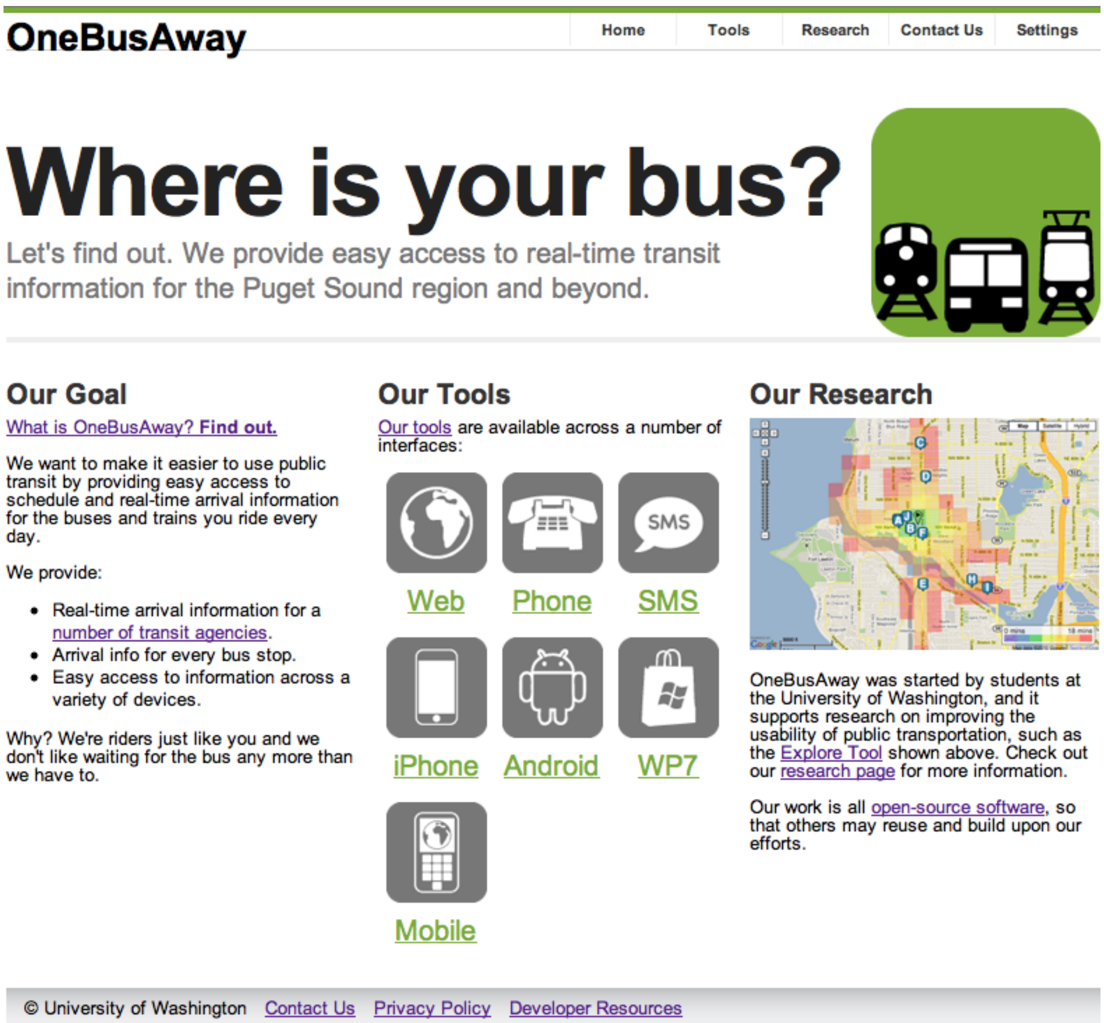

Figure 4.1: The http://onebusaway.org homepage.

description of the project, links to the various OneBusAway interfaces, and more details about the research driven by OneBusAway.

There are three primary OneBusAway interfaces powered by the website:

- the standard desktop web interface;
- the iPhone-optimized mobile web interface; and
- the text-only web interface.

We will cover each interface briefly in the following subsections.

4.1.1 The Standard Desktop Web Interface

The standard desktop web interface [79] is designed to loosely mimic the interface of the main Google Maps website [40] that many users are already familiar with. Specifically, the primary view is a Google map view, with a search field at the top and a search results panel on the left. Users can browse the map directly to see transit stops at a particular location, as shown in Figure 4.2. Additionally, users can search by route to display the map of that route and stops along the route, as shown in Figure 4.3. One important interface detail is that we calculate the direction of travel for routes serving a particular stop and show a directional arrow for the stop on the map. This direction-of-travel arrow is particularly useful to riders when they are attempting to disambiguate between two transit stops that are right across the street from each other, but serve routes headed in opposite directions.

After selecting a stop, users are presented with a list view of upcoming arrivals and departures at that stop, as shown in Figure 4.4. Each entry in the stop view shows information about a single transit vehicle, presenting route number, destination, and estimated time of departure as both a fully-specified time and a minute countdown. When the vehicle is less than one minute away, the minute countdown changes to display ’NOW’. A vehicle that has already departed has a negative value for its minute countdown. By default, results are sorted in order of departure, but results can also be sorted by route or destination, and additionally filtered by route number. The minute countdown is additionally colored to indicate the on-time status of the vehicle. The color conventions are the

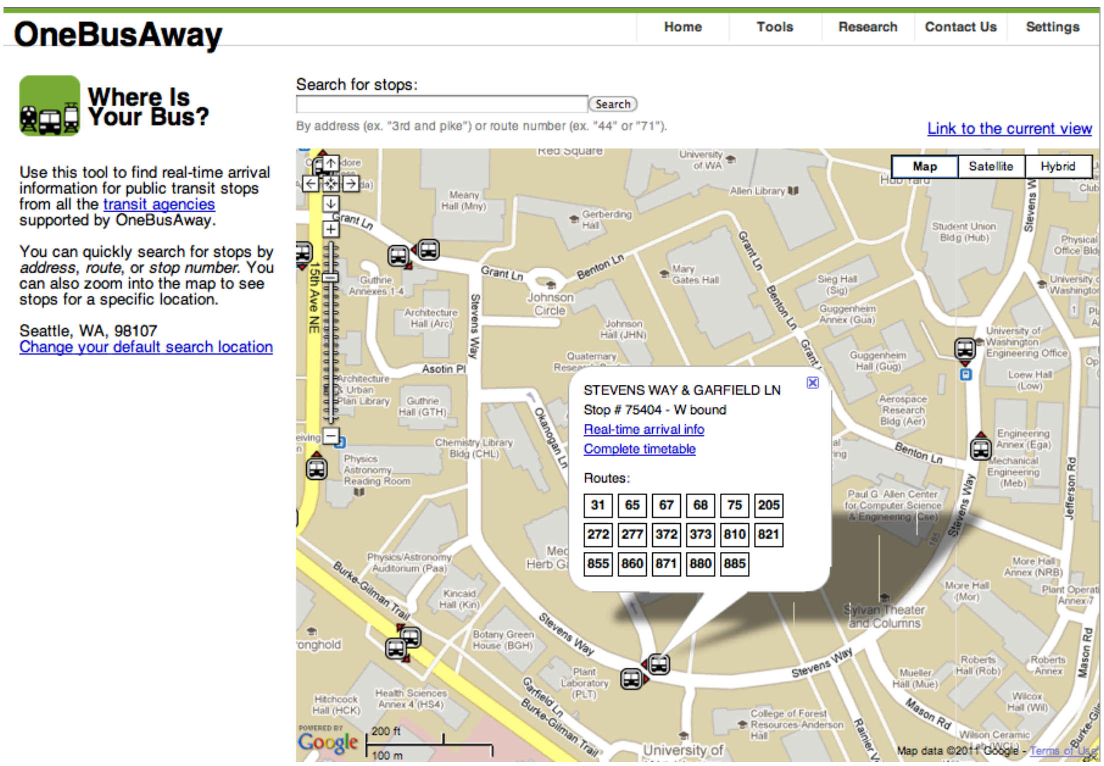

Figure 4.2: The standard desktop web interface, showing transit stops on the University of Washington campus, with a specific stop detail info window shown.

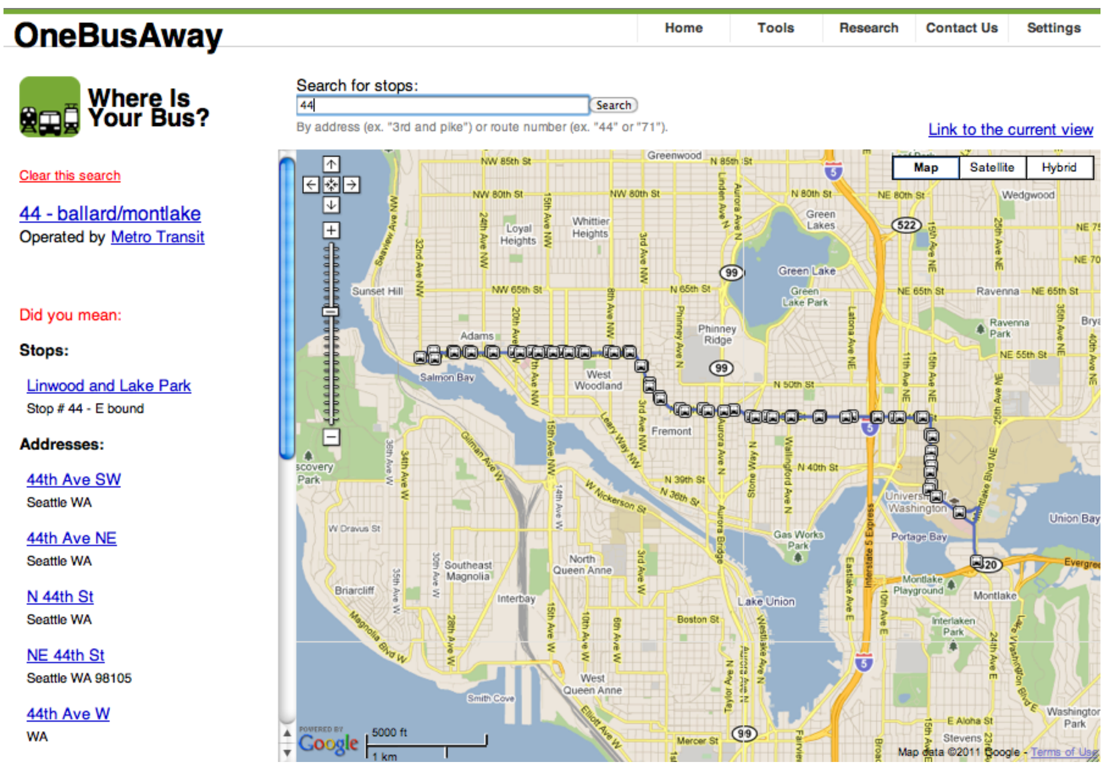

Figure 4.3: The standard desktop web interface, showing transit stops along King County Metro Route 44.

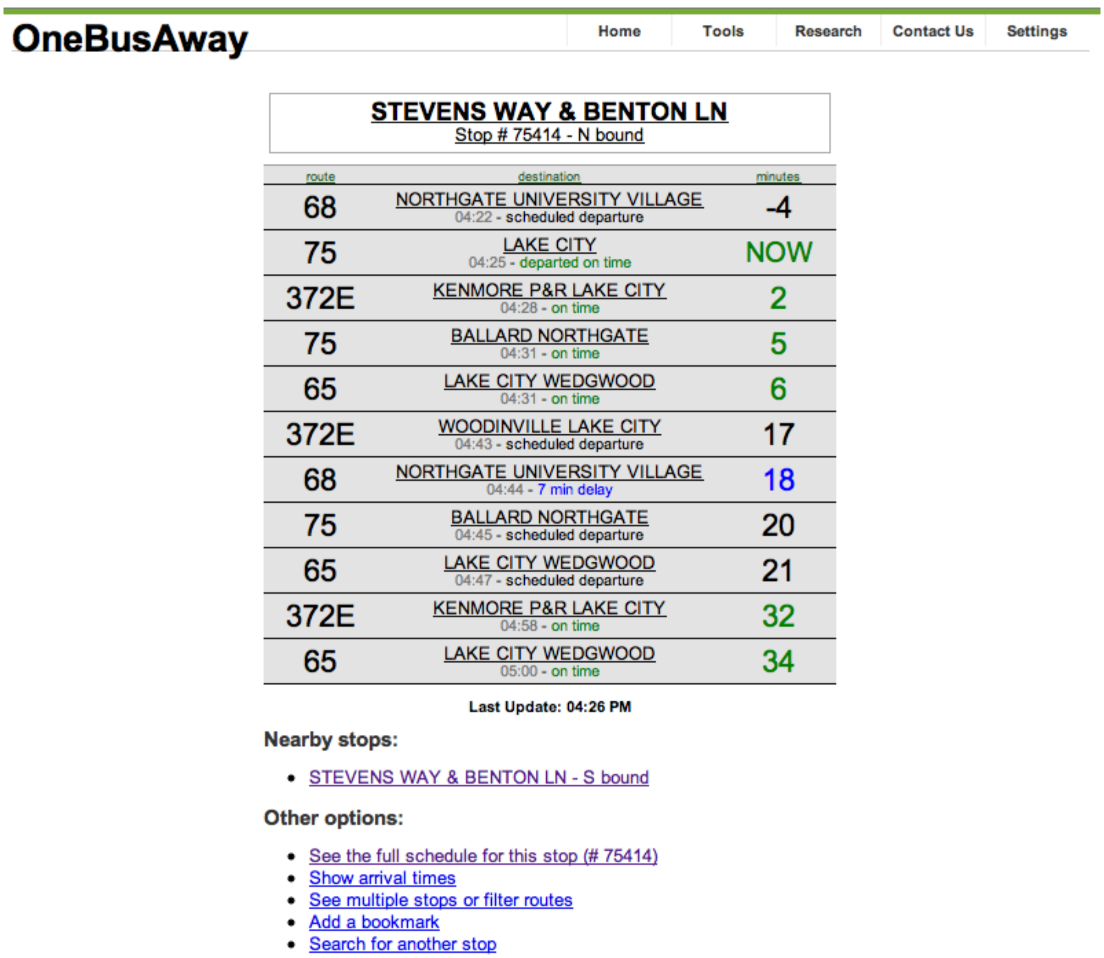

Figure 4.4: The standard desktop web interface, showing real-time arrival information for stop # 75414 on the University of Washington campus.

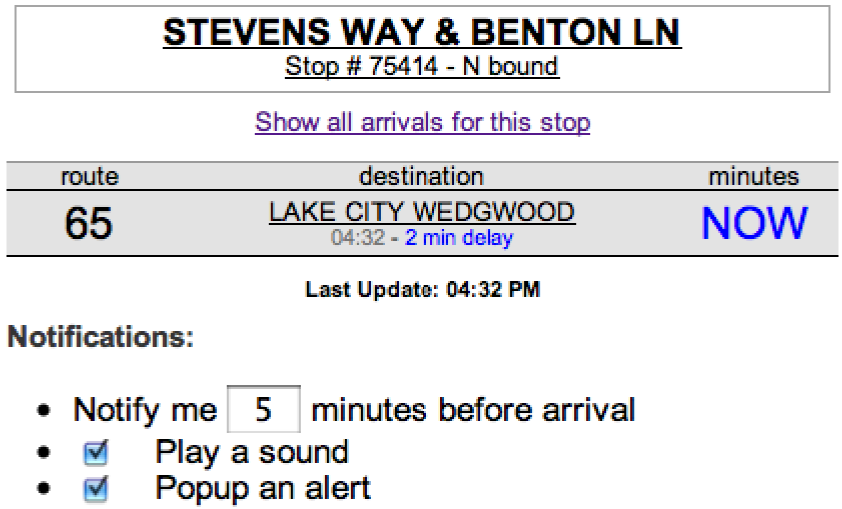

Figure 4.5: The standard desktop web interface, showing the alarm view for a particular bus arrival.

same as those adopted by the MyBus.org site: green means a vehicle is running on-time, blue means late, red means early, and black indicates that no real-time arrival information is available. We additionally spell out the same information with a text label such as “on time”, “7 min delay” or “scheduled departure”.

Scheduled departures, which indicate vehicles with no real-time arrival information, are a tricky part of the interface. A transit vehicle might not be communicating real-time arrival information for any number of reasons. Some are benign, such as a radio malfunction on an otherwise normally-operating bus, while others are more severe, such as a broken-down bus that is neither communicating real-time information nor arriving any time soon. Unfortunately, we cannot distinguish between these two cases given the information currently provided to us by transit agencies. Faced with this ambiguity, we default to showing the scheduled arrival time of the transit vehicle and indicating to the user that we do not have real-time information, allowing them to decide how to act. Unfortunately, not every user is clear on the distinction between scheduled and real-time arrival information, as discussed in Sections 5.3 and 8.1.2.

From the stop view, users can select a particular vehicle and set an alarm that will automatically

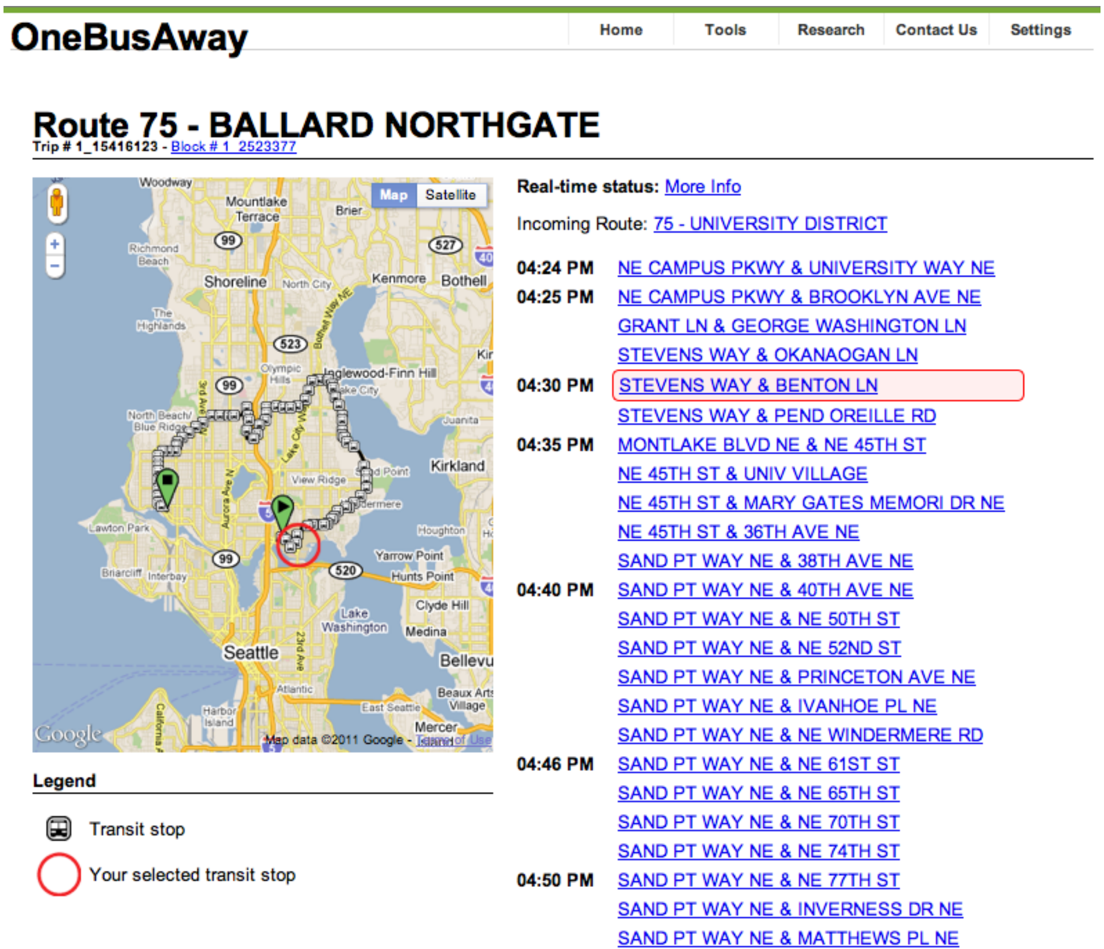

Figure 4.6: The standard desktop web interface, showing the trip details for a particular vehicle.

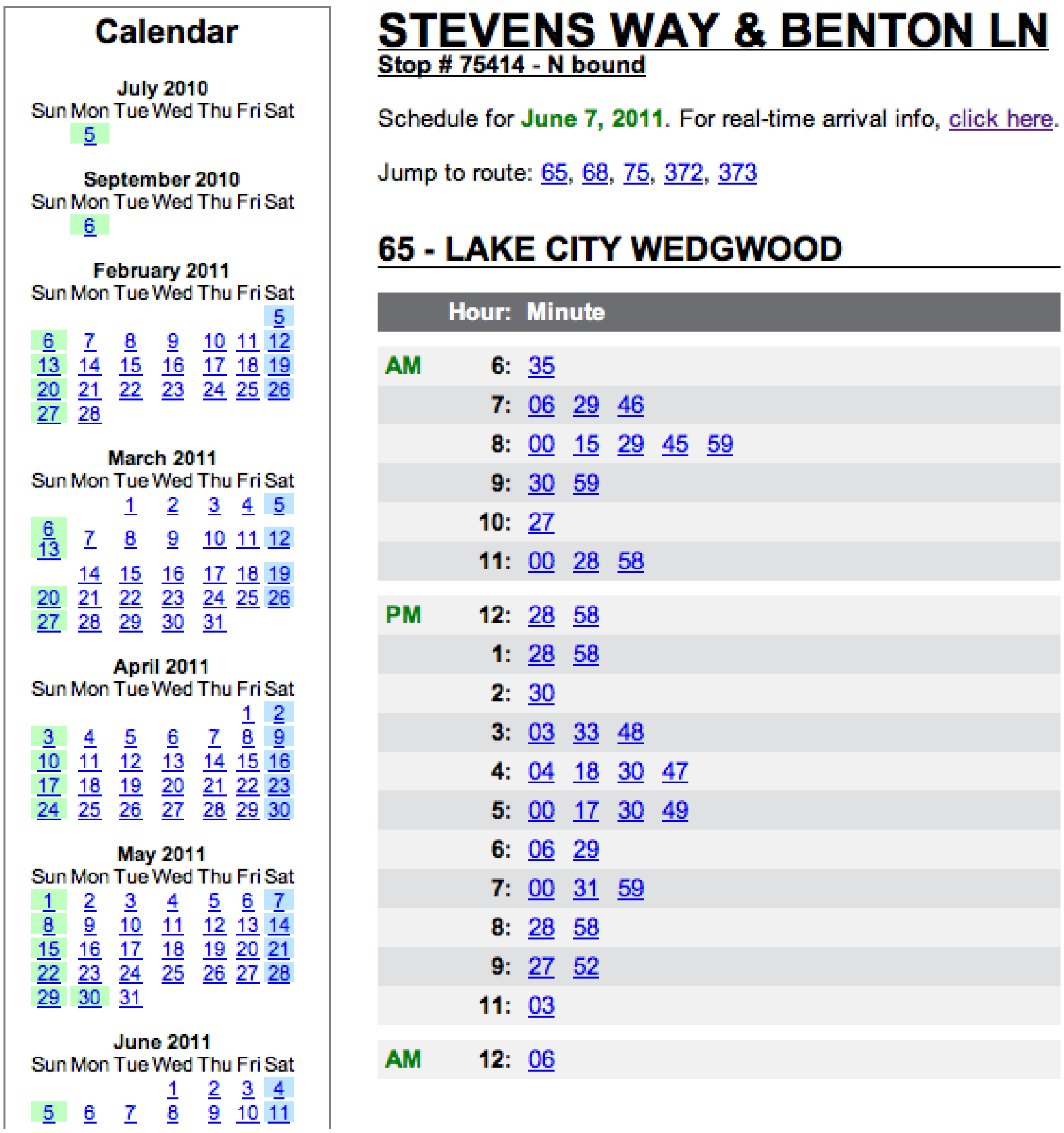

Figure 4.7: The standard desktop web interface, showing the schedule details for a particular stop.

notify them with a sound and a browser alert when it is time to catch their bus, as shown in Figure 4.5. Users can also see more details of the current route and trip of a particular vehicle, showing the path of travel, stops serviced, and estimated schedule, as shown in Figure 4.6. Finally, users can see a complete schedule for a particular stop, as shown in Figure 4.7. Note that the schedule for each route is shown in a stem-and-leaf format, where arrivals and departures are grouped by hour to visually indicate frequency of service. For example, there are more entries during the morning and evening commute. Also note that we show the schedule on a day-by-day basis, with a calendar indicating different service days on the left. While it would be preferred to provide a summary schedule view that shows weekday versus weekend service in one combined schedule, it was difficult to automatically generate such a schedule, considering all the edge cases around irregular and holiday service.

4.1.2 The iPhone-Optimized Mobile Web Interface

The iPhone-optimized mobile web interface [77], shown in Figure 4.8, was designed first and foremost for the mobile browser on the iPhone. For the first year or two of the availability of the iPhone, native apps were not an option for the platform. Instead, optimized webapps were the only outlet for running something like an "app" on the phone. These webapps basically consist of webpages optimized touch-screen web browser of the iPhone. When native apps were finally allowed on the iPhone, I eventually developed and released a native app for the iPhone that could take advantage of location-aware and mapping features of the phone (see Sections 5.1 and 5.2). However, the iPhone-optimzed web interface continued to be useful to users of other smart phones, such as the Blackberry, which had a decent web browser but little-to-no native app support. That said, the graphics and layout of the iPhone-optimized mobile web interface are still too much for the simple text-only web browser on simple feature phones, which is why we have a text-only web interface as well, as described in the next section.

The iPhone-optimized mobile web interface has one primary function: to show real-time arrival information for a specific transit stop, as shown in Figure 4.8. Like the standard webapp, I provide the ability to filter a stop to show just a particular route. We provide two mechanisms for looking up a stop: by stop number and by route number. The quickest is certainly the stop number lookup,

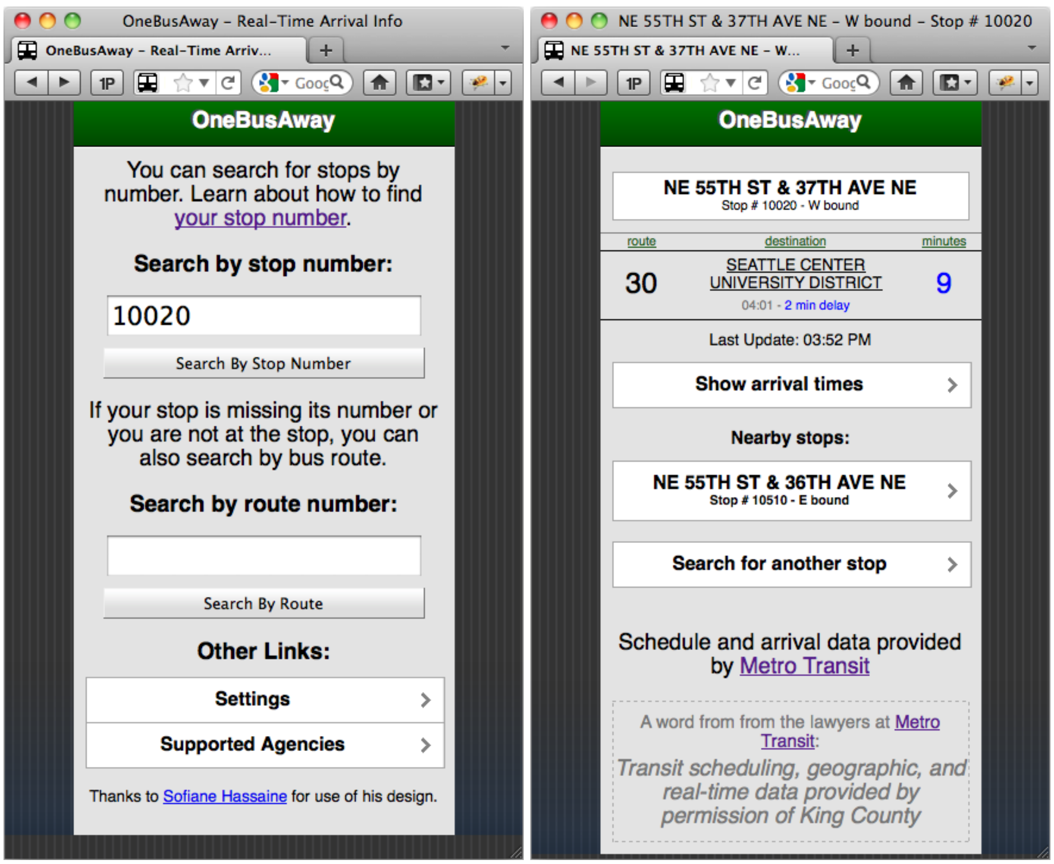

Figure 4.8: The start page and stop-view page for the OneBusAway iPhone-optimized mobile web interface.

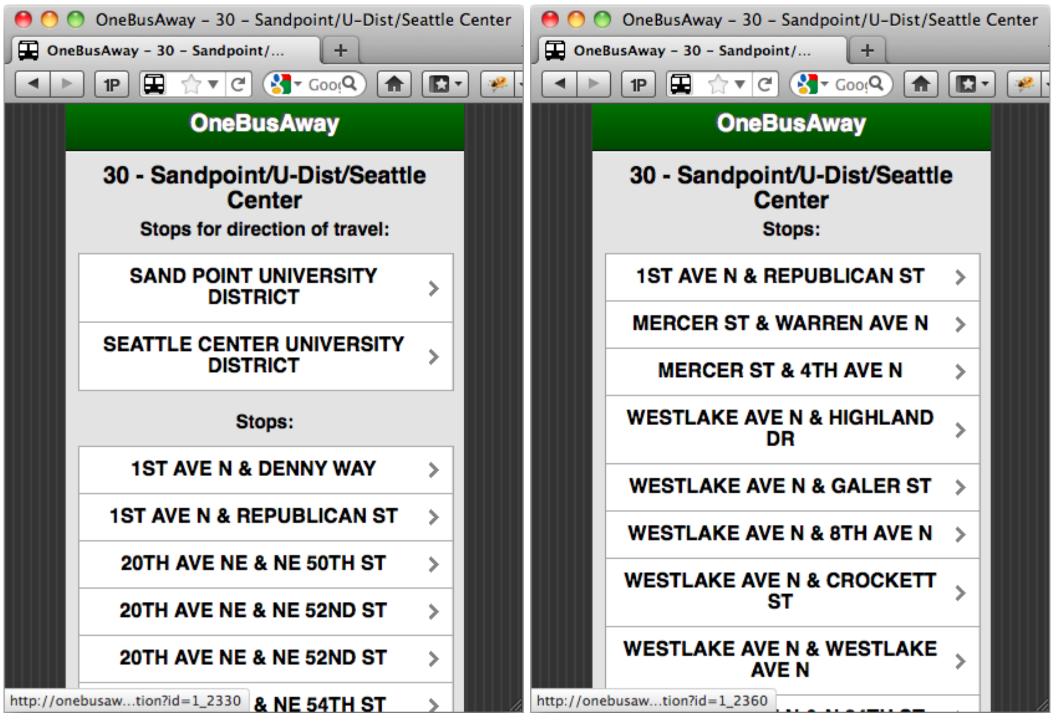

Figure 4.9: The iPhone-optimized mobile web interface route-based stop search, as a series of selections to narrow down to a particular stop.

but for a number of reasons, the stop number is not always available to the user. For example, the stop may be missing its posted schedule, which contains the stop number. In other situations, riders might wish to lookup real-time arrival information before they have even reached the stop, perhaps before leaving home or work. These stop number lookup issues also affect the SMS and phone IVR interfaces, as discussed in the next sections.

In this case, riders can search by route number, at which point they will be presented a series of pages that allow them to narrow down amongst the stops for a particular route in order to find the one they are interested in, as shown in Figure 4.9. The primary narrowing mechanism is the ability to allow the user to select the direction of travel and then receive an ordered list of stops for the route headed in that direction. Previously, we had the ability to further narrow down the selection by choosing amongst the neighborhoods the bus traveled through. However, while this feature was liked by some users, it was difficult to find generally agreed-on neighborhood labels for all the areas where OneBusAway provided service. Indeed, many users were often confused by the neighborhood labels we supplied or disagreed about where one neighborhood stopped and another began, highlighting the inherent ambiguity in neighborhood label data, at least in Seattle, Washington. For these reasons, we dropped the neighborhood feature.

One challenge we ran into with our stop-lookup methods came up when we first expanded OneBusAway to include more than one agency. Specifically, when we expanded from just King County Metro to include Pierce Transit as well, we discovered that route and stop ids were not always unique. This was a problem when a user entered a stop or route number, expecting one result but potentially getting multiple results back. We discuss the interface trade-offs and eventual implementation decision to use a zip-code based default search area for each user in Section 5.2.3. This default search area functionality is also used in the text-only web interface, SMS text-messaging interface, and phone IVR interface, as described below.

4.1.3 The Text-Only Web Interface

The text-only web interface [80], shown in Figure 4.10, is designed to be usable with a very basic text-only web browser on a feature phone. It uses no graphics and very basic layouts to display information. The features offered and navigation are very similar to that of the iPhone-optimized mobile web interface, but just presented using a simpler layout.

4.2 The Phone IVR Interface

The phone interactive-voice-response (IVR) interface is a simple touch-tone-phone based interface that is designed to allow riders to quickly receive real-time arrival information about a particular transit stop over their mobile phones. The phone IVR interface has a long history and was actually the very first interface built as part of OneBusAway.

An initial version of the interface was developed during the summer of 2006 as a mashup between two services: a free plain-old-telephone (POTS) to voice-over-ip (VOIP) service called IPKall (`http://www.ipkall.com/`) and the MyBus.org real-time information site for King County Metro. In 2006, mobile internet was slow and expensive, most affordable phones could not use it

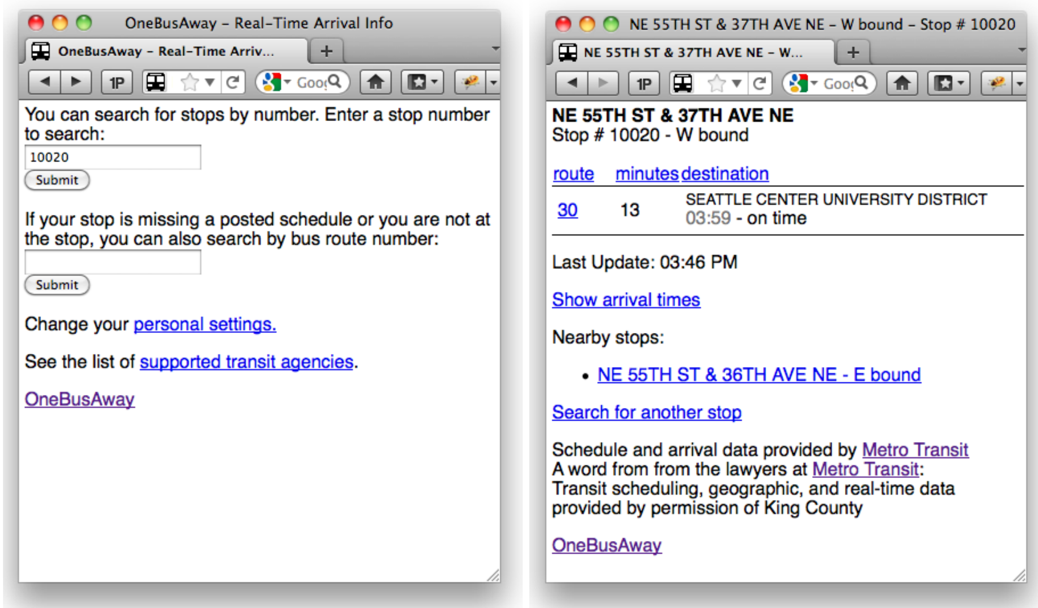

Figure 4.10: The start page and stop-view page for the OneBusAway iPhone-optimized mobile web interface.

anyway, and the iPhone revolution was still two years off. The initial phone mashup made it easy for anyone to quickly enter a MyBus timepoint id into their phone and have real-time arrival information read back to them. Unfortunately, it was an idea ahead of its time, since the id system used by MyBus did not match the number system used for physical bus stops, making it impossible to know what timepoint id to use when away from internet access. I, along with a few other dedicated users, kept cards in our wallets with frequently accessed MyBus ids. The system was better than nothing but hardly ideal for normal riders.

Fast forward to 2008 when I received access to the raw King County Metro schedule database, allowing me to build a proper system that could use the stop ids posted at stops to quickly look up real-time arrival information over the phone. It was here that OneBusAway was officially started. While the phone IVR system as it exists today still has the basic functionality of entering a stop number and receiving real-time arrival info, it has grown to include other features as well. Key additions include the ability to filter results by route number, which is important at busy stops where the full arrival listing can take minutes to read off. We also added the ability to bookmark frequently accessed stops, which reduced the need to find or remember long stop ids and speeds up access to information. Finally, we added the ability to lookup a stop by route number, which allows riders to find information about a stop even when the posted stop number is missing from a stop, an unfortunately all-too-common occurrence for many local bus stops.

The phone IVR interface is important for OneBusAway as it is the most broadly accessible interface in the system. If riders have any type of mobile phone, and increasingly almost all riders do, they can access real-time arrival information. With the basic phone IVR interface, the information is not just limited to those with more recent smart phones like the iPhone. We discuss these issues of access and fairness in further detail in Chapter 6.

There are a number of design challenges to building interfaces for phone interactive-voice-response systems. Primary among them is the limited input modality of the numeric keypad input method. Additionally, there is a trade-off between providing an interface that is verbose enough for new users to understand it, while still allowing for “power users” to quickly navigate the system without having to wait through long prompts. For the most part, we adopt standard practices like allowing a user to short-circuit a menu selection by pressing the number for a particular menu item before the description of that item has been read. The filter and bookmark mechanisms mentioned above also allows for quicker access.

A particularly challenging interface was the stop-lookup-by-route number feature. Here, we wanted to adopt similar functionality to that of the iPhone-optimized mobile web interface, where a series of selections could be used to first pick a route and then narrow down the set of appropriate stops until the target stop is found. Unlike the mobile web interface, however, reading off the entire stop list can be quite lengthy. If you happen to be looking for the last stop along the route, that wait can be quite annoying. We tried to mitigate this effect by first asking the users for a route number and then the appropriate direction of travel. We then started listing stops and gave the user the ability to jump back and forth along the list using the keypad, with one pair of keys for a small jump of one stop and another pair for large jumps of 10 stops. With this feature, the users can use their general knowledge of the route (ex. "my stop is near the middle of the route") to quickly jump to the general region of stops they are interested in and then refine their selection until they find the appropriate stop. It is not a perfect solution, but we found it be the lesser-evil of a variety of interface possibilities.

4.3 The SMS Text-Messaging Interface

The SMS text-messaging interface provides the same core functionality as the phone IVR interface, but through a text-messaging interaction. Specifically, riders text the keyword "onebus" followed by their stop number (ex. "onebus 75414") to the SMS shortcode 41411 and they will receive a brief text message back listing upcoming real-time arrivals and departures at that stop. Under the best of circumstances, an SMS message does not provide much room for information: only 160 characters. In our case, the situation is even worse, as we are dependent on a free SMS service that also includes an advertisement in the text-message, reducing the available characters to 140. As such, we take care to be as brief as possible in our return message, using abbreviations where appropriate to reduce the size of the message.

Like the phone interface, we allow the user to filter by route number, which can be critical in reducing the response size at busy stops that service ten or twenty routes. Also like the phone interface, we provide a bookmark mechanism to provide easier access to frequently accessed stops. Unlike the phone interface, however, we do not provide a stop-lookup-by-route number feature.

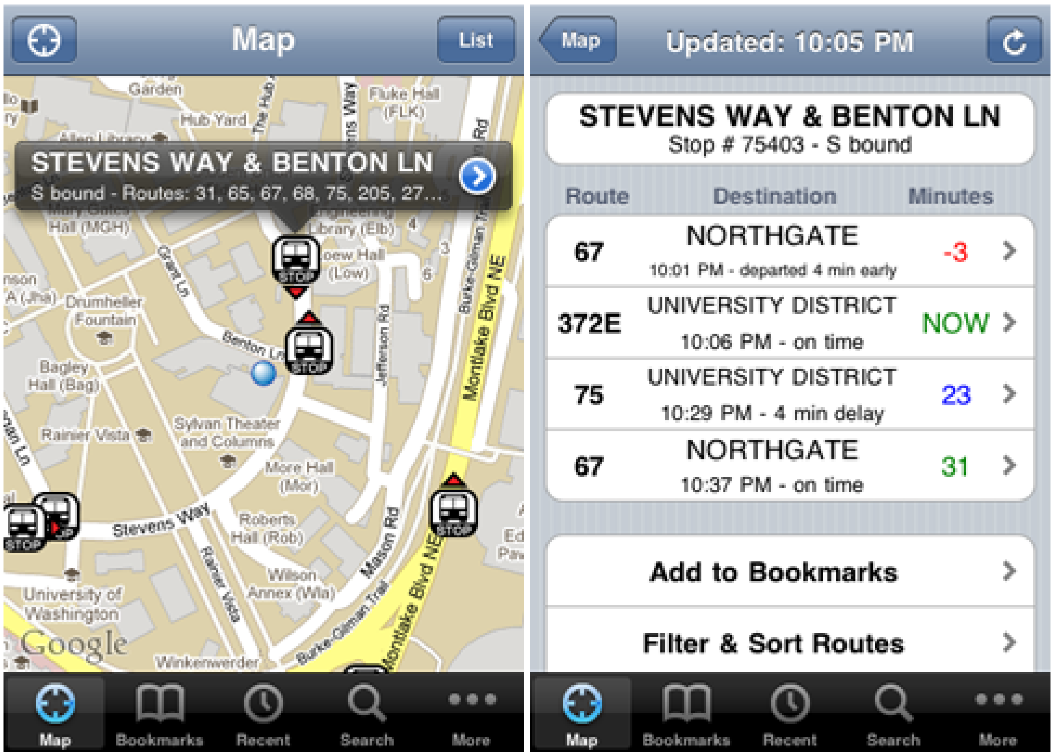

Figure 4.11: The start page and stop-view page for the OneBusAway iPhone-optimized mobile web interface.

We felt the interaction would not adapt to the even smaller output bandwidth of a text-message or the high number of user-interactions required, each of which could result in a charge to an SMS user. Perhaps in the future the system could take advantage of the fact that SMS users can more easily input text characters, as opposed to just numbers as in the phone interface, allowing for a lookup based on stop name. However, it is not clear that official stop name used in the public transit schedule feed is always the same as the name a user might associate with it.

4.4 The iPhone App

The OneBusAway native iPhone app, shown in Figure 4.11, provides a location-aware application for quickly accessing real-time arrival information for nearby public transit stops. Unlike the interfaces described thus far, the iPhone has built-in localization capabilities, using a fusion of sensor data from GPS, WiFi, and cell-tower localization to quickly get a location fix on a users phone. This location information can significantly reduce the time it takes to access real-time arrival information for a nearby stop, as described in further detail in Section 5.1 and [27].

Beyond the key addition of the location-aware capabilities, the iPhone app has a lot of the same features available in the other interfaces: a map view, bookmarks, recent stop view, and search for stops by route, address, and stop number.

4.5 The OneBusAway REST API

The OneBusAway iPhone app is powered on the backend by web-based REST (Representational State Transfer) API, a standard technique for providing dynamic data to mobile apps. When we created the REST API for the iPhone app, we decided to make the API freely available to developers so that they might create apps of their own. Other transit agencies have had success publishing their transit data through an open API that allows developers to create applications using the data. For example, TriMet in Portland has dozens of apps using their data [104]. Since our own local transit agencies did not publish APIs of their own data, we believed that we could provide similar functionality on the agencies' behalf. More importantly, given our limited resources, we cannot hope to create native apps similar to the native iPhone app for all the current mobile development platforms. We hoped the developer community would help us in that regard.

That hope proved correct, as developers stepped forward to write OneBusAway apps for Android, Windows Phone 7, Palm Pre, and other platforms. The Android and Windows Phone 7 apps actually went on to become official apps featured on the OneBusAway website. At the time of writing, we have given out API access keys to over 90 developers and we have almost 60 developers subscribed to the OneBusAway API mailing list. Developers have used the API to create apps including desktop widgets, command-line interfaces, plugins for the Chumby programmable alarm-clock stuffed-animal, Bluetooth watch interfaces, and touch-screen transit kiosks in use by Amazon. At the time of writing, the OneBusAway API powers real-time transit results in Microsoft's Bing Maps public transit directions product for the Seattle area.

We believe such APIs can be similarly powerful for driving innovation for almost any transit agency, which is why we provide access to our API and the source-code that powers it for free as

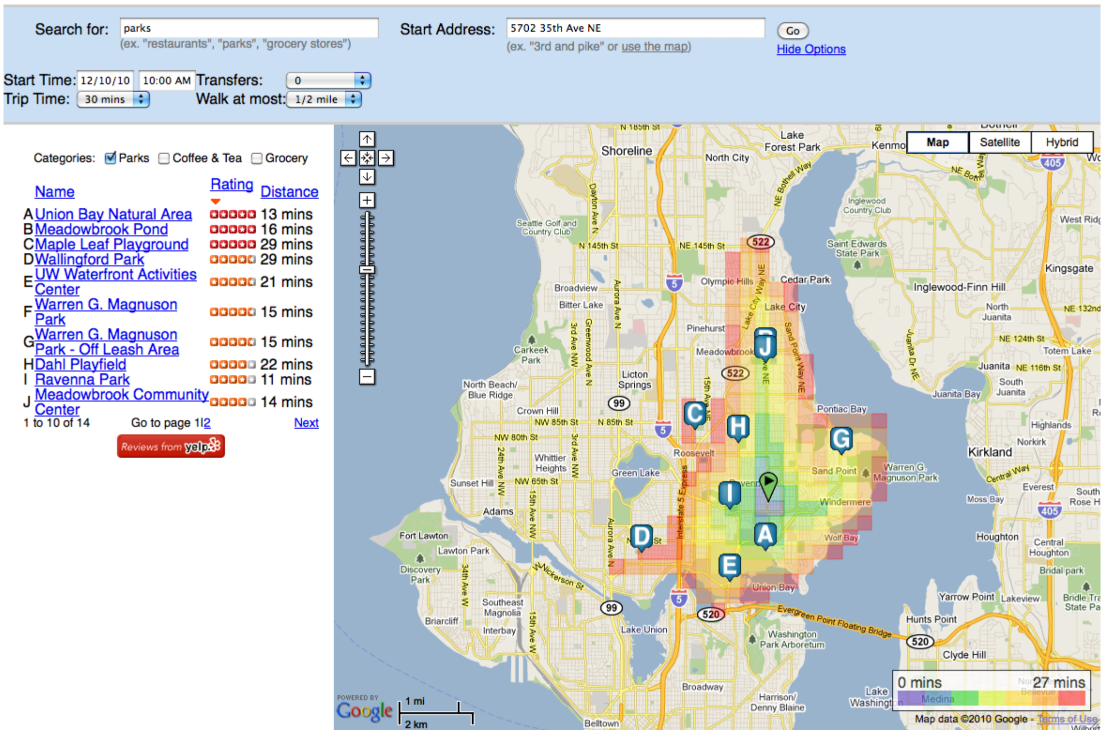

Figure 4.12: The OneBusAway Explore tool shows nearby parks easily reachable by public transit, along with their review rating.

open-source. For more details, see the API documentation site at:

`http://code.google.com/p/onebusaway/wiki/OneBusAwayRestApi`.

4.6 The Explore Tool

The OneBusAway name original referred to a simple question: what can you get to that is just one bus ride away? More specifically, can we help you find local businesses, restaurants, parks, coffee shops, and other attractions that are easily reachable using public transit? Our answer to that question is the OneBusAway Explore tool [75]. In the Explore tool, as shown in Figure 4.12, we created a mashup between a transit trip planner engine and Yelp (`http://yelp.com/`), an online website that lists reviews of local businesses.

Typically, sites like Yelp can show you nearby places, where "nearby" is defined simply by the as-the-crow-flies distance from your starting location and the nearby place. The problem is that for riders dependent on public transit, not all "nearby" places are created equal. Specifically, a place that is nearby as-the-crow-flies can be difficult to reach using public transit, and vice versa. The Explore tool attempts to address this problem by first calculating the area reachable using public transit from the start location, and then performing the local place search within that area. Figure 4.12 shows the tool in action with a search for nearby parks. The colorized heatmap indicates the travel time to different locations on the map using public transit. Within that area, we perform a search for parks, calculating the transit travel time each location. On the left side of the screen, we show the search results along with their average Yelp review. Combined, all this information allows riders to more easily find a local park that is both well reviewed and easily reachable using public transit.

Though the OneBusAway Explore tool is technically interesting, and I can anecdotally report that I have used it to find my dentist, it is not a frequently used tool on the OneBusAway website. The tool was only accessed 1,300 times during the month of May 2011. By comparison, the standard OneBusAway desktop web interface was accessed 57,000 times during the same period. What is more, we have not had much opportunity to formally evaluate the tool through user studies. We still believe that the Explore tool is interesting, however, and think it could be a useful tool for riders if properly promoted. For further details on Explore tool, see our full journal article in [106].

4.7 The Service Alerts Webapp

We believe that real-time public transit information of all types is important in improving the usability of public transit. One critical component of real-time information includes service alerts: details about reroutes, cancellations, delays, and other changes in service. Informing riders about these service alerts in a timely fashion is critical to improving the rider experience, but transit agencies currently struggle with this task. There are many reasons for this difficulty, which we will elaborate in Chapter 7. However, the primary explanation is that service alert information typically has to travel a long human chain of command before it is published to riders in a usable form. We believe that by providing tools to transit agencies that allow quick and easy management of service alert information that produces data in standardized forms, we can bypass the human bottle neck that is currently holding real-time service alerts back.

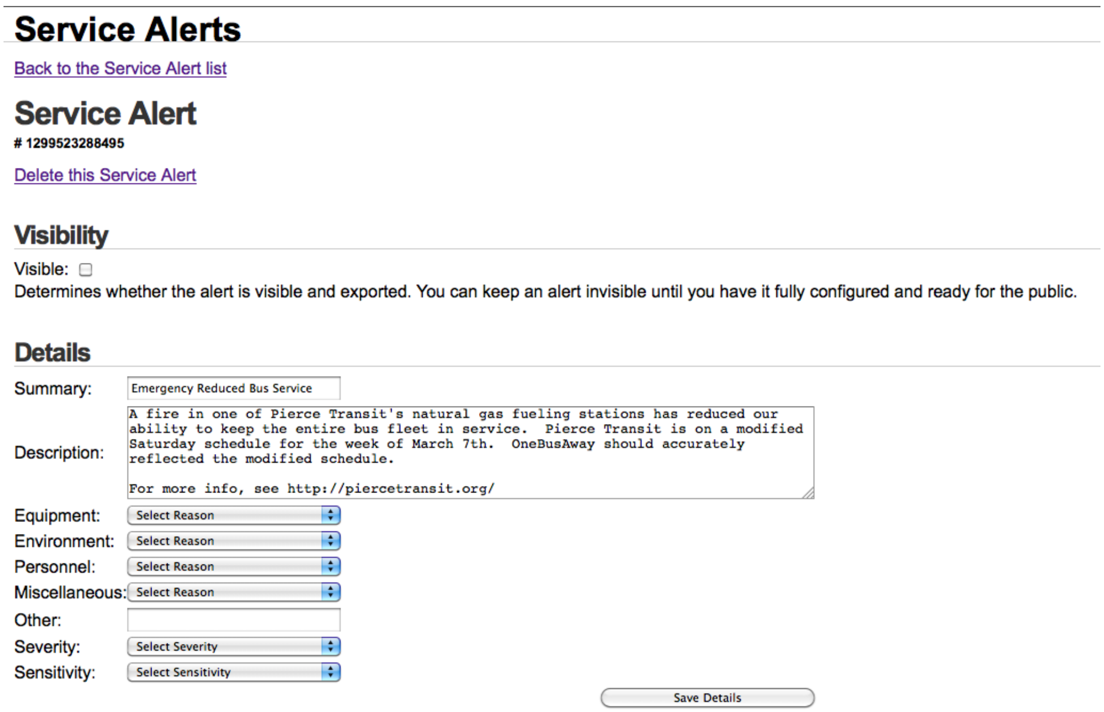

Figure 4.13: The OneBusAway service alerts webapp allows agency staff to quickly input real-time service alert information, such as information about reduced bus service due to an accident.

Towards that end, we have created a service alerts webapp that can be used to quickly and easily manage service alert information. The webapp allows for the creation, modification, and deletion of complex service alerts. The user interface (UI) for editing an actual service alert is shown in Figure 4.13. In addition to the service alert itself, tools are provided to quick attach meta-data to the alert to indicate which transit agencies, routes, trips, stops, and even specific arrivals and departures are affected by a particular service alert. This granularity allows for much more appropriately targeted service alerts, so that the agency need not notify riders about alerts they do not care about. Contrast this with most transit agencies' current approach, which includes email and SMS alerts to all subscribers about service changes. While these alerts are certainly a welcome improvement over previous rider communication efforts, they still take a fire-hose approach that is not well suited to targeted alerts that only impact a small group of users.

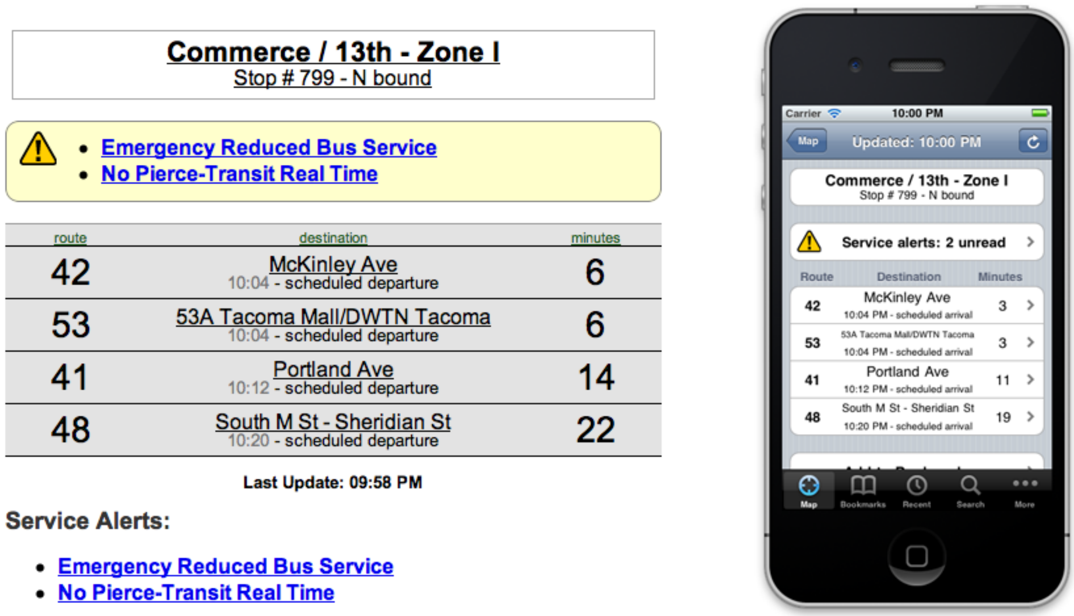

Figure 4.14: The OneBusAway web and iPhone apps reflecting active service alert information.

Our service alert webapp does not actually power any rider notifications directly, but instead produces data in a standard format that can be consumed by other applications to present to riders. The data standard is called SIRI (Service Interface for Real-Time Information) and is an open European standard that describes XML-based protocols for exchanging real-time transit information [97]. Our webapp specifically produces SIRI SX (Situation Exchange) data. By having the service alert webapp produce structured service alert data as opposed to directly driving a user interface, we can decouple the service alert management component from the various rider notification components. As a working example, we have extended a number of the OneBusAway web interfaces to consume SIRI SX service alert data. Figure 4.14 shows a demonstration of service alert notifications in both the OneBusAway webapp and iPhone app.

4.8 The SIRI Repeater

As we mentioned in the previous section during the discussion of the service alerts webapp, SIRI is one of the real-time public transit data standards supported by the OneBusAway toolset. The

SIRI standard actually encompasses a number of different types of real-time information, including real-time vehicle positions, service alerts, schedule changes, and other key real-time transit data. We believe SIRI is an important standard, as data published in the SIRI format has the potential to power a huge range of interesting public transit rider information tools, including all of the OneBusAway tools described so far. In fact, one of the challenges in extending OneBusAway to work with other agencies has been the lack of standardization around real-time public transit data. Right now, we receive real-time vehicle location data from a number of transit agencies, each in a different format. We have had to write adapters for each of those agencies to make them work with OneBusAway. This lack of standardization has slowed down the pace of innovation in the development of tools for public transit riders.

Encouragingly, a number of transit agencies in the U.S. have started to move towards SIRI as a standard for exchanging real-time transit information. Because we believe that SIRI can have a powerful boost on driving the development of new and interesting tools, we have been developing tools of our own to help agencies produce and share SIRI data. We have already discussed the OneBusAway Service Alerts Webapp in the previous section, which specifically produces SIRI SX data. We have also been working on another tool called the SIRI Repeater that more generally works with SIRI data [78]. The SIRI repeater does just what it says: it repeats SIRI data. Specifically, the SIRI repeater can process multiple concurrent incoming SIRI real-time data streams and republish that data to potentially multiple listening systems. The repeater supports filtering and access control mechanisms, such that an agency could use the repeater to rebroadcast real-time vehicle location information to authorized developers, while filtering out sensitive information from the data stream, such as the driver id of each vehicle. At the same time, the unfiltered stream can be republished in unmodified form to internal systems for internal agency use.

4.9 OneBusAway Usage

We have described a number of riders tools that make up the OneBusAway system. It is interesting to mention some usage statistics for these tools to help gauge their relative usage and popularity.

First, we briefly described the current service coverage area provided by OneBusAway. The system provides coverage for a number of transit agencies in the Puget Sound region of Washington

User Interface	Number of Unique Users
iPhone App	28K
Android App	20K
Web Interface	15K
Windows Phone 7 App	5K
Phone IVR	2K
SMS	1K

Table 4.1: Unique user count for each interface for the week of June 12, 2011. Numbers are in thousands of users.

State: King County Metro, Pierce Transit, Community Transit, Sound Transit, Intercity Transit, and Washington State Ferries. These transit agencies cover over 14,000 transit stops and serviced some 188 million unlinked transit passenger trips in 2010. By agency, that breaks down to 112.8 million for King County Metro, 23.0 million for Sound Transit, 22.4 million for Washington State Ferries, 15.3 million for Pierce Transit, 9.7 million for Community Transit, and 4.8 million for Intercity Transit.

With those ridership numbers as context, we now mention OneBusAway usage statistics.

Table 4.1 quantifies the relative usage of each interface by counting the number of unique users who used each interface over the course of the week of June 12, 2011. As you can see from the usage stats, the iPhone and Android apps dominate usage, with a combined unique user base of almost 50K users for the week (we assume that there is not much overlap between iPhone and Android users). The newer Windows Phone 7 app still has a way to go to catch up. Another interesting number is the Web Interface count of 15K users for the week. This number includes both users of the standard and iPhone optimized web interfaces, at roughly a 60% - 40% split. Unfortunately, we do not have unique user counts for the text-only interface since the non-Javascript enabled browsers typically used when accessing the text-only interface do not register in our analytics package. However, extrapolating from raw server log data, we estimate the text-only interface is seeing no more than 1K unique users during the target week. The phone IVR and SMS interfaces are the two least frequently used in the OneBusAway system. We believe these tools could be more widely used by riders without more recent phones who might favor these interfaces, but we lack the marketing budget to reach out to these riders and let them know about our program.

It is important to note that these usage numbers are not strictly cumulative. There is certainly overlap in usage between the web interface and the various mobile interfaces. Unfortunately, we have no mechanism for uniquely identifying a user across the various interfaces. However, making the reasonable assumption that there is not much overlap between the various mobile interfaces, since most users only have one phone, we can roughly estimate that we are seeing over 50K unique users of our system each week. To put that number in perspective, some estimate that close to 13% of King County Metro riders use OneBusAway each week [64].

Chapter 5

INTERFACE DESIGN

Throughout the design and implementation of the various OneBusAway user interface components, we have undertaken a variety of design evaluations and studies in an attempt to iterate and refine our tools.

The initial interfaces for the first version of OneBusAway were informally evaluated in the summer of 2008 with a number of students and with frequent transit users. After integrating feedback from these users, the OneBusAway website was launched with its initial toolset: a web interface, a mobile-optimized web interface, and an IVR phone interface.

The set of tools provided by OneBusAway has since grown and the design of the various tools, along with development of new features, has been further shaped by feedback from users over the past two years. OneBusAway provides a number of feedback mechanisms (email, Twitter, blog, bug tracker, IdeaScale page) that allow a user to make comments or suggestions about the tools. Because OneBusAway is open-source software, users have also submitted improvements of their own. For example, one user wanted the ability to see real-time arrival data for multiple nearby stops integrated in a common view. That user coded up the improvement, submitted a patch, and the feature is now available to all users of OneBusAway. Others have contributed localization features to OneBusAway that allow it to be used in other languages and other countries.

Of course, not all feedback concerns issues with interface usability. The bulk of user feedback is a result of data and reliability issues: real-time arrival information is occasionally wrong, underlying schedule data has errors, neighborhood labels are incorrect, or a server is down. These are typical issues inherent to running a service used regularly by a large group of users. See our discussion on crowd-sourcing in Chapter 8 for additional thoughts on handling this feedback.

In this chapter, we present the result of a number of design studies and evaluations that have shaped the design and functionality of various OneBusAway interfaces and applications over time.

5.1 *iPhone Application Evaluation*

To evaluate the design of the OneBusAway iPhone application, we solicited volunteers from followers of the the OneBusAway Twitter feed and from graduate students in our computer science department in the summer of 2009. From a pool of initial respondents who were sent the application, a total of 16 respondents installed the application and completed both the pre- and post-evaluation surveys. Survey questions were mostly multiple choice, such as ”How often did you use the OneBusAway iPhone app?” with choices of ”Multiple times a day”, ”Once a day”, ”Occasionally during the week”, ”Rarely” and ”Other”. A free-form comment field was included as well.

The pre-evaluation survey was designed to get an initial measure of each user’s current transit usage, their usage of OneBusAway, and what other transit tools they already use. For the most part, the participants were already active users of OneBusAway. A full 47% of the respondents use OneBusAway multiple times a day, while an additional 33% use it occasionally during the week.

The post-evaluation survey was designed to obtain feedback and to assess the utility of the application. The survey was administered two weeks after initial application deployment. For the most part, the response was very positive. A full 87% of respondents rated the utility of the application as “Very useful”. Usage of the application was high, with 69% of the respondents using the application multiple times a day. The survey results also include data regarding which search mechanisms were most frequently used in the application. The results roughly report the number of times a given mechanism was used on average during a week.

The results, summarized in Table 5.1, show that bookmarked stops were the most frequent method, though finding nearby stops using GPS was not far behind. These results were used to refactor our design, prioritizing the UI for the most frequent search methods.

Overall, comments were positive. Most users were extremely positive about the location-aware capabilities of the application. Some example feedback:

> I LOVE the finding stops by my current location feature - killer feature that will destroy all others.

Another respondent:

Search Method	Frequency
Bookmarked Stops	5.38
Nearby Stops	4.35
Current Map View	3.17
Recent Stops	2.46
Search by Route	2.30
Search by Stop Number	1.15
Search by Address	0.66

Table 5.1: Search method ranked by average frequency of use per user during the week

> It's breathtaking how much easier it is to pick out a nearby bus stop using "my current location", compared to choosing an intersection out of a list of stops, or typing it in directly. It's a difference of kind, not degree, especially when I'm outside my usual neighborhoods. I showed it to someone whose jaw actually dropped.

Users also commented on the overall flexibility allowed by the application. One user commented:

> The OneBusAway app makes me feel more comfortable with spontaneously changing trip plans or going to different stops

These comments were borne out in survey results, which showed that 93% of respondents were likely to walk to a different bus stop based on information from the application. We will touch on these results further in Chapter 9.

Additional user comments provided valuable feedback on some interface elements of the application, which were incorporated into subsequent iterations of the application's design. For example, the original application required two button presses to refresh arrival information at a stop. A number of users requested a more direct refresh mechanism, which lead to a reshuffling of the UI to support a direct refresh button as well as a more aggressive automatic refresh policy.

5.2 Location-Aware Timing Study

In the discussion of the iPhone application, one feature that riders were very positive about was the location-aware functionality of the app. In initial implementations, none of the OneBusAway interfaces had location-aware capabilities. Instead, OneBusAway mobile tools required the user to enter the stop number of the stop they were interested in. While this method works well when the user is physically at the stop and and the stop actually has a posted stop number, it is not a useful strategy when the stop number is missing, or when the user is not yet at the stop, but instead, for example, is at a nearby restaurant, park, or coffee shop. The iPhone app provides this functionality in the form of a location-aware map interface that can show transit stops near the user's current location.

5.2.1 Study Design

To evaluate the utility of the location-aware feature, we performed a within-subjects user study with 12 participants to compare how long it takes to perform a typical information lookup operation with the assistance of a location-aware map-based interface, a map-based interface without location information, and finally a text-based search tree from our mobile web interface. The specific task was to find real-time arrival information for a nearby bus stop. With the location-aware map-based interface, the user's current location is displayed on a map. Pressing an action button automatically zooms the map to the current location, far enough out to show the five closest stops. In contrast, with the map-based interface without location information, the user can employ standard map navigation techniques to zoom and pan the map to the current location, at which point an action button is provided to automatically display all transit stops within the current map view. For the text-based search tree method, the user first enters a route number of interest. A search tree of stops is presented, organized by direction of travel, neighborhood, and street. The user can then use this interface to drill down to find any stop along a particular route. This interface is currently in use for the phone and mobile web interfaces.

Intuitively, the location-aware map-based interface should be the fastest to use, but we wanted to perform a formal evaluation to confirm our intuition. We recruited 12 graduate students and staff (8 grads and 4 staff with 9 men and 3 women) from our computer science department to perform a quick evaluation of the three stop lookup methods. While all the participants were regular bus riders, only half were regular users of OneBusAway, with a mix of the various interfaces. Users were shown the OneBusAway native iPhone application and encouraged to familiarize themselves with basic navigation and usage of the map view. Each user was asked to find a specific nearby stop. The stop in question is located directly across from the building where the participants worked and all participants were familiar with the stop. Starting from a zoomed-out map of Seattle, or the root of the stop search tree for the route-neighborhood-street stop tree, each participant was timed to measure how long it took to access the real-time arrival info for the specified stop. The order in which the three methods were presented was randomized among the different participants.

5.2.2 Study Results

The results, summarized in Figure 5.1, confirm our hypothesis that the location-aware map-based interface is the fastest method for navigating to a target stop. Across the board, each participant was fastest when using the location-aware map-based interface (9 secs on average). The remaining two interfaces were both slower on average (30 and 25 secs, respectively); however, the difference between the two average times is not statistically significant (TTEST,P=0.15). However, users expressed more confusion with the tree-based interface in verbal feedback during the evaluation, as the combination of route, destination, neighborhood, and street was not always intuitive.

5.2.3 Study Conclusions

The design implications are clear: location-aware functionality can significantly increase the usability of an interface. While we are already using location information in our mobile apps, it should also be possible to use location information for browser-based interfaces as well. Increasingly, mobile and even desktop browsers are exposing location information to Javascript webapps through standardized interfaces.

Unfortunately, the interfaces that could most benefit from location information are the ones where we do not have it: phone IVR and SMS. We see from the study that the stop search tree method employed in the existing phone and mobile web interfaces is not ideal. The problem is even worse than described, however. One challenge we have faced with our stop number lookup system

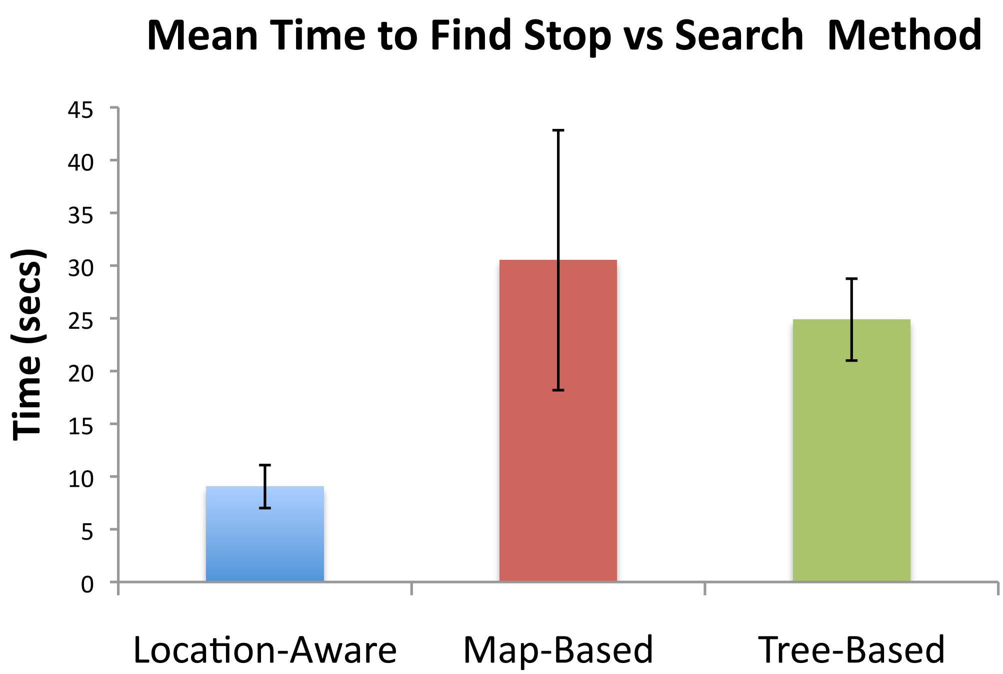

Figure 5.1: Results from the timing study show that, on average, the location-aware interface was fastest for users, while the slower map-based-without-location and tree-based interfaces were both slower, though neither was clearly the slowest.

is that stop numbers are not unique across local transit agencies. In fact, we have found transit stops maintained by different transit agencies with the same stop number just a few miles apart. The same issue can also apply to route numbers as well, though less geographic overlap has been found regarding routes.

The duplicate stop id issue has been a problem in our phone IVR and SMS interfaces because it can be difficult to know which stop a rider intended when they input a stop number. We have explored a couple of methods for dealing with this issue. At first, we considered assigning default transit agencies to a user. If two stops with the same id were found for a lookup, we would default to the one for the user's default transit agency as appropriate. We ultimately did not choose this method for a number of reasons:

- In our region, there can be four or five transit agencies operating in the same overlapping geographic region. Picking a default agency can be difficult when riders utilize multiple agencies on a given day.

- As a further complication, many riders are not necessarily even aware of which transit agency is providing service for a particular route. This can be particularly complex in the case of one agency out-sourcing operations to another, as is the case with King County Metro and Pierce Transit operated Sound Transit service in the Puget Sound region of Washington State.

In light of these challenges, we went with a more location-oriented approach. Specifically, when a rider uses the phone IVR or SMS interfaces for the first time, we ask them to input their zip code to give us a general idea of their location. We then use this location information to establish a default search area when doing searches for stop and route numbers. This removes the burden of understanding the complexities of inter-agency transit operations and focuses simply on the question, ”Where are you?” This method is not without issues, however. As we noted, there can be cases where two stops with the same number are located near each other geographically. In this situation, we simply present both stops to the user and ask them to pick which one they meant.

Our default-search-location approach also breaks down for transit riders who make long-distant transit commutes each day between distinct geographic locations. Consider a rider who commutes from Tacoma to Seattle each day by bus, for example. For these riders, we introduced bookmarking functionality. By bookmarking a stop, we can store the underlying unique entity id for a stop that will have none of the ambiguity issues of a stop number. Some riders have found the zip-code system to be confusing. Ideally, there would be a method to receive fine-grained location information for phone IVR and SMS users. However, there is no obvious technology to generate this location information. It is true that mobile phone providers have access to this location information in the form of E-911 location services, but that data is not shared with application developers.

5.3 Arrival Uncertainty Interface Evaluation

Traditionally, most real-time arrival information systems for public transit have generally adopted the interface of a simple countdown clock: a display of the number of minutes until a bus will arrive.

While automatic vehicle location (AVL) systems strive to accurately predict the estimated arrival time, the reality is that there is a fair amount of uncertainty in the arrival predictions. For example, in Figure 5.2, we see schedule deviation information for a particularly unreliable route in Seattle. The figure specifically show schedule deviation versus progress along the route, illustrating how late the bus typically is when it reaches a particular point along the route. The figure was generated from five months worth of trips, showing the relative distribution of data over time. Notice the wide range in how early or late the bus can be when it reaches particular points along the route.

That large arrival distribution shows why real-time arrival information is critical for riders of this route, but it also demonstrates the challenges of accurate real-time arrival prediction. To illustrate this more clearly, we have isolated ten trips in Figure 5.3 to show successive schedule deviation over time for a particular trip. First notice how a bus that is five minutes late at the beginning of the trip is not always five minutes late at the end of the trip. Most real-time arrival prediction systems, including the ones used by OneBusAway, simply forward-propagate the current schedule deviation of a transit vehicle when predicting the arrival time at a future stop. Clearly, that is not always an accurate assumption. We can attempt to model future schedule deviation as a function of current schedule deviation, but its clear from the examples in Figure 5.3 that its a noisy relationship at best.

We can create functional models that make a good effort at modeling future schedule deviation while also modeling the uncertainty of the prediction as well, often as a distribution. But what is the best way to present that uncertainty information to riders? Currently, OneBusAway does not make any effort to present accuracy or uncertainty estimates for real-time arrival information in our user interfaces. The situation is even worse when no real-time information is available for a transit vehicle. In these cases, we currently default to showing the scheduled arrival time, but there is often even more uncertainty in this case. Is there some way we can present that uncertainty in an understandable and actionable way, as well as drawing additional attention to the difference between a predicted real-time arrival versus a scheduled arrival time?

We set out to evaluate a number of potential user interface options for indicating uncertainty in arrival time. We know from previous feedback (see Section 8.1.2) that users of OneBusAway in particular did not have a clear understanding of the difference between an arrival estimate backed by real-time information versus one that defaults to the scheduled arrival time in the absence of real-time data.

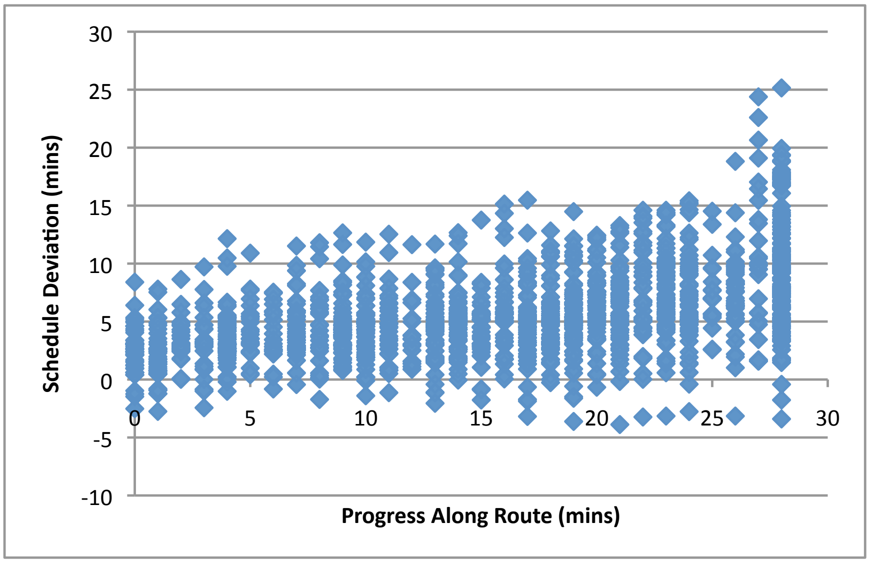

Figure 5.2: Schedule deviation histogram for King County Metro Route 44 for five months of trips. The scatter plot shows schedule deviation versus location along the route in effective schedule time.

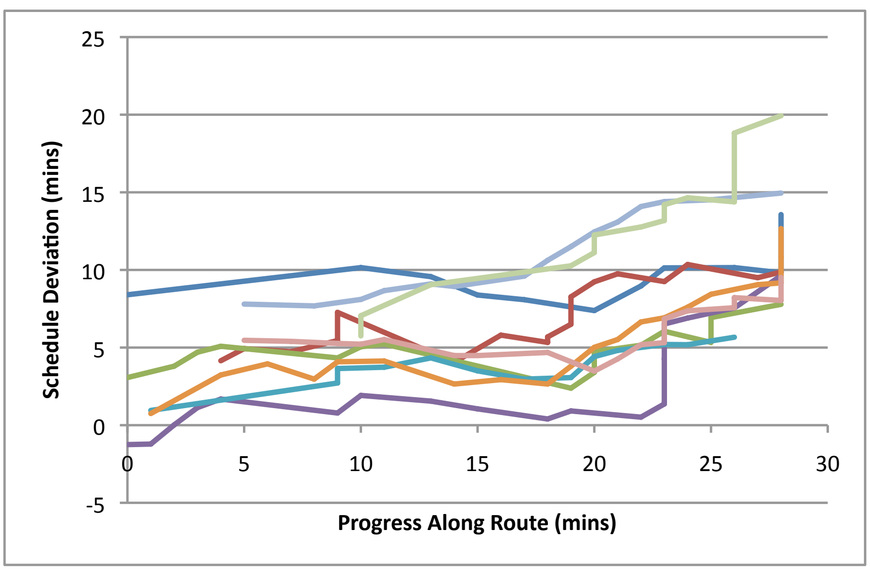

Figure 5.3: Schedule deviation histogram for King County Metro Route 44 for ten specific trips. The plot shows schedule deviation versus location along the route in effective schedule time.

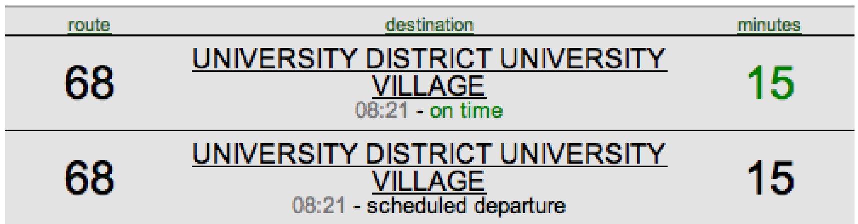

Figure 5.4: Real-time versus scheduled arrival in the OneBusAway web interface.

Figure 5.4 demonstrates the difference between a real-time versus scheduled arrival in the existing OneBusAway web interface. Notice the use of color (green for on-time versus black for scheduled) and different textual labels. We wished to explore how we could draw further attention to this distinction to the user, while also indicating something about the uncertainty of the arrival prediction. We created a series of mockups that presented potential user interface concepts for evaluation.

5.3.1 Study Design

As part of our evaluation, we recruited 11 students from our computer science department to participate in a quick user study. The students were recruited over email and invited to a 20 minute evaluation session with snacks served as part of participation. The participants were frequent users of public transit, with the majority using public transit every day. All but one of the participants were also already users of OneBusAway.

Each participant was interviewed by a study facilitator at a desk with a laptop where a series of UI mock-ups were presented. The mockups were presented in three phases, with interview questions asked concerning the mockups in each phase.

In phase one, the existing OneBusAway real-time versus scheduled arrival user interface was presented, as shown in Figure 5.4. Each participant was asked to identify the the difference between two arrival entries, both in terms of presentation and what it meant about the underlying transit vehicles.

In phase two, five additional mockups were presented individually to the user in randomized or-

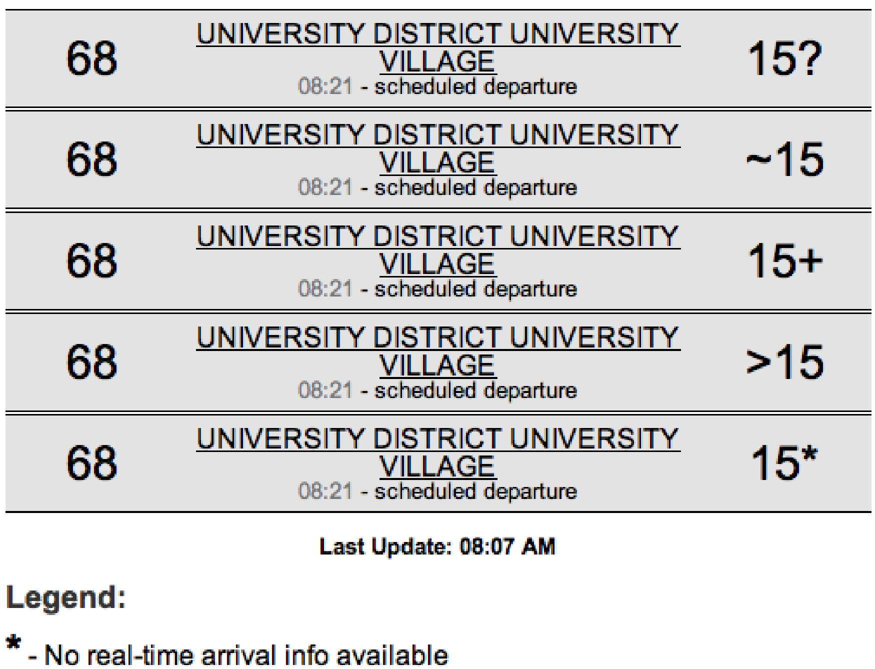

Figure 5.5: The five scheduled arrival symbol UI treatments for evaluation.

Figure 5.6: Real-time versus scheduled arrival in the OneBusAway web interface.

der. The five mockups, show in Figure 5.5, each use symbol to convey some additional information about the scheduled arrival. The five symbols were ?, $\sim$, +, $>$, and *. The * character includes a legend below that states “No real-time arrival info available”. As each mockup was presented in turn, the participants were asked to describe what they believed the addition of each symbol implied about each scheduled arrival.

In phase three, a final mockup presenting a real-time arrival range was presented to the user, as shown in Figure 5.6. Again, the participants were asked to describe what they believed the presentation implied about the coming arrival.

5.3.2 Study Results

In the first phase, 8 of the 11 participants were able to articulate the difference between a real-time and scheduled arrival, as presented in the first mockup. The remaining three participants had a harder time articulating the difference. Many of the participants commented that they felt more certainty about the arrival with real-time information and less certainty about the scheduled arrival. Interestingly, three of the participants mentioned that they would leave *earlier* for a scheduled arrival. This is interesting, since transit vehicles are by and large very rarely early, real-time tracking or not, suggesting that some riders might be leaving for the stop earlier than they need to when no real-time is available. Of course, the consequences for arriving at the stop too late for an early bus are more severe than arriving too early for a late bus. A number of users also commented that it was difficult to read the small text indicating ”on-time” versus ”scheduled departure” in the interface.

- **? Mockup** - Almost all the participants equated the addition of the question mark as an indication of less certainty about the arrival time. At least one user reported that they would feel less anxious if the bus was late with the addition of this symbol.

- $\sim$ **Mockup** - Most of the participants also equated the $\sim$ symbol with less certainty, but interestingly a majority of the participants considered the $\sim$ to indicate more precision than the ? symbol. A few of the participants were concerned that while students in a computer science program might understand the meaning of $\sim$, they were worried that members of the general public might not.

- **+ Mockup** - The majority of the participants interpreted the + symbol as meaning 15 minutes or more, noting that the symbol implied more uncertainty and the possibility of a late arrival. Some suggested they would cut their arrival time at the stop a bit closer based on this info.

- $>$**Mockup** - The majority of the participants interpreted the $>$symbol to mean more than 15 minutes. Many made a comparison between + and $>$, noting that + was inclusive while $>$was not. Participants were not a fan of this mockup on the whole, as they were not sure how to adjust their arrival time at the stop based on this information.

- *** Mockup** - Most of the participants liked the asterisk and understood the convention of going to look for a footnote or legend on the page to explain what the symbol meant.

In the final phase, we presented participants with a ranged arrival time mockup. One interesting result we found was the distinction participants made in how they would interpret this information when they were still in their home or at work preparing to leave versus waiting at the bus stop itself. When deciding when to leave their home or office to catch the bus, most of the participants reported that they would ultimately use the lower bound to determine when to leave in order not to miss the bus. However, once they were at the stop, the full range would give them more information about how long they might have to wait for the bus to actually arrive. As one participant explained, the range helps with some of the uncertainty, commenting "It's ok if it's five minutes late."

A few participants wanted more details about how the range was calculated or how certain they could be of the arrival times. One subject reported that he would probably aim for the middle of the range, though he admitted that if the bus came closer to the earlier part of the range, he would be in trouble. Another user explained that he might run for a bus that was still within its time range that he might have skipped with a more specific arrival estimate.

5.3.3 Study Conclusions

Though our study size was small, the quick evaluation of a number of potential user interface mock-ups gives some clear direction for interfaces to implement and evaluate on a larger scale. In the first phase of the study, we confirmed that some portion of our participant pool had trouble with the distinction between real-time and scheduled arrival information. Additionally, a number of users complained about the existing user interface's ability to convey that distinction. This result is consistent with our existing intuition about the difficulty some OneBusAway users have in understanding the difference between real-time and scheduled arrivals.

In the second phase, we explored a number of strategies for annotating arrival information to either draw attention to the fact that we were less certain about the arrival time or that we did not have real-time information for a particular vehicle. For the former, the ? symbol seemed to be a popular choice for indicating general uncertainty, while the + symbol might be appropriate where the uncertainty is heavy-tailed towards a late arrival. For highlighting a scheduled arrival, a simple asterisk and legend had broad support. It might also be possible to include the scheduled arrival legend more prominently for new users, but gradually make it less prominent for expert users who have been using the app for a while or who have selected to hide the legend directly.

In the third and final phase, the interesting take away from the arrival time interval mockup is the way participants make use of arrival time when they are preparing to leave their home or office to catch a bus, versus when they are actually at the stop. There may be opportunities to dynamically adjust the our UI based on location context in these situations, favoring an earliest arrival time prediction for planning UIs and an arrival interval when the rider is at the stop.

Chapter 6

A PRINCIPLED PRIORITIZATION SCHEME FOR EXTENDING ONEBUSAWAY

Initially, OneBusAway had just one user: myself. As such, most of the design decisions were driven by what I felt would make my own use of public transit easier. As the site grew in popularity and feedback started to come in from users about how OneBusAway might be improved, a number of things became clear. First, the issues I faced as a transit rider were not always the same as those faced by other riders. Second, I did not have enough hours in the day to implement all the new features suggested by users. Finally, some new features were clearly better than others, with various trade-offs in what I might implement. I needed a principled approach for both understanding the full range of issues faced by both users and non-users of public transit alike, how those issues might be addressed with technology, and finally, some scheme for deciding which improvements to implement first.

We found that approach in Value Sensitive Design (VSD) [32], a principled technique for examining the set of ethical values implicated in a technological system. A complete description of the VSD process is beyond the scope of this document, but it generally involves a three part method of conceptual, empirical, and technical analysis of a particular technology and the potential impacts on an identified group of direct and indirect stakeholders, with respect to their values.

Typically in the VSD approach, one would evaluate a single technology. We took a slightly different approach. I, along with my colleagues Kari Watkins and Yegor Malinovskiy, undertook a conceptual and empirical analysis of public transit in general, identifying the various stakeholders, their values, and specific value-tensions that arose from the variety of barriers to the use of public transit we enumerated in our analysis. Many of those barriers are listed in the introduction to this document. At this point, we believed we had an effective map of the space of stakeholders, values, barriers, and tensions involved in public transit service. Now, instead of evaluating a particular technology with respect to that value space, we brainstormed as many potential ways as we could to use technology to address some of the identified barriers. We were left with an extensive list of some 80+ ideas for improving the usability or encouraging the use of public transit through technological means.

We do not have the developer man-power to implement 8, let alone all 80 of these ideas, so a prioritization scheme is critical. For inspiration, we look to the work of the UrbanSim project [31] and their own principled prioritization scheme for implementing new features.

In the remainder of this chapter, I will describe our VSD analysis of the public transit domain, discuss a principled prioritization scheme for ordering the various technical proposals that came out of the VSD analysis, and conclude with a discussion of how this process ultimately led to our next major implementation effort. We begin with the three major components of the VSD process: conceptual, empirical, and technical investigation.

6.1 Initial Conceptual Investigation

Using the principles of VSD, the OneBusAway team first conducted a conceptual investigation listing groups of direct and indirect stakeholders. In our analysis, stakeholders are those affected by the public transit system in some capacity. We consider both direct stakeholders, who are impacted by or use the transit system explicitly, and indirect stakeholders, who do not use the system but take part in or are affected by its operation. The direct stakeholders included various categories of riders, such as riders of different age groups, genders, and socio-economic groups, commuters and non-commuters, choice and captive riders, riders with access issues (blind, deaf, cognitive, wheelchair), riders with children, and riders with accessories (bike, suitcase, stroller, packages). The indirect stakeholders included non-riders on various other modes, transit employees (bus drivers, general manager, transit planners / schedulers, GIS / data-source employees, field supervisors and dispatchers), and other members of the community (businesses, employers, advocates, citizens, elected officials).

A preliminary list of the pertinent values was developed for each of these groups, along with a brief discussion of how new systems might benefit or harm the stakeholders in that group. The full list is included as Appendix A.1. The result of the conceptual investigation was a detailed description of the stakeholder tensions implicated by transit rider information tools. We show an

Stakeholder	Values	Benefits	Harms
“Typical” rider	Efficieny	Decision Support	
Captive rider	Self-image, Dignity, Efficiency, Community	Decision support	Become reliant on the system and reduce interaction with others, Economic pressure of getting an iPhone since other riders have it
Choice rider	Efficiency, Community	Decision support	Become reliant on the system and reduce interaction with others
Children	Efficiency, Accountability, Privacy, Safety	Decision support	Privacy invasion by nosy parents, parents may blame OneBusAway if something goes wrong
Teens	Efficiency, Accountability, Privacy	Decision support	Privacy invasion by nosy parents, parents may blame OneBusAway if something goes wrong
Parents with children	Efficiency, Privacy	Decision support, extra confidence and control	
Older riders / Elderly	Efficiency, Dignity	Decision support, extra confidence and control	Complicated gadgets that can confuse seniors, issues with print size

Table 6.1: An excerpt from our stakeholder value, benefits, and harms analysis. We specifically highlight a number of categories of direct stakeholders. See Appendix A.1 for full analysis.

excerpt from the full list in Table 6.1 to give a flavor of the analysis.

6.1.1 Additional Rider Value Modeling

In additional to the values, benefits, and harms analysis described above, it is useful to perhaps consider a conceptual model of rider motivations as well. In [34], the author summarizes two schools of thought concerning the modeling of user behavior:

- **Rational-choice model** - an individual acts out of self-interest
- **Norm-activation models** - an individual acts out of altruistic values and personal norm activation (e.g. moral obligation)

I think the reasons individuals have for deciding to use public transit, and the tools we might create to encourage that decision, have elements of both models. Clearly, there is an argument to be made that tools like OneBusAway make using public transit easier and potentially affect any decision made by a user attempting to optimize their use of time. At the same time, there is certainly an indication from some of our empirical evaluations that riders are also motivated by altruistic values towards the environment and their community. We have not specifically set out to evaluate and measure the relative contributions of these two models of human behavior, but such an evaluation might be useful as we consider our principled prioritization scheme for evaluating new features for OneBusAway.

6.2 Initial Empirical Investigation

The second portion of the VSD analysis was an empirical investigation that built on the conceptual investigation described above. The focus of the initial empirical investigation was to refine our list of harms, benefits, and values, as well as determine the types of transit rider tools that would increase satisfaction and the potential to ride. The process included a literature search and review of transit agency rider / non-rider surveys, interviews with transit agency personnel, an IdeaScale feedback site designed to solicit feedback from current OneBusAway users about their ideas for improving OneBusAway, and finally a group forum and cultural probe with the King County Metro Transit

Advisory Committee (KCM TAC). A cultural probe is a targeted survey inquiry of a group. The TAC is a committee of over a dozen transit riders, selected from geographically distinct regions of King County, that is designed to give broad rider feedback to the transit agency. We felt they were an interesting group to survey considering their broad representation of riders and their knowledge of transit issues.

6.2.1 Direct Stakeholder Interaction

The interaction with the KCM TAC took the form of a modified Futures Workshop [51] and Cultural Probe [36] described previously in Human-Computer Interaction literature. In the group forum, participants were asked to list their critiques and suggestions for the transit system. Questions included:

- What do you like about public transit?
- What do you hate about public transit?
- What is unique about how you use transit?
- What information do you need to ride the bus?

After this brainstorming session, each participant was left with a goody bag containing a series of fill-in-the-blank lists, a group of postcards, and a map with sticky dots. The instructions from this cultural probe exercise are attached as Appendix A.2. The lists expanded on the questions asked in the group forum, instructing respondents to fill in 5 things for each question, including the 4 questions from the group forum listed above, as well as these 6 questions:

- What about public transit would change?
- What about public transit would you keep the same?
- What are your tips and tricks for using transit?
- What frustrations do you have finding that information?

Figure 6.1: Four examples of the postcards that riders could use to describe situations where public transit a particular emotion. See Appendix A.3 for the full set.

- What are your favorite websites and why?
- Which websites do you find easiest to use?

The pre-addressed stamped postcards showed faces with various emotions (smart, disappointed, exhausted, resourceful, confused, annoyed, helpful, calm or peaceful, scared, happy, angry) on front. Riders were encouaged to fill out a postcard and mail it back when public transit inspired a particular emotion. The back side of each card had blank space to tell us what about public transit on that particular occasion inspired that particular emotion. An example of four of the postcards is show in Figure 6.1 and full set is available in Appendix A.3.

On the map of the KCM service area, respondents were asked to place different colored dots near:

- Where you live
- Where you go by bus to work or school
- Where you go by bus for shopping or entertainment
- Where you would like to go by bus, but cannot

In addition, they were given a crayon to draw areas of King County that are inaccessible by bus from where they lived. A copy of the map is shown as Appendix A.4.

6.2.2 Direct Stakeholder Evaluation Results

Responses during the group forum tended to focus on the communal and economic benefits and harms of transit. For benefits, over half of the benefits listed involved community improvement or exploration. The remainder focused on the lower costs associated with transit and its environmentally positive aspects. Concerns regarding transit also focused on community issues, but lack of control dominated the list. Participants were concerned about the unpredictability and unreliability of buses, as well as the limited possibilities inherent to a fixed route/schedule system. When questioned about what the participants felt was unique about the way they use transit, responses included multi-modal variants, complete dependence, and riding with additional accessories or children. Participants were then asked what information they needed to ride the bus. Real-time information and routing were of primary interest. Additional suggestions mentioned way-finding via common landmarks, as well as touch-screen capability. The responses received from the group forum are listed in Appendix A.5.

Once the group forum above was complete, goody bags containing the cultural probes were distributed with a reminder to mail them in as they were completed. Responses began arriving within a week of the meeting. In total, 8 surveys, 14 postcards and 6 maps were returned from the 10 participants that were present at the KCM TAC meeting. Responses ranged from being exceptionally verbose and detailed to single word descriptions.

Best Things About Public Transit
Not driving – traffic, weather, crazy drivers, stress
Other activities – Relaxing, nap, read, studying, etc
The challenge of trying to take the bus
People watching
Helping other people with where they are trying to go
14 items in total...
Worst Things About Public Transit
Use of smaller buses on less-used routes
Better timing of buses to help reduce wait time when transferring
More frequent buses – evenings, weekends
Get rid of rude, surly drivers
Transit schedules customized for non-commute riders
30 items in total...
Information Needs for Using Public Transit
More frequent buses – evenings, weekends
Trip planner doesn't make it clear which stop to get off at or where to catch a bus
Trip planning for primary and return trip
When will a bus be crowded
Better maps: where you are getting off the bus, especially for new areas, street-level detail
19 items in total...
Tips and Tricks for Using Public Transit
Use bike racks for bike+bus
Through routes to avoid a transfer
Transfer are cheaper than paying twice
Will often take a longer single trip instead of a shorter transfer
Bring something to do while waiting, riding – especially for children
9 items in total...

Table 6.2: An excerpt from the Cultural Probe survey results. We include five results from each section. See Appendix A.6 for full result set.

Participants were most diligent in filling out the surveys, providing detailed responses to each of the questions. These responses were perhaps easiest to convert into user needs, as the participants were directly solicited for the benefits and harms associated with their transit riding experience. The benefits expressed were similar with those elicited in the futures workshop, save for an additional benefit of overall system efficiency. Harms were listed in greater detail than those obtained from the group session; however the overall trends remained the same. An additional component that was revealed was the importance of drivers to the overall experience - surly drivers were considered harmful to the transit experience. Responses regarding useful information for transit use included representation in forms that does not require a smart phone and information regarding the current conditions on an upcoming bus, such as passenger load and cleanliness. Relatively few additional insights were obtained from questions that asked for tips and tricks, in part due to a lower response rate. Eliciting website usage provided similar results, as many participants struggled to come up with five transit websites, although we considered any “usable” site acceptable. An excerpt from the the top 5 lists portion of the cultural probe survey results are shown in Table 6.2 and the full results are included in Appendix A.6.

Postcards returned as part of the cultural probe were harder to interpret, but reinforced certain issues that have been brought up in list form. Responses were sometimes detailed:

> Today transit made me feel Angry. Surly driver (Rt 66) did not respond to ‘Good Morning’ and did not call out stops - did not apologize when sudden jerk made passenger almost fall

to brief

> Today transit made me feel WET!

To interpret these postcards, our group attempted to understand the deeper issue behind the feelings expressed by the participants. For example, the “Angry” card suggested that there should be some better means of allowing for communication between riders and drivers. However, certain cards, such as the “WET!” example, could not be interpreted into anything more than the face value. The card responses received are coded in Appendix A.7.

The maps provided to the participants were perhaps the most challenging to interpret. The responses were coded into tables, presented in Appendix A.8, but the data provided little additional insights to potential OneBusAway improvements. However, the notes found on some of the more detailed maps gave some additional hints to potential improvements and were considered, along with the harms and benefits obtained from the probes and forums, during the Technical Brainstorming session described later on.

6.2.3 Bus Driver Interviews

In addition to the stakeholder group forum and cultural probe described above, we interviewed subjects who are indirect stakeholders in the transit rider tool building process. Informal interviews were conducted with planning and engineering professionals at both KCM and Sound Transit. In addition, more formal semi-structured interviews were conducted with representatives from the Amalgamated Transit Union for KCM. The intent of these interviews was to obtain information about how rider tools may affect indirect stakeholders in the process and get feedback about which tools should be built.

Three semi-structured interviews were conducted with members of the transit union accounting for collectively over 60 years of bus driving experience. The bus drivers were asked several warm up questions, including:

- What are the 5 best things about driving a bus?
- What are the 5 worst things about driving a bus?
- What would you change about driving a bus given the chance?
- What would you leave the same about driving a bus?

They were then asked a series of rider information needs questions, including:

- What kinds of information do riders typically ask you for?
- How frequently do you get these types of questions?

- What kind of information should KCM provide to riders?

They were then asked a series of questions pertaining to their views on safety and privacy. Safety questions included the types of things they currently have to do while operating a bus and their ability to add an additional task reflecting their bus being standing-room only or that the wheelchair spaces are taken. The privacy questions addressed their opinions about real-time information, including the value to passengers and the potential violation of driver privacy by providing the information as countdown to arrival as well as a historic on-time status for that particular bus. The questions also included a series of questions about running "hot", or early, and the impact that real-time information might have on this situation.

The interview concluded by giving the bus drivers an opportunity to share other benefits or harms that they could foresee from providing greater rider information.

6.2.4 Bus Driver Interview Results

The themes regarding the best aspects of driving a bus revolved around social interaction and independence. However, this independence was countered by what was considered the worst aspect: management and policy's interference with their ability to do their jobs well. Aspects of the job they would want to change touched on this same theme, with reduced political interference and improved interaction with other parts of KCM topping the list.

The drivers thought KCM should be providing basic and advanced trip planning components and real-time information. However, they also specifically mentioned that KCM should be providing information on how the public can impact service, fare information including how to pay, and effective rider alerts. They made specific suggestions about interior stop announcement signs including alerts and materials to encourage transit accessibility to entertainment.

There was discrepancy about the idea of pushing a button to provide greater information about a full bus, full racks, etc. - some felt they would remember and others did not think they would always remember - or that other drivers would not remember. Most importantly, unless drivers really cared about the information the extra effort produced, they would not even try to remember. The idea of providing the information was considered good, but they were not sure it would make a difference to most riders. If you sit at your desk because of a full bus an await the next one, then that would help the entire system, but if you are already at the corner, most people will still climb on even if they know another emptier bus is coming in just a minute. It was felt that this information needed to be 100% accurate, otherwise no one would use it.

For both early and late buses, drivers alter how they drive to match the schedule. There was some discrepancy about how well drivers know that they are on schedule. If they are significantly early, they will sometimes pull over and sit, but this is psychologically painful for them and the riders, so they try not to. Instead, they drive very slowly and follow guidelines painstakingly, such as allowing all passengers to sit before they start to drive.

Some thought drivers would adhere to the schedule more if people were more aware of on-time status, but that this might actually make on-time status worse. Drivers will often purposefully run late or early at the beginning of a route because they know what will happen further down the line. They attempt to drive so that most of the route is on-time using their knowledge of historic traffic and the day's events. With more information, early running might stop completely, but late running might increase. Likewise, for routes that tend to run early, efforts to stick to the schedule at the start of the route might lead to running even earlier later in the route, forcing the driver to hold a particular stop, to the frustration of the riders on-board . If drivers are given pressure to stay on-time at all the stops, this may also put more pressure on the schedulers at the transit agency as well.

Drivers considered the current AVL system to be inaccurate, but providing real-time information was highly important to riders, especially in the city where people have options for their wait time. However, caution in the use was emphasized because drivers can get back on schedule. So, riders always need to plan for a couple of minutes before the anticipated arrival time. None of the drivers saw real-time arrivals as a violation of their privacy and indicated that it is part of their job to perform in the public eye. However, information about the percentage of on-time arrivals historically for a route was seen as a violation of their privacy. Many worried that this would lead to disciplinary action over something the driver is unable to control. It could also increase public confrontation with drivers, such as an in-your-face passenger asking them "Why are you always late?"

Feelings on the "rate my stop/route/driver" were mixed. Drivers felt that any ratings would have to be anonymous and not considered in any disciplinary action by the agency. One driver felt it would not be a bad thing to let drivers know they were considered "grumpy", but another was worried that the public might not use it in the right way. In general, they were worried about discipline coming out of tools and possible physical or mental harm from rowdy passengers. This ties to stress on the job being listed as another worst aspect of the job during the warm-up section of the interview.

The bus drivers really wanted to have OneBusAway type tools on their console so that they could help passengers. Indeed, a common theme from drivers was the desire to have more information to enable the drivers to answer passenger questions. Or they would like to have OneBusAway type tools in an on-bus kiosk, so passengers could help themselves get information about where to get off or the timing of their transfer. The biggest benefit was that “you might actually get drivers to ride the bus sometimes”! The detailed responses from the driver interviews are shown in Appendix A.9. For a more thorough discussion on the impact of real-time transit information tools on bus drivers, see Section 6 of [105].

6.2.5 Literature Search

In addition to the direct stakeholder interaction and bus driver interviews, our group pulled a wealth of information on the reasons why people do and do not ride transit from the existing literature. This included a number of reports produced by transit agencies across the U.S. after surveying their riders through on-board surveys and non-riders through telephone surveys ([70] [14] [103] [15] [8] [12] [108] [24]). The detailed notes from these surveys are shown in Appendix A.10 and are summarized below.

These transit rider / non-rider surveys indicated that customers were concerned with the following improvements, listed in order by importance:

- Wait time when transferring
- On-time performance
- Cleanliness of shelters
- Personal safety on bus after dark
- Travel time by bus

- Ability to get parking at park-n-ride lots
- Frequency of service (especially at night)
- Availability of seating
- Where routes go
- Inside cleanliness
- Drivers safety / competency
- Personal safety waiting after dark
- Driver courtesy
- Number of stops bus makes
- Number of transfers to make
- Ability to get info from routes / schedules
- Driver helpfulness with route / stop
- Availability / difficulty with luggage, bikes

In addition to these, non-riders faced additional barriers to public transportation use. These were characteristics that they not only would like to see improved, such as those listed above, but things that were literally preventing them from choosing public transportation. This list included:

- I like my car
- Planning around bus schedules
- Have to transfer

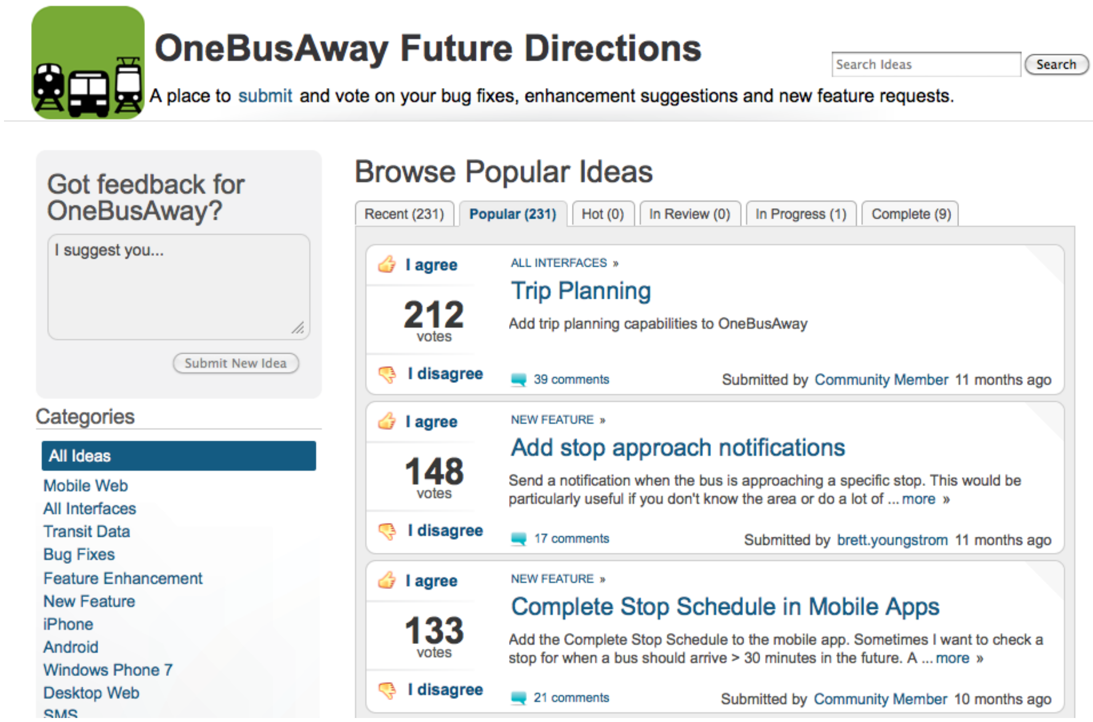

Figure 6.2: The top three active ideas on the OneBusAway IdeaScale feedback site, as of June 2011.

- Need car for emergency / daytime travel / errands / kids
- Need to transport stuff
- No stop near work / home
- Not knowing how to use the system

6.2.6 *IdeaScale Feedback Site*

In addition to our other stakeholder investigations, we have also deployed an IdeaScale site at `http://onebusaway.ideascale.com` to allow users of OneBusAway to submit feedback, propose new features, and vote on which ideas they think are most important (see Figure 6.2). The IdeaScale feedback site was implemented after the technical solution brainstorming detailed in the

Votes	Idea
212	Trip Planning
148	Add stop approach notifications
133	Complete stop schedule in mobile apps
112	Arrival info beyond next 30 minutes
70	Route map as line on map
60	Option to search for “next bus to XY”
47	View multiple stops
47	Display actual bus location on the map using GPS feed
47	Feedback - Best Service Ever!
39	Please bring back the box.

Table 6.3: The current top 10 ideas from our IdeaScale feedback site, as of June 2011.

next section, and while there have been a number of novel ideas proposed with the feedback site, many of the suggested features and ideas map directly to our proposed technical solutions.

Since the launch of the feedback site in 2010, some 3266 users have submitted 231 ideas, made 304 comments, and cast 1727 votes. As shown in Figure 6.2, trip planning support has been the most requested feature by a large margin. We present the current top 10 ideas in Table 6.3. While there are many ideas for features and improvements, some of the feedback is there just to say thanks: “Feedback - Best Service Ever!”

6.3 Technical Brainstorming

Through our conceptual and empirical analyses, we have identified a number of harms and benefits arising from various aspects of public transit that affect the different stakeholders in our study. As mentioned previously, instead of focusing our study on one specific technical solution that might address one of the identified harms or benefits, we are taking a broader look at the set of all potential technical solutions, so that we might make an informed decision about which solution to implement given our limited resources.

Part of that informed decision process involved constructing an extensive list of potential technical solutions. We generated the list through a brainstorming process guided by the results of our conceptual and empirical investigations. Some of the results of our empirical investigations are directly translatable into technical solutions. For example, the “Information Tools” sections of our cultural probes study solicited feedback such as “Trip planning for primary and return trip”, which is a direct deliverable in terms of a technical solution we could implement.

However, not all the results from our conceptual and empirical evaluations were immediately translatable to technical solutions. For example, in a list of positive aspects of public transit, a user listed “More social activity - can talk with fellow passengers, children.” Here, there is nothing wrong with public transit that needs fixing. Instead, we can imagine a class of applications that supports the existing positive activity. That led us to suggest an application to support transit social networking, allowing riders with similar interests (mothers with children, a book club) to coordinate their riding.

Of course, users also listed a number of negative aspects of public transit: “Get rid of rude, surly drivers”, “Violence / disturbances on the bus”, and “Loud, rowdy passengers” are a couple of examples. For these issues, we considered a “Rate My Route” application that allows users to provide feedback on various aspects of their transit experience and make decisions about which trips they take based on that feedback. While we hope users could use this feedback in a positive way, such an application could have other unintended negative consequences as well. To avoid stale data, the prominence or relative weighting of feedback and reviews could decay over time.

Some problems listed by riders are difficult or impossible for us to fix directly. Some riders asked for more dedicated right-of-way for transit vehicles and more frequent buses, especially during evenings and weekends. Though we cannot provide more right-of-way or more buses ourselves, we can turn the problem around, and provide applications that highlight where service is available. This might be a commute calculator application that suggests the level of transit service at various places in the area, or a last call app that notifies you when the last bus of the night is about to depart.

When our brainstorming process was complete, we had collected a list of over 75 potential applications, which we list in Appendix A.11. We will not discuss the full list of potential applications here. Instead, the list of potential technical applications can be roughly grouped into a number of categories. We discuss those categories below, along with a few examples for each category.

6.3.1 Social Engagement

A number of applications would support increased social interaction and engagement amongst users of public transit. Example applications might encourage and enable riders to organize book clubs for riders of a particular route, or allow mothers with children who ride the bus to match their schedules so they might ride together, creating an ad-hoc social network for this group.

Another major application that fell in this category was the set of "Rate my Route" tools. This application would allow riders to rate various aspects of their transit experience: ride quality, the driver, the route, the area, and stops. Feedback would be shared amongst all riders to allow them to make better decisions about using public transit.

6.3.2 Incentives

A number of applications worked to encourage riders to use public transit through various incentive systems. A typical example was an interactive game where riders were awarded points based on how often they used transit. Special "merit badges" would be awarded for completing specific tasks such as "visiting all the light rail stops" or "giving up your seat on a crowded bus to another rider". This category of applications uses a variety of incentives such as games or perhaps rewards from sponsoring retailers to encourage transit usage.

6.3.3 General Planning Tools

This category of applications supports high-level planning of the use of public transit and, more generally, the impact of transportation in general on the wider community. These applications are distinct from trip planning applications (discussed below), because they focus less on planning a specific trip using public transit and more on the class of trips enabled by public transit in general. These applications include various calculator applications that allow one to easily measure the various financial, environmental, social, and traffic congestion impacts of various transportation modes. Such tools might help you plan a better commute based on various impacts or pick a new place to live entirely.

6.3.4 *Trip Planning Tools*

A number of applications were suggested to improve the capabilities of trip planners. From overall usability improvements to adding new data sources, such as historical and real-time performance data, there are a variety of improvements and new ideas that might enhance one of the fundamental tools used by public transit riders.

6.3.5 *Maps and Information Tools*

Many of the suggested applications focused on improving maps and other information display systems used in public transit. Changes were suggested for route maps to support better local context through detailed street names. A customizable map-maker application was suggested to create maps targeted to certain neighborhoods, tasks, or class of users. Applications in this category generally focused on providing general information about basic transit service through maps and other formats.

6.3.6 *Notifications*

This category of applications focused on notification capabilities. Being able to automatically notify riders when their stops are coming up or when their bus is running late were all frequently-requested example notification applications. In addition to notifying riders, a number of applications in this category offered the ability of riders to notify the transit agency of conditions of the system, such as buses or stops that needed cleaning.

6.3.7 *Accessibility*

Many of the applications in our list directly address the issue of improving the accessibility of public transit. They included issues of general accessibility, such as providing features across a variety of mobile devices instead of just smart-phones. They also included specific issues of accessibility, such as providing tools for blind and deaf-blind riders, or improving the functionality of the paratransit system.

6.4 A Principled Application Prioritization Strategy

We do not have the developer man-power to implement 8, let alone all 80 of these ideas, so a prioritization scheme is critical. For inspiration, we look to the work of the UrbanSim project [31]. Briefly, the UrbanSim project provides a system for simulating the development of urban areas, allowing urban planners to model different development scenarios and see how the city might change over time. The primary measures of change come in the form of indicators: measures of various statistics about an urban area that capture the effect of particular policies. Examples might include “Population,” “Number of Households,” or “Acres of Vacant Developable Land”.

Having used VSD in some of the development of UrbanSim as well, UrbanSim researchers understood the large space of stakeholders involved in urban planning decisions, with their complex web of value tensions, and the potential of bias, real or simply perceived, to bring into question the legitimacy of any UrbanSim result. UrbanSim developers were also faced with a similar problem as that faced by OneBusAway: a lengthy potential list of indicators to implement and no clear guidance on which indicators were most important.

To help resolve this issue, the developers proposed a principled prioritization scheme that focused on three aspects of any indicator: 1) coverage of the space of potential indicators, 2) organizational partner and stakeholder concerns, and 3) pragmatics. By triangulating between these three aspects, developers could assign a weighting to a particular indicator, hopefully extending the completeness of the UrbanSim indicator set while considering stakeholder concerns and the realities of implementation cost.

We propose a similar principled prioritization scheme for OneBusAway. Specifically, we triangulate between three aspects:

- **Stakeholder concerns and values**

  The stakeholder concerns and values identified in our VSD analysis are a fundamental aspect for consideration when prioritizing a new feature. While most of our proposed features are directly inspired by stakeholder concerns and values, an open question remains about the relative importance of a specific concern or value to a specific stakeholder group. We discuss strategies for measuring the relative importance below.

- **Impacted stakeholder dependence on transit**

  We feel it is important to recognize that not every rider has the same level of dependence on public transportation. Some riders are choice riders: they might own a car or have access to other modes of transportation, such that they have some control over their decision to use public transit. Other riders are transit dependent: public transit is their only means of transport mobility. For example, heavily transit-dependent populations, such as the city's homeless population, blind and deaf-blind riders, and the poor, might all be impacted more directly in improvements to the usability of public transit than choice riders who only use transit occasionally. At the same time, the pool of choice riders is potentially much larger as well. There is no perfect way to balance stakeholder dependence on transit, but it is important to recognize it in the prioritization process.

- **Technical and organizational pragmatics**

  Some new features are certainly easier to implement than others and developer man-hours will continue to be limited. Additionally, funding and availability of data can also play a part in the feasibility of a new feature. The resources required to implement a feature will always be an important aspect for consideration.

As discussed above, one aspect of our prioritization scheme considers the importance of stakeholder concerns and values. While our VSD analysis has helped to enumerate the space of stakeholders, their values, and their concerns surrounding public transit, the relative weighting of those values and concerns are more difficult to measure. Our empirical evaluations can help in this regard by providing metrics to quantify those weightings. Specifically, the relative ranking of concerns in rider / non-rider surveys and in our IdeaScale feedback site both provide important context for prioritization. Certainly, there will never be a mathematical formula that serves as our prioritization mechanism, but the prioritization can still be done in an informed manner.

6.5 Identified Stakeholder Tensions

As described above, our prioritization of information tools depends in part on an analysis of stakeholder concerns and values. In addition to the aspects mentioned in the previous section, we can also consider stakeholder value tensions in our prioritization of proposed technical solutions. Stakeholder value tensions capture situations where one stakeholder's value or a technical solution that supports that value are in conflict with those of that stakeholder or another. The following value tensions have been identified to date.

6.5.1 Rider Efficiency

Many of the tools for OneBusAway, both existing and potential, aim at improving the efficiency of a rider's interaction with public transit. However, in the process of supporting each rider's value of efficiency, we find ourselves in tension with a variety of other values both for riders and for other stakeholders in our analysis.

Rider **privacy** is an important value that is a source of tension for many of the tools we have developed for OneBusAway and many that we would consider developing. These tools, from a powerful location-aware smart-phone application to a basic SMS interface, all leave bread-crumbs of personal location data as users interact with the system. Requesting real-time arrival information or planning a trip gives detailed information about the user's current location and travel patterns and raises questions about how OneBusAway is using and/or protecting that information.

Rider **accessibility**, **economic cost**, and **fairness** are all in tension with more efficient and powerful OneBusAway tools, as many of these potential tools could require increasingly advanced and increasingly expensive smart-phones. While the set of applications enabled by such devices are exciting, they rule out those riders who either cannot afford these devices or perhaps have trouble using them because of visual or hearing impairments. There is a larger question of fairness if we are developing tools that make public transit easier to use for only a subset of the total transit-using population. There is a potential tension with trust for riders. For many of the tools, the end result is a more efficient transit experience when the tools work correctly. When the tools do not work correctly, it can make the rider's trip take much longer, especially if they miss a bus. As the transit tools push the limits of the available real-time data, we also push the limits of how much each rider can trust the results of the tools. Beyond simple data errors, there is the potential for users to game the system as well. A tool that allows riders to crowd-source information concerning the status of bike racks or available wheelchair spaces on the bus could be gamed by riders who claim that both are full, when they are in fact empty, in order to discourage other riders with bikes or wheelchairs from taking a particular bus and slowing down the route.

Values for transit drivers may also be in tension with rider efficiency. Driver **safety** may be an issue for systems that require the driver to manually input vital stats about the bus, such as when the bus is full, when the bike rack is full, or when both wheelchair spaces are taken. While such information could prove useful to riders in any number of tools, it requires an additional task of the driver, potentially involving input data into their management console and taking their attention from the road.

The **privacy** of transit drivers and the transit agency **self-image** may also be in tension with rider efficiency. Many of the tools that share information about the on-time status of a particular bus or on-time statistics for an entire route may be useful to riders, but they also potentially make more transparent each drivers on-time performance along with the on-time performance of the agency overall. Drivers and the agency might not want this information made public. This trade-off is part of the overall tension between rider **trust** and **transparency** in OneBusAway tools and transit agency **accountability**, as building tools that are transparent for riders with regard to underlying transit information might require exposure of more information from the transit agency and hold them to a higher standard of accountability.

Agency **economic** interests may be in tension with rider tools that promote efficiency. These tools may be great for riders, but they can be costly to maintain for transit agencies. Even when a 3rd-party such as OneBusAway is providing the tools, time and money must be spent preparing and maintaining the transit data feeds that power these tools. In fact, **economic** interests are often in tension with many of the values listed in our analysis, as one of the main road-blocks to potential solutions is often a financial barrier.

6.5.2 Other Stakeholder Values

Potential OneBusAway tools might target the rider value of personal **safety** by providing tools that give real-time arrival information so a user does not have to wait any longer than necessary for a bus or going further by providing information about the relative security of particular stops or even broader neighborhoods. While these tools directly address riders' value of **safety**, they may be in tension with rider **trust** and **accountability**, especially when the tools provide information that is incorrect. Furthermore, these tools might be in tension with the values of **community** and **privacy** if they give riders the ability to label stops, other bus-riders, particular drivers, or even entire neighborhoods as “sketchy” or “unsafe”, when in fact they may be harmless.

The value of **sustainable development** is a motivating value to provide tools that increase the usability, and as result the overall use, of public transit. However, these values are often in tension with the values of **independence**, **self-respect**, and **self-image**. Many members of the community find a personal car to be more flexible and socially validating than the public transit alternative. It is definitely the case that a personal car may be easier to use for a broader range of trips. Car ownership might also be seen as a symbol of status when compared with riding the bus.

We have considered developing tools that work to build a social network around transit usage to increase the sense of **community** and **self-image** for transit-riders. However, such social network tools are often in conflict with the value of rider **privacy**, as these tools can potentially share a lot of private information about individuals across their social networks.

6.6 Conclusion

Invoking the VSD approach for the design of OneBusAway has significantly changed the overarching goals of the project. The consideration of indirect stakeholders has revealed the full spectrum of impact that OneBusAway may potentially have. One of the most significant impacts is the consideration of transit drivers in the design. Through driver interviews and tension analyses, it became apparent that the successes of OneBusAway improvements depend on their acceptance by drivers, which are the primary interface between riders and the transit system. Furthermore, VSD has allowed for a more systematic design process that scrutinized the original conceptions of the potential improvements of OneBusAway, allowing for a more comprehensive solution approach.

We believe a similar VSD analysis and prioritization scheme could be useful for many projects. OneBusAway is not alone in a world of projects that hope to help some stakeholder group or enact social change through technical solutions. Like OneBusAway, these projects do not have infinite resources either. The combination of VSD analysis and principled prioritization scheme can help developers understand the impacts of their technical solutions that help them maximize outcomes with limited resources.

The results of our initial investigations have left us with both a lengthy list of potential tools to develop and a beginning list of how those tools might impact direct and indirect stakeholder values. While we will continue to refine this analysis as we further explore the space of public transit rider information tools and perform additional investigations, we believe we have sufficient coverage of the space to start building more tools. We present some initial work towards that end in the following chapters.

Chapter 7

REAL-TIME TRIP PLANNING AND SERVICE ALERTS

In Chapter 6, I presented a principled prioritization scheme for helping to choose new features to implement in OneBusAway. I will now describe how those evaluations and prioritizations all point to real-time trip planning and service alerts as a key addition to OneBusAway. I will describe my initial work in implementing a real-time trip planner tool with service alert support. Finally, I will highlight some of the challenges and opportunities that come with these additions.

Let me first define what I mean exactly by real-time trip planning and service alerts. I have already discussed that trip planners are a critical piece of any transit traveler information system, and most transit agencies and some commercial companies provide some form of public transit trip planning. For the most part, those systems only provide scheduled itineraries. That is to say, the planned trips reflect scheduled departure and arrival times, as opposed to the actual real-time predicted departure and arrival times. These existing trip planners also often do not take into account temporary changes in service, like cancellations or reroutes, that can affect a planned trip. I hope to provide a real-time trip planner that integrates real-time arrival information and real-time service alerts to help plan the best route between point A and point B given the current known conditions of the world, and to help re-plan the best route as conditions change. Real-time service alerts about delays, reroutes, and cancellations will be critical part of this infrastructure.

7.1 Prioritizing for Real-Time Trip Planning and Service Alerts

Let us consider this proposed feature within the framework of our principled prioritization scheme.

- **Stakeholder concerns and values**

  Across multiple empirical evaluations and design studies, one feature repeatedly rose to the top: trip planning. For riders, trip planning tools play a critical role in improving the usability of public transit, especially for new and occasional riders. For transit drivers, trip planning tools can reduce the burden of having to explain trip plans to lost riders, who tend to hold up the bus as they ask for directions. For transit agencies, it reduces the number of call-center staff needed to answer questions over the phone from riders about trip plans, saving the agency those resources. The addition of real-time information in the form of predictions and service alerts further improves the situation, giving more information to riders and putting even less burden on drivers and agency staff. Trip planning is also the most requested feature on our Ideascale feedback site (see Figure 6.2).

- **Impacted stakeholder dependence on transit**

  Real-time trip planning tools are critically important to transit dependent and choice riders alike. OneBusAway is currently geared primarily to power users who know their transit system reasonably well and know how to get from point A to point B. However, for new or choice riders who are less familiar with their public transit system, trip planning is a critical feature. Trip planning is also critical to certain transit dependent riders as well. As we consider what it would take to implement a system like Opportunity Knocks for cognitively impaired riders [84] or some of the systems for blind and deaf-blind riders [3], real-time trip planning that takes into account changing service conditions is an essential building block, for both these systems and any other that would attempt to help riders with specific impairments in using public transit.

- **Technical and organizational pragmatics**

  On the other hand, the technical pragmatics of for real-time trip planning are an issue: implementing real-time trip planning and service alerts is by no means trivial. Creating a trip planning engine that can provide fast and accurate routing that considers real-time information is difficult. Creating an engine that can hold up to the performance demands of websites, mobile apps, and other user requests pounding it with high volume traffic is harder still, and remains an open area of research. That said, I stand on the shoulders of giants and our involvement with the open-source OpenTripPlanner (OTP)engine [81] has reduced the amount of implementation required on our end dramatically. The servers required to power such as system are non-trivial, and will require funding to purchase and maintain. The real-time data required to power such a system is also non-trivial, and will require support from participating transit agencies.

When it comes to the decision of whether a mobile or standard web interface should take implementation priority, it is clear that mobile comes first. The immediacy of a mobile tool matches well with the on-the-fly decision making that a real-time trip planner would allow. A vision for how our mobile real-time trip planner might function takes inspiration from the Opportunity Knocks prototype, but with some important distinctions.

First, I will place less emphasis on automatic destination detection. I believe that most users of our tool will either specifically search for transit directions to a user-specified destination because they have never been there and need guidance, or they will select a bookmark for a frequently accessed destination, much in the same way riders currently bookmark frequently accessed stops in OneBusAway. The user-interaction step of querying the real-time status of their route will provide a strong indicator of the destination goal for the rider.

Second, in order to preserve battery life, I will adopt the techniques outlined in Section 3.6 to rely more heavily on the accelerometer as an indicator of when travel has started, and only then, fire up the GPS. We may go so far as to rely on the GPS of the transit vehicle itself once we have detected a rider is on a vehicle with some confidence. The vehicle's tracking system may be more robust to situations such as transit tunnels, for example, while further reducing the battery load on the user's mobile device.

Third, I can opportunistically notify the user with additional sources of novelty. Consider, for example, that we have detected that a rider is not going to make a transfer because their bus is running late and there is now some new, more-optimal path to their destination. The tool could notify the user of this possibility and allow the user to change their target itinerary if they so desire.

I am happy to say that these initial ideas and visions for an application have actually started to come together into a finished product, as I will describe in the next section.

7.2 Mobile Real-Time Trip Planner Application for iPhone

I have made the case for the real-time trip planner, so let us now describe the resulting product. The application has been developed for the iOS platform first (iPhone, iPad, etc.) as the existing

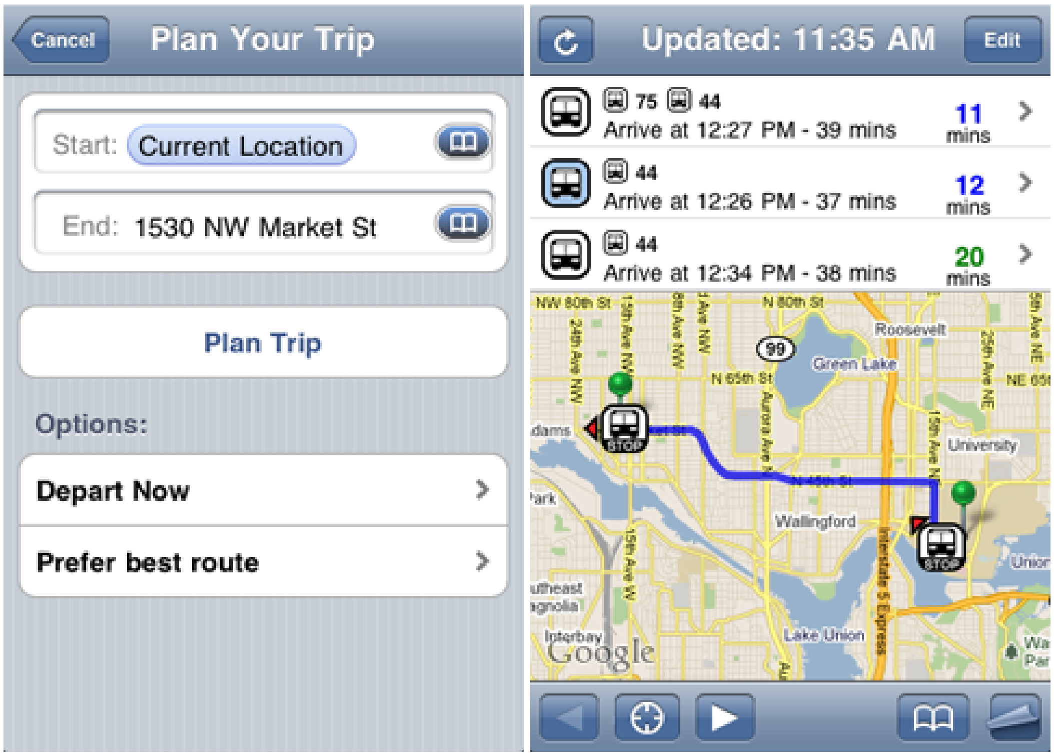

Figure 7.1: On the left, the primary interface for planning a trip. On the right, the resulting display of planned itineraries.

OneBusAway iOS app has the largest user base of any of our mobile applications and it also happens that I own an iPhone and believe strongly in regularly using the apps I develop. It is important to note that the application is currently in the early stages of development, so features and functionality may change over time. However, the application is sufficiently complete to be useful to riders and I have begun beta-testing the application with our OneBusAway beta-test pool.

7.2.1 User Interface

The user interface of the mobile real-time trip planner application was initially inspired by the Google Maps directions application for iPhone, but a number of important differences have emerged as I have iterated on the application. I show the primary interface screens in Figure 7.1. On the left, we see the primary dialog for planning a trip. The user can enter their origin and destination locations, using either their current location, a street address, a place or business name, a bookmarked location, a recently queried location, or an address from their address book. The goal is to give the user a variety of options to quickly and easily specify the start and end points of their trip. Additionally, I allow the user to specify the timing of the trip. By default, trips are planned starting at the current time, but I also allow the user to specify a departure time in the future or a target arrival time. Finally, I allow the user to specify their trip preferences to weight the type of itinerary results returned by the planner. The app support the following options:

- Prefer best route (selected by default)
- Prefer fastest route
- Prefer fewer transfers
- Prefer less walking

I discuss how these options influence the trip planner in Section 7.3.3.

On the right-hand side of Figure 7.1, I show the results of a trip planner search. Here we see three possible itineraries, with the table at the top of the screen summarizing each trip. For each itinerary, I show the set of routes involved, including the type of vehicle (bus versus train versus other), along with the estimated arrival time, total travel time, and time until the start of the trip. By default, one of the itineraries is selected and the resulting path of travel is shown on the map below. The user can quickly switch between itineraries by selecting them from the list above. The current itinerary is highlighted in blue. Notice that the minutes until the trip start time in the right hand column are highlighted with different colors. I use the same color convention as the existing iPhone app (as described in Section 4.4), where green means the vehicle is on-time, blue means the vehicle is late, red means the vehicle is early, and black means no real-time information is available for the vehicle. The color-coding gives the user a quick indication of the real-time status of a trip.

When the user has picked an itinerary from the list of possible trips, they may use the left and right arrow buttons in the bottom left corner of the screen to step through the itinerary. The left-most image in Figure 7.2 demonstrates the first leg of the trip, including the target start time, the transit

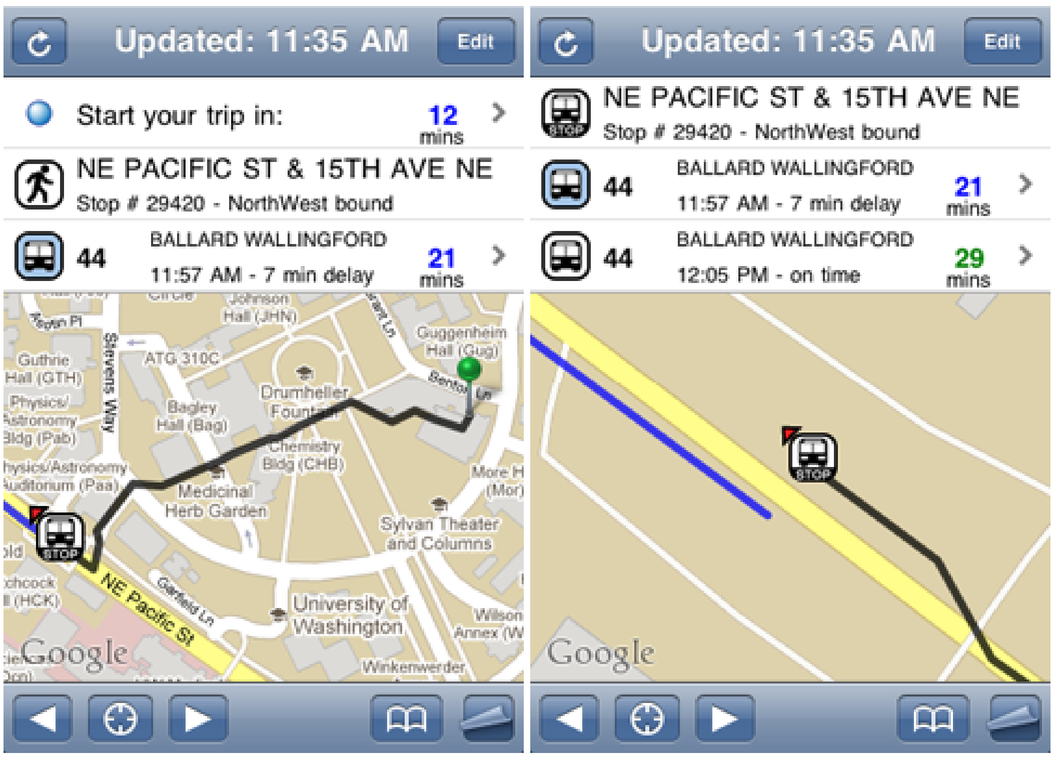

Figure 7.2: On the left, trip planning directions for walking to a transit stop. On the right, trip planning directions for departures from a stop.

stop to walk to, and the estimated departure time of the vehicle from that stop. The leg of the trip is visualized in the map below as well, indicating the walking path between the user's current location and the transit stop. The right-most image in Figure 7.2 shows the next leg of the trip, the transit stop itself. Here I again include the name of the stop, as well as the scheduled departures at that stop. The map shows a zoom-in view of the stop's location. It is worthwhile noting that multiple departures are shown at the stop. This display is similar to the existing OneBusAway iPhone app and gives the rider the option of quickly picking between multiple itineraries departing from the same stop. This is divergence from the UI of most trip planning applications, which typically have you choose one itinerary and then stick with it. However, the reality of real-time trip planning, and public transit in general, is that conditions change and the itinerary that made sense at the beginning of the trip does not always make sense now. I want users to have the option to quickly and easily change their minds.

Figure 7.3 shows additional screens as the user continues to step through a particular itinerary, including the path of travel for a particular bus (left) and the arrival stop (right). Like the departure stop, the arrival stop includes details about the stop itself along with upcoming arrivals. Again, the user can quickly switch between itineraries based on arrival time.

One nice feature of the real-time trip planner application is the ability to set alarms. Specifically, the user can set alarms to go off at the start of the trip, at the time of departure for a particular stop, and the time of arrival at a particular stop. These are all useful features that allow the user to plan a trip at some point in the future and then stick their phone in their pocket and receive a notification when it is time to leave. I show the alarm UI in the left-most image of Figure 7.4. The user can set the alarm to go off a certain number of minutes before the actual event, which is useful, for example, when the user needs a few extra minutes to get ready between the alarm going off and walking out the door. Or, as another example, the user might want the alarm to go off a few minutes before reaching their arrival stop, so they can pay closer attention to their surroundings in order in order to figure out where to disembark.

Like the existing OneBusAway iPhone app (see Chapter 8), I have a problem reporting mechanism built-in to the new trip planner app, as shown in the the right-most image of Figure 7.4. The problem reporting mechanism is primarily there to allow us to debug issues with our trip planner implementation, as each problem report includes details about the queried trip.

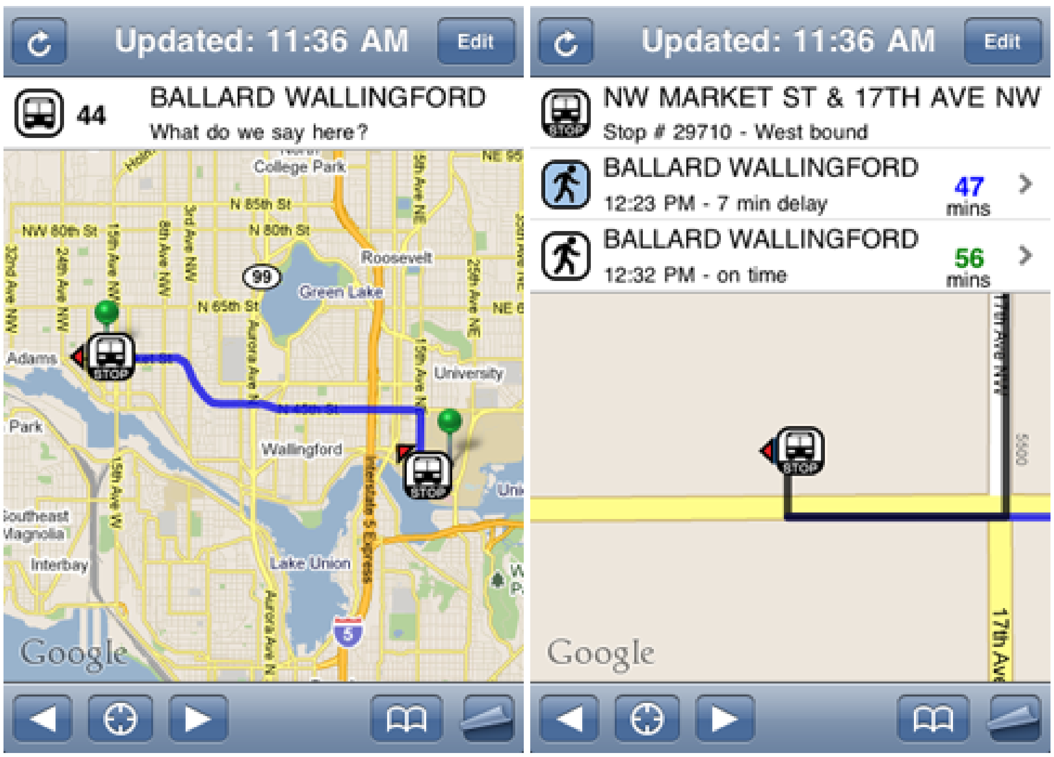

Figure 7.3: On the left, trip planning directions for public transit between two stops. On the right, trip planning directions for the arrival at a stop.

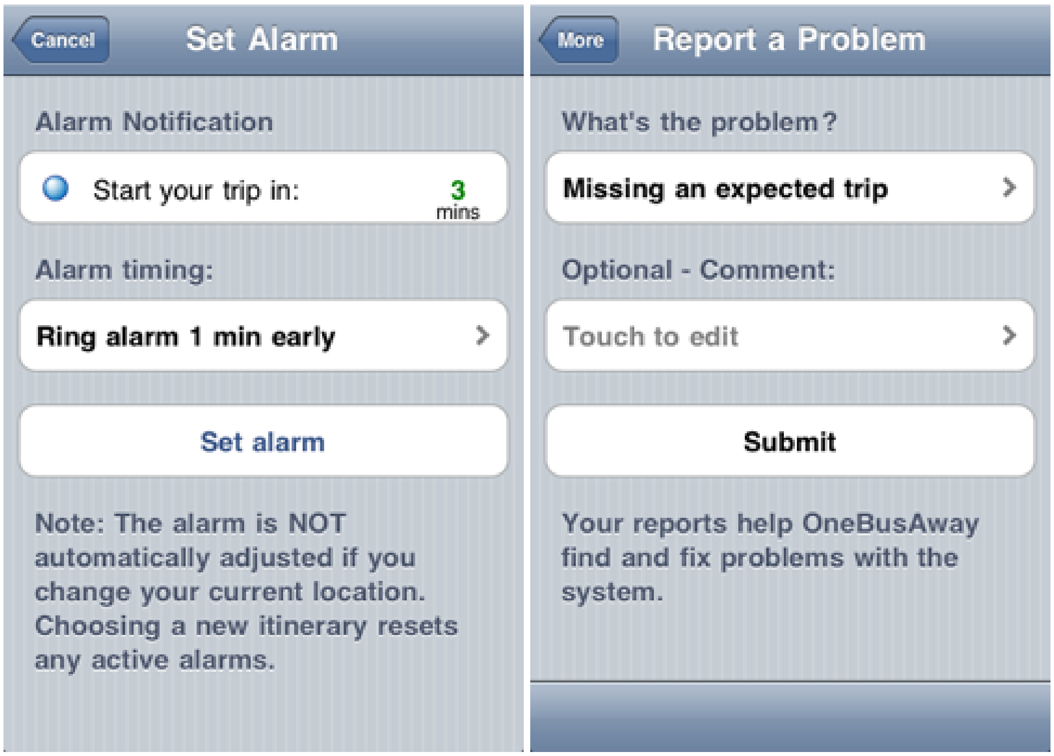

Figure 7.4: On the left, the interface for setting an alarm. On the right, the interface for submitting a problem report.

One interesting feature of our trip planning application is that I have some level of state estimation built into the app so that the app can automatically update and advance through the itinerary as a rider progresses through their trip. The app has the concept of the “next step”, which is the leg of the trip the rider is currently on. The rider can hit the cross-hairs button on the bottom left of the screen to jump to their current next step at any time. More importantly, the app can integrate location data from the phone to automatically advance through the legs of the itinerary, updating the display automatically to show the current next step for the rider. This feature works well for the walking, waiting, and boarding phases of the trip, but more work is needed to refine the automatic detection of a rider’s current transit vehicle.

In addition to automatic itinerary advancement, the app automatically refreshes the status of the current itinerary every minute, getting the latest real-time information for vehicles servicing the itinerary and advising the rider on the status of their trip. This is a major departure from the functionality of most trip planning apps. Traditional apps only have access to schedule data, so once a trip has been planned, the conditions never change. By comparison, the real-time trip planning app can automatically detect situations where the rider's current itinerary is no longer appropriate. For example, a rider might have walked too slowly to their transit stop and missed their bus. Or perhaps the rider is on the bus, waiting to make a transfer, but will miss their transfer because of delays. The app can automatically alert the rider in these situations.

7.2.2 Design Goals

It is worthwhile to discuss some of the design goals that went into the real-time trip planner app and how those goals have influenced the design. First, one primary goal of the app is to replace the need for the existing OneBusAway iPhone app completely, such that riders would **always** use the real-trip planner application when looking up real-time transit information.

This is is a controversial goal, as the two apps are quite different in terms of functionality and usage patterns. Let us first attempt to motivate this design goal. To understand why I would want a rider to use the real-time trip planner for every trip they take, it helps to think not about the trips where transit goes mostly right, but instead to consider the trips where things go horribly wrong. Think detours, reroutes, cancellations, delays, and other service changes. Ideally, I would like to be able to let a rider know about those situations so they do not end up getting on a bus that is not going to get them to their destination.

To be able to give riders the best advice, the app really needs to know where the riders are going. By knowing both your origin and destination, the app can evaluate all the trip plans with regard to real-time delays and service alerts to give riders the best information. An example service alert indication is show in Figure 7.5.

The problem with the existing OneBusAway iPhone application is that the app only has the origin context for a rider. That is, we know where they are coming from, but we often do not know where they are going. Of course, we can still show some service alert information within this context, but there may be a surprise reroute waiting for a rider further down the line that may or may not affect them depending on which stop they are getting off at. Since our goal is to only notify

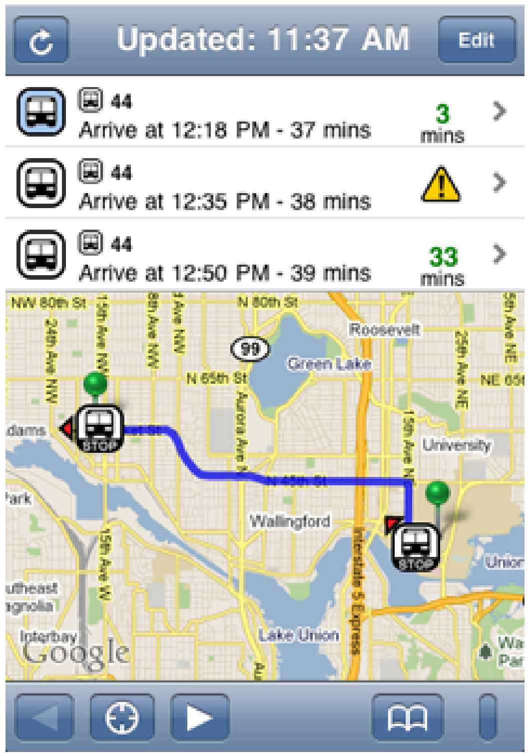

Figure 7.5: Example of a trip result with an active service alert.

riders of the service alerts that affect them and spare riders the details of the service alerts that do not, knowing the full origin and destination for a trip is critical.

So ultimately, a design goal is to have the user tell us their origin and destination for every trip they take using OneBusAway tools. Unfortunately, this gets away from some of the simplicity of the existing OneBusAway application, where we show nearby stops, the riders pick one, and then they are off. Having the riders tell us their destination is inherently more tricky.

The app has a number of strategies for addressing this issue. First off, the apps makes it straightforward for riders to indicate their destination in a number of ways:

- a street address
- a place or business name
- a bookmarked location

- a recently queried location
- an address from their address book
- a pin dropped on the map
- current location

Chief amongst these, I believe bookmarks will be the most frequent method for specifying a destination. Just as bookmarks are heavily used in the existing iPhone application to specify origin (see Section 5.1), bookmarks will serve as a quick and easy way for a user to specify their desired destination. For most users, this will mean bookmarking where they work and where they live, with most trips terminating at one of those two locations. For other destinations, I want to make it very easy for a rider to specify an address or place name. For example, the app also support a "dropped pin" functionality similar to the existing Google Maps application. Specifically, the user can hold their finger down on the map for 1-2 seconds and a pin will drop down at that location, allowing the user to plan a trip to that destination.

7.3 Implementation

It is useful to mention a few implementation details for our real-time trip planner application that might prove useful for others implementing similar systems. First off, public transit trip planning over a large transit network is not a trivial problem even in the schedule-only domain [5]. A number of approaches and techniques have been proposed for efficient routing over such networks. As a base, I have extended the OpenTripPlanner (OTP) project [81], an open-source trip planning engine that I have helped co-develop along with a number of developers from around the world and under the initial guidance of Portland's TriMet, who are the founding sponsors of the project. The OpenTripPlanner project provides a general framework for routing problems, with base support for walking, bicycling, and public transit navigation out of the box.

While the base-line implementation for public transit routing in OTP offers reasonable performance for small, single-city routing, I found the performance to be not so good for larger, multi-city transit networks like those supported by OneBusAway. As such, I replaced the public transit routing component of OTP with my own implementation. Specifically, I adopted the Transfer Patterns approach outlined in [6] for its ability to quickly produce routing results for very large transit graphs. The method considers each pair of stops in the transit network and precomputes the set of optimal transfer points between those stops over the course of the day. At query time, stops are examined near the source and destination points for the trip, and a directed graph is constructed from the set of transfer points is collected between those stops. Heuristic directed search is performed on the resulting directed graph. The directed graph of transfer points is dramatically smaller than the graph that would be typically explored in a more traditional full graph search approach, leading to very fast trip planner queries in practice. The downside to this approach is that computing the set of transfer patterns in advance is an expensive operation. Fortunately, the operation can be performed offline and in parallel. Even so, a number of optimizations are adopted in practice that speed up the transfer pattern calculation step at the expense of exactly optimal results. See [6] for more details. To give some context to computation time, our transit network of Puget Sound transit agencies, with 14K stops and 60K trips, takes some 300 hours of CPU time to process. A multi-node compute cluster is critical for parallelizing the computation task and making transfer pattern computation reasonably quick.

7.3.1 Reducing the Number of Transfer Patterns

I have made a number of extensions to transfer pattern routing that I believe are worthwhile mentioning. First, I have taken steps to reduce the set of transfer patterns calculated in the offline computation phase. As mentioned, a number of heuristics are already applied to reduce the transfer pattern set, but the resulting patterns can still be quite large for a medium size transit network such as the Puget Sound region served by OneBusAway. Reducing the number of transfer patterns means less space is consumed in main memory and less time is spent exploring spurious transfer patterns in each search phase.

One optimization I made in this regard was to consider the common case of two transit stops on opposite sides of the street, as is common in many bus networks. In a default transfer pattern implementation, one would consider the set of stops reachable for each of the two stops in turn. Since the transfer pattern exploration step explores all reachable stops from the origin stop, the transfer patterns produced for a particular stop will often include many convoluted transfer patterns that no user would make in practice. These include patterns for destinations that are in the opposite direction of travel for a particular stop and that would in practice always be served by buses departing from the stop on the opposite side of the street.

To help eliminate these patterns, I start with the standard Dijkstra search starting departures from the origin stop, but I also include starting nodes for nearby stops (a radius of 100 meters was used in our implementation) with the start time for each node adjusted to include the walk time from the origin stop. This simulates a rider simply walking across the street from their origin stop to catch a different bus. The graph search is allowed to proceed as usual until the entire network has been searched and optimal paths have been found to each stop in the network. Then, when reading off paths from the origin stop to destination stop, I ignore any path that traveled through one of the initial nearby stop nodes. In practice, I found this reduced our transfer pattern set by nearly 40%.

7.3.2 Real-Time Departures and Arrivals

The next important extension comes with the addition of real-time information. Here, I do not have a particularly exotic approach. I simply replace the next-departing-trip between two stops query from a default transfer pattern implementation with one that takes real-time information into account. Unfortunately, this additionally complexity comes at a cost. Where as the time for a static schedule lookup in the original transfer pattern paper was measured in microseconds, the equivalent real-time lookup is now closer to a few milliseconds. As result, while the original transfer pattern paper measured query times in less than 20 milliseconds, our approach is now measured in 100s of milliseconds. While those times might not be good enough for Google, they are sufficient for our needs for our initial deployment and evaluating our trip planner application.

7.3.3 Multi-Itinerary Trip Planning

Our final extension concerns multi-itinerary trip planning. Most trip planners in practice produce multiple itineraries for a rider to choose from. However, little is said in the trip planner literature on efficiently calculating multiple results. I will describe my approach in the hopes that it might be useful to others implementing their own trip planner. As stated above, our routing engine works by performing a heuristic directed search of the reduced transfer pattern directed graph between the start and end point. Typically, the search terminates as soon as the destination state is reached in the graph search. I take the approach of allowing the search to continue to run, collecting multiple results as the search finds different paths to the destination node. The trick comes in pruning these results. Consider an example as a point of illustration. The best route between two locations might be to board bus X at stop A and alight at stop B, walking to the destination. The next best route according to the graph search might be to board bus X at stop A and alight at stop C, which is one stop beyond the original stop B. In practice, this additional itinerary is not useful to rider, as the two results are essentially the same. I address this issue by assigning a block-sequence key to each itinerary. The block-sequence is effectively the sequences of transit block segments (as defined by the block convention in the GTFS spec) visited during the course of a particular itinerary. When the graph search discovers two results with the same block-sequence, I keep the itinerary with the best score only. In this way, I can avoid the case described above where two itineraries have slightly different entry and exit stops, but are both effectively the same sequence of routes.

It is also worth defining what I mean by “best” trip. I wish to evaluate a trip on more than just its run time. For example, consider two itineraries, both with the same total duration. The first trip requires just one direct bus, while the second has a transfer between two buses with a 10-minute layover. Many riders might prefer the first itinerary since it requires no transfer. However, if I were to increase the length of the direct trip, there would come a point when many riders would pick the trip with a transfer. How do we capture these rider preferences? The OpenTripPlanner framework uses a model I will refer to as **perceived time**. That is, for each leg of a journey, there is the actual time spent traveling and then there how long that time feels like to the rider. In practice, time spent on the bus itself passes close to real-time, while time spent walking to a stop and waiting for a bus seem to pass more slowly [21]. In Chapter 11, we demonstrate results that show how OneBusAway helps with that misperception of time, but the “percievied time” model is a reasonable starting point for modeling rider preferences. There is already a significant amount of work in the transportation literature devoted to measuring these “perceived time” parameters for various portions of public transit travel [54]. For example, in practice, walking seems to pass 2.2 times more slowly than riding a bus, while waiting at a stop passes 2.5 times more slowly. Some studies have show that the simple act of transferring between two buses can add 15 minutes to the perceived length of a trip. I calculate the perceived time of a trip using these parameters, and then use the total perceived time to compare different itineraries.

Of course, there is arguably no such thing as a "typical user" when it comes to transit, so I give riders the option of tailoring their perceived time preferences to suit their needs. When I discussed the trip planner iPhone app preference settings in Section 7.2.1, the "Prefer best route" settings use these default values pulled from transportation literature as described above. The "Prefer fastest route" sets all perceived time parameters to 1, such that perceived time and actual time are now equal. The "Prefer fewer transfers" and "Prefer less walking" options both increase the penalty for transferring and walking, respectively.

7.4 Challenges and Opportunities

I have made the case for real-time trip planning and service-alerts and presented my initial implementation of a real-time trip planner application. That said, there is still much interesting work to be done in this space, and I wish to highlight some of the opportunities and challenges that remain. First, there are a wealth of HCI questions related to the most useful way of conveying real-time trip planning information to riders.

How do we best communicate the level of uncertainty in a particular trip itinerary? Real-time arrival predictions are just that: predictions. We can imagine a system that calculates probability distributions of expected arrival and departure times and produces a final probability of how likely a rider is to miss the bus during a tight transfer. What is the tradeoff in utility when a particular itinerary might get a rider to their destination 10 minutes faster, but there is 20% chance the will miss their transfer, leaving them with a 30 minute wait? How do we present real-time itineraries to riders when their best option for getting home is an unfamiliar route that is now more practical because their normal route is cancelled today? What are the best strategies for notifying users of new and existing service alerts and of changes in service, balancing the tradeoffs of hoping to notify them of changes they do care about versus bugging them with changes they do not? There are a wealth of questions to consider and I have only scratched the surface with my initial implementation and empirical design explorations of a real-time trip planning tool. Evaluating the long-term impacts a well-designed tool might have on the usage of public transit will likely have to wait for later research.

In terms of service alert notification strategies, we might leverage the methods from [61] and [60] to build models of frequent and regular trips and destinations. Once identified, we could then provide preemptive targeted notifications about a particular trip with some confidence that it is a trip regularly taken by the rider. Again, we can leverage the fact that the user will likely have interactions with OneBusAway that will put strong priors on the set of potential significant places for detection.

In terms of challenges, I have already highlighted some of the technical implementation issues. However, those are relatively straightforward. One of the more difficult challenges is getting accurate real-time service alert information from the public transit agencies. While many agencies release their schedule data in open formats and a smaller number make their real-time arrival information available, only a handful of agencies world-wide make their service alert information available in machine-readable formats. It is only recently that many agencies have even made service alert data available in human-readable formats like emails, tweets, and website updates. In order to achieve our goal of targeted notifications of service alert information, we will need service alert information from the agency with all the associated machine readable meta-data about affect routes, stops, times, and consequences.

For the most part, agencies are currently in no position to provide this information on their own. Fortunately, we have a grant from the Bullitt Foundation to explore ways of making it easier for transit agencies to publish real-time service alert information in standard, open, and machine readable formats appropriate for use in systems like OneBusAway. I have discussed in Section 4.7 some of my initial work on tools to help transit agencies produce and manage service alert information, either integrating with or augmenting their existing rider information publication channels. This task is not trivial. Especially as we push for service alert information about time-sensitive, short-lived events, like a broken-down bus or a temporary reroute, agency staff have expressed concerns about their desire to publish accurate information. In the case of temporary service alerts, the agency may not know with any certainty when a broken-down bus will be replaced or a temporary reroute terminated. The agencies are reluctant to publish information in these situations. Agency staff are also concerned about their ability to manage yet another information entry task in what is already a chaotic and demanding information chain of command. We are respectful of both these concerns, and we are continuing work around additional empirical evaluation of agency values, needs, and concerns through staff interviews in order to both get buy-in from the agencies and in order to produce a tool that would actually help the agency staff while also giving us the service alert data we need.

One way or another, I believe these challenges can be met, which is why I am excited about the prospect of real-time trip planning and service alert functionality in OneBusAway, both as a researcher and as a rider.

Chapter 8

CROWD-SOURCING IN ONEBUSAWAY

In this chapter, I discuss how crowd-sourcing can be used in real-time information systems like OneBusAway. I will specifically describe a system I implemented for identifying transit data errors through crowd-sourcing. I will also discuss some other areas where crowd-sourcing could be in used in real-time transit traveler information systems as well.

8.1 Identifying Transit Data Errors through Crowd-Sourcing

The issue of data accuracy is important to the success of OneBusAway. For the system to improve the usability of and satisfaction with public transit among riders, it is critical that the information riders receive be accurate. OneBusAway is built on top of open data from public transit agencies in the form of GTFS data [38] describing the static stops, routes, and schedules that make up a transit network, and real-time location feeds that provide real-time arrival information for specific vehicles. Both these data sources can have subtle errors that may be difficult for transit agency staff to identify on their own. Within the framework of our principled prioritization scheme, this is an issue that affects all riders, who are our core direct stakeholder constituency, as well as indirect stakeholders like agency staff. When "decision support" is a critical benefit of our tools to all riders, it is essential that the information driving those decisions be accurate. We need a better way to find and identify errors.

We take advantage of the large user-base of OneBusAway, including many individuals who are quite knowledgable about the specifics of their public transit system, to help identify and correct those errors. Errors can take a number of forms: a stop with the incorrect name or location, a route that incorrectly skips a stop, a trip with the wrong arrival time, or a vehicle that provides inaccurate real-time arrival information, to list a few. Our intuition is that users will discover many of these problems after they have already started their journey and they are out at a stop, waiting for a bus. Thus, we have added functionality to our iPhone app to allow users to quickly provide

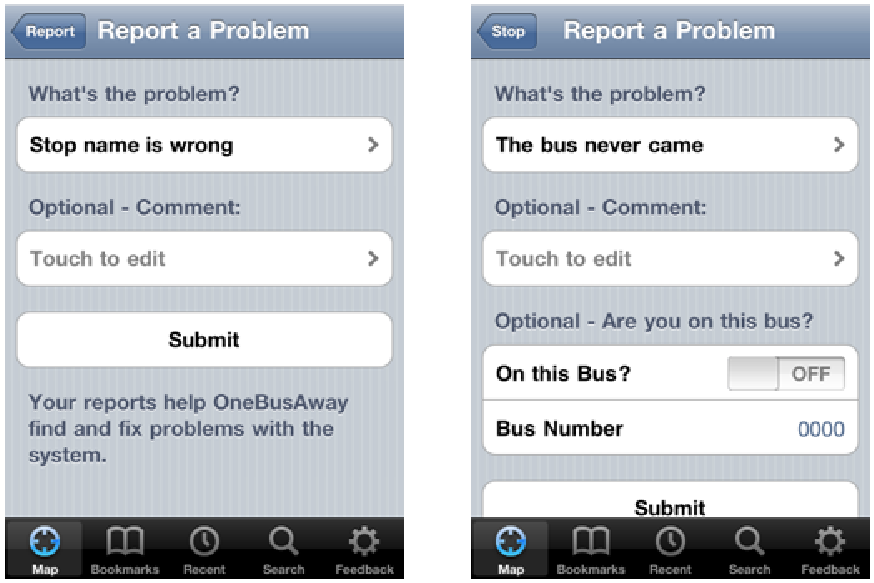

Figure 8.1: The OneBusAway iPhone app interfaces for providing feedback on problems with stops and specific trips.

feedback about a problem. The interfaces for entering problems about a specific stop or a specific trip are shown in Figure 8.1. We provide a list of common issues for a rider to pick from, while also providing a free-form comment field to describe other issues.

It is useful to contrast this feedback mechanism with other feedback channels in OneBusAway. We allow OneBusAway users to contact us over email, Twitter, Facebook, and through our Ideascale feedback portal. We receive feedback and problem reports through all of those channels, but it is important to note that the feedback is often missing critical information that makes diagnosing an issue difficult. For example, a user email might simply say "The route 44 never came!" At this point, we have to write the user back and ask for specific details about which stop the rider was waiting at, the time of day, and other information that can be potentially hazy in the mind of the user.

With the iPhone interface, on the other hand, we can automatically attach meta-data about the specific time, location, stop, and trip that allow us to quickly identify where the problem took place. This information can prove invaluable in diagnosing problems, particularly in cases where the underlying meta-data indicates that there was no problem, but instead that rider was standing at

Stop Problem Report	Count
Route or scheduled trip is missing	286
Stop name is wrong	94
Other	85
Stop location is wrong	20
Stop number is wrong	4

Table 8.1: Transit stop problem report types and counts.

the wrong stop or looking for information about an incorrect bus.

The iPhone app allows two types of problem reports to be submitted by a user: stop reports and trip reports. Stop reports allow a rider to report an issue with a stop, such as an incorrect stop name or location, or that a particular route is missing from the stop. Trip reports allow a rider to report issues with a particular vehicle or trip, such as incorrect real-time data or problems. We include a couple of default problem options for each report type, but also allow the rider to specify "Other" and include a free-form comment. For the trip report, we optionally allow the rider to indicate that they are on the particular bus in question and to specify the number of the bus. This can be useful information when attempting to diagnose a real-time tracking issue, especially when we can correlate the information with the riders location. We discuss both stop and trip reports separately in the next section.

8.1.1 Stop Problem Reports

In the six month period between December 2010 and May 2011, we received some 488 stop problem reports.

We show the frequency of various stop problem report types in Table 8.1. The table shows that the most frequent report type is "Route or scheduled trip is missing", indicating that a particular route or trip should be showing up in the OneBusAway app for a particular stop, but for whatever reason is not. These problem reports are a good example of crowd-sourcing the identification of transit data errors, as such reports are typically the result of a transit agency accidentally dropping a route or trip from its schedule data. One might question how an agency could drop the schedule for an entire route from its system by accident, but it does happen with some frequency. These problem reports allow us to quickly identify the problem and bring it to the agency's attention. Beyond missing routes and trips, the remainder of problem reports often concern less drastic data errors, including incorrect stop names, numbers, and locations. By helping the agencies to fix these errors in their data, it not only helps OneBusAway users, but it can also help all consumers of agency data, including riders who use agency websites and information tools directly.

It is also interesting to examine some of the quotes from riders left in the free-form comment field. Most of the comments simply add more context to the report or offer additional explanation when the "Other" problem type is selected. A few quotes are shown below:

> 255 not appearing in Bay B of IDS. I know it will be there because I am driving it. :)

> The 65 bus is ALWAYS late, and not by just a couple minutes. It is constantly 5-10 minutes late or simply fails to show up. Something needs to be done about this because I am tired of walking 5 blocks to the next stop to catch a different bus.

> Stop was removed last year since it was decided it was too close to the previous stop.

> Stops 1399 and 76300 should be combined into a single stop. They both refer to the same physical location.

As demonstrated in the first quote, it is clear that its not just bus riders who use OneBusAway, but drivers as well.

8.1.2 Trip Problem Reports

In the six month period between December 2010 and May 2011, we received some 5992 trip reports.

We receive many more trip problem reports than stop problem reports, so it is interesting to examine the types of problems reported, as summarized in Table 8.2. By far, the most common trip problem report, capturing 94% of all trip reports, concerns real-time arrival of transit vehicles: buses that arrive later than predicted, earlier than predicted, or not at all. We anticipated we might receive

Trip Problem Report	Count
The bus never came	3194
It came later than predicted	1758
It came earlier than predicted	684
Other	280
The bus does not stop here	52
Wrong destination shown	26

Table 8.2: Transit trip problem report types and counts.

a large number of these reports, but we did not think it would dominate the results so completely. Part of the reason we introduced the trip problem reporting feature was to help us identify places where the real-time tracking system deployed by the transit agencies had system flaws with regard to real-time arrival prediction. However, these reports actually pointed to a different problem.

At the time when a trip problem report is submitted to the system, we also take a snapshot of real-time arrival information for the specified trip and include it with the problem report when it is written to the database. In this way, we can go back and compare what our system said about a particular bus with what the user was reporting. When we went back to examine a portion of the trip problem reports, we found that for many of the reports where the user reported a bus arriving later or not at all, we had no real-time arrival information for that bus. In these cases, we defaulted to displaying the scheduled arrival time in the iPhone app. Of course, the bus could still be running late, which means it would appear to arrive late when compared to OneBusAway or perhaps not at all if the user submitted the report after the scheduled arrival time but before the bus physically arrived.

These problem reports hinted at a significant problem for some of our users: they did not understand the difference between real-time and scheduled arrival data. Though we take pains to highlight the difference in the iPhone app UI, the distinction is still lost on some users, causing them to interpret the scheduled arrival time as the predicted arrival time. We are working to clarify this in the UI, as explained in Section 5.3. All told, around 70% of the trip problem reports seem to be attributable to the confusion between real-time versus scheduled arrival information.

The remainder of the trip problem reports point to real problems as well. Additional examination of the data suggests that 10% of the reports are attributable to real-time arrival “jumps” where a vehicle sends in a location update, does not update for a number of minutes, and then later sends in a location update that is significantly different than the extrapolated location. This points to a problem with the bus radio data network where it has trouble regularly communicating updates to the base. Similarly, 5% of the trip problem reports are attributable to stale data problems where a bus sends in a location update and then fails to send in any update at all for a lengthy period of time. In OneBusAway, we mark real-time arrival data as stale after five minutes, but a lot can happen in five minutes in terms of bus location. We are exploring ways of measuring and displaying the uncertainty of stale arrival prediction information, as described in Section 5.3.

Another 6% of problem reports can be attributed to a stalled bus, where the vehicle is active but stuck at some point along the route, such that the arrival time to continues to increase with the bus never getting any closer. Another 6% of the reports could be attributed to actual bad prediction data where it was difficult to tell exactly what had gone wrong with the system. Interestingly, less than 1% of the trip problem reports seem attributable to the rider picking a different stop in OneBusAway than the one they were actually standing at when they reported the problem. Granted, this assumes we trust the GPS location and horizontal accuracy information reported by the user’s iPhone, but for the most part, it seems that riders very infrequently look up a stop in OneBusAway by accident that is different than the one they are physically standing at. We had hoped that UI cues like stop orientation and direction of travel would help to avoid such problems, especially when two stops are right across the street from each other, and this seems to be supported by the problem report data.

It is also interesting to examine some of the quotes from riders left in the free-form comment field. Most of the comments simply add more context to the report or offer additional explanation when the “Other” problem type is selected. A few quotes are show below:

> It says every 7 mins but I’ve been waiting for nearly 20...

> It never stopped at our stop either. Just drove right past. There were 5 of us waiting.

> This bus driver is continually late and sometimes affects the 2 express behind him.

> He would better serve a local route, with his lollygagging style and tourist-y route comments.

> Bus never began route, parked empty at 15th and Madison with emergency lights on.

8.1.3 Challenges

While our crowd-sourced data error identification system has been helpful in identifying a number of common and recurring issues with incoming schedule and real-time data, as well as issues with our UI, the system is not without issues of its own.

One big problem is the sheer volume of reports. The over 6000 reports submitted over a six month period translates to roughly 30 reports a day, which can be a lot for one graduate student to process. Specifically, it has been difficult to find time to process and address each of these reports. Obviously, a large portion of these reports dealt with the real-time versus scheduled arrival time UI issue, but it is still a large volume of information to keep up with.

As part of our value sensitive design analysis, described in Chapter 6, transit agency staff were identified as key stakeholders. We specifically note a potential value tension between riders, who generally value their trust of the OneBusAway and their specific ability to identify and correct errors, and agency staff, who generally value their limited resources and who we specifically risk overwhelming with a barrage of user error reports. Other explorations of crowd-sourcing speak to this tension [110].

Another potential issue we have identified is that our problem reporting system may not be adequately addressing the rider value of accountability. Specifically, riders can currently submit a problem report but they receive no feedback about whether a problem is being addressed. As one rider asked in an email, "Where does this feedback go?"

To address these issues, we are continuing to work with transit agency staff to get a better feel for the challenges they face generally in doing their jobs and specifically in delivering transit data and responding to error reports for that data. At the same time, we are also exploring different opportunities for helping riders to submit feedback and receive updates on that feedback from transit agencies.

8.2 Other Opportunities for Crowd-Sourcing

There are larger questions surrounding crowd-sourcing in a transit traveler information system. Is it possible for user feedback from OneBusAway users to augment information about vehicle locations, broken-down vehicles, reroutes, packed buses, and other pieces of information that would often be generally useful to riders? While there are definite opportunities, we have similar concerns as others [110] about the reliability and accuracy of this data, in the face of unknowing or malicious manipulation by users. Unlike traditional crowd-sourcing applications where data from a large number of users can be used to smooth out and correct variations and errors in a task, we would be lucky to have a single reporter on a particular bus. The stakes are particularly high as well, as a faulty report about the delay, detour, or cancellation of a bus might cause riders to miss their bus when they need it most.

For the most part, the answers to these questions are largely beyond the scope of this dissertation. That said, it is useful to keep them in mind as we develop new features for the system.

Chapter 9
EVALUATING ONEBUSAWAY

There are a number of ways we can evaluate the success of OneBusAway. One approach is to simply count the number of users who actively use OneBusAway: as long as the number keeps going up, we must be doing something right. Indeed, our usage numbers are good, as described in Section 4.9. However, more targeted evaluations of OneBusAway can give us specific insights of where OneBusAway is working and where it needs improvement. There are a number of specific questions we wish to answer:

- Are OneBusAway users more satisfied with public transit?
- Do OneBusAway users spend less time waiting for the bus?
- Do OneBusAway users use public transit more frequently?
- Do OneBusAway users feel safer using public transit?
- Do OneBusAway users walk more?

There are a variety of strategies we can use in our attempt to answer these questions, with a variety of trade-offs. In this chapter, we will present the results of a large-scale survey of OneBusAway users that attempts to address some of the questions outlined above. In Chapter 10, we present the results of a controlled user study that sought to specifically evaluate how OneBusAway changes transit usage. Finally, in Chapter 11, we look in more detail at how OneBusAway affects actual and perceived wait-time and walking distances.

Beyond the questions outlined above, other questions remain. Specifically, our Value Sensitive Design stakeholder analysis from Chapter 6 suggests a number of additional targeted evaluations we might perform. For example, we could take a closer look at usability and awareness issues around our phone and SMS interfaces, focusing on low-income transit-dependent riders. While we believe these evaluations are important, they are beyond the scope of this dissertation and are left as future work.

9.1 Survey Evaluation

To date, the largest evaluation of OneBusAway was a survey in August 2009 with 488 responses. The survey, published in [28], attempt to answer the questions presented above. Overall, the results were very positive. OneBusAway users reported an overwhelming increase in their satisfaction with public transit, a reduction in time spent waiting for the bus, more trips made using public transit, an increase in the perception of safety of public transit, and increase in the amount of walking over the course of a week.

While these results are largely positive, they raise some interesting questions about our efforts to evaluate OneBusAway. There are two primary issues with the survey methodology. First, the data is all self-reported, which brings in to question the accuracy of quantitative results such as the number of trips taken using public transit, time spent waiting, and distance walked. Second, we had no large control group of non-OneBusAway users to compare against. Our recruitment methods for the survey also certainly attracted a larger number of users who liked OneBusAway, as opposed to users who were dissatisfied with the system or who had stopped using it.

Performing the longitudinal studies required to measure long-term behavior change, while more common in environmental psychology literature, are not typically the strong-suit of the HCI field [34]. However, the large user-base of OneBusAway should make these studies more practical and we discuss a number of evaluations that attempt to examine more rigorously some of the quantitative measures identified above.

9.2 Method

To evaluate the effects of using the OneBusAway system, we developed two user surveys. The full survey artifacts are available in Appendices B.1 and B.2. The first, primary survey was engineered to query users about their usage of OneBusAway and how OneBusAway had changed their overall perception of public transit, including issues of satisfaction, utility, perceived wait time, frequency of travel, safety, and other factors, through a standard online survey.

Survey participants were recruited through notices on the OneBusAway website, the OneBusAway Twitter feed, and a number of Seattle-area blogs where OneBusAway had been mentioned in the past. Our advertisements stated "Help us understand how you use OneBusAway" and as an incentive, survey participants were optionally entered in a drawing for two $25 gift certificates. Our goal was to reach regular users of OneBusAway, along with users who had tried OneBusAway before, but were not necessarily regular users. The survey was anonymous, but users were invited to email a special OneBusAway address on completion of the survey to be entered in the gift certificate drawing.

A total of 488 respondents took the survey during five days in August of 2009. We gathered basic demographic information about survey respondents, including gender, age, annual income, and number of children in household. Overall, respondents were 70% male. Age ranges of respondents included 18-24 (18%), 25-34 (55%), 35-44 (17%), 45-54 (7%) and 55 or older (3%). Annual household incomes were under $20k (8%), $20-40k (16%), $40-60k (18%), $60-80k (16%), $80-100k (18%), and over $100k (24%). A total of 13% of respondents reported having children in their households.

We can compare the demographic ranges from survey respondents with the demographics of typical transit users in the region. A 2006 survey of King County Metro riders [24] shows that our survey respondents are more predominantly male and younger, while income levels are comparable. Of riders in the 2006 survey, 46% were male, with age ranges of 16-24 (15%), 25-34 (20%), 35-44 (19%), 45-54 (23%) and 55 or older (24%); household incomes were under $25k (16%), $25-35k (7%), $35-55k (19%), $55-75k (18%), $75-100k (17%) and over $100k (24%).

Our survey sample population is likely skewed toward OneBusAway users enthusiastic enough to take a survey. Even so, it is worth noting that the 488 respondents who took the survey were nearly 10% of the daily OneBusAway user base at that time, thus providing significant coverage of our user base.

One interesting finding from the initial survey was that users reported walking more as a result. Given significant national concerns with health and obesity, and the value of walking for health, we wanted to pursue this issue in more depth. To do so, we developed a shorter second survey that asked for specific details about connections between OneBusAway and changes in walking behavior.

Of the 488 respondents from the initial survey, 193 entered the gift certificate drawing, providing us with their email contact information. We advertised the follow-up survey to those respondents. Survey participants were optionally entered in a second drawing for two more $25 gift certificates. A total of 139 respondents took the follow-up walking survey during five days in August of 2009, a response rate of 72%.

For both surveys, free-form responses were coded using a coding table for each question, which are summarized as statistics in the results section.

9.3 Results

With the exception of walking results, which are discussed later in specific detail, all results are from the first, primary survey with 488 respondents.

9.3.1 Usage of Transit and OneBusAway

We asked survey respondents how often they rode the bus on a weekly basis. The results, presented in Figure 9.1, show that the majority of respondents (more than 60%) could be classified as daily riders, making 9 or more bus trips each week. Additionally, we asked respondents for what purpose they rode the bus. Results are presented in Figure 9.2 and show that commuting to work is the most frequent response, though non-commute trips such as leisure, personal business, and shopping are frequent as well.

The survey also asked respondents which OneBusAway tools they used, if any. We show the relative percentage of total respondents for each individual interface in Figure 9.3, with the iPhone-optimized and standard web interfaces dominating the usage. We can compare the relative ratios of users of the various tools in the survey results with actual usage statistics from our server logs to assess how closely the distribution of users in the survey matches real-world-usage. The ratio of web users to phone users in the survey is 7.0 while the ratio in actual usage is 6.8. The ratio of web versus SMS for the survey is 8.4 and 9.0 in actual usage. These ratios show a reasonably close match in usage ratios between the survey and actual OneBusAway usage.

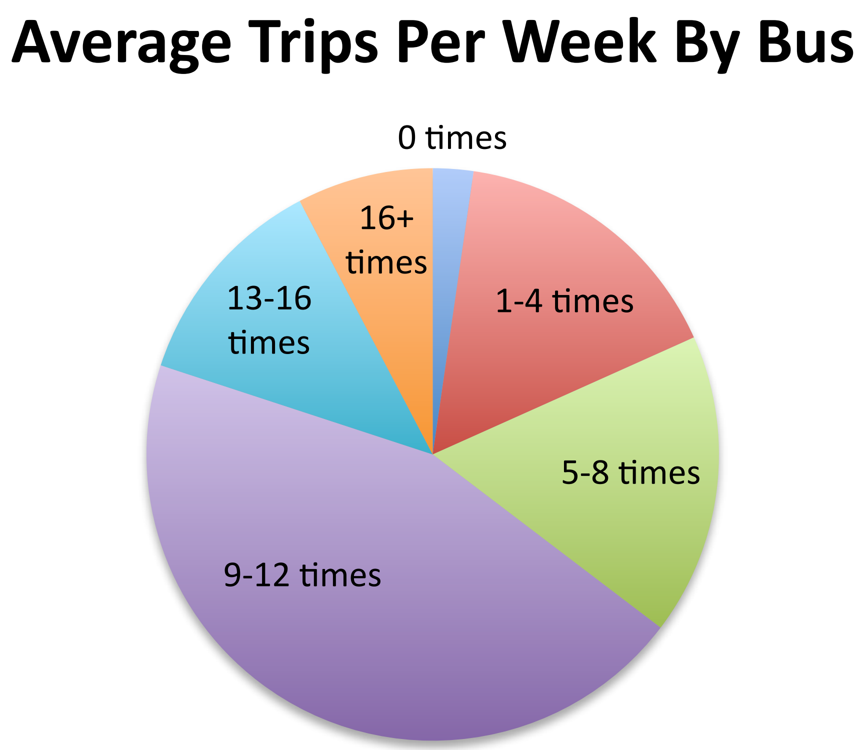

Figure 9.1: Average number of trips per week by bus from survey respondents. More than 60% of respondents could be classified as daily riders (9 or more trips a week).

9.3.2 OneBusAway and Changing Behavior

In the following subsections, we present various results describing how using OneBusAway has changed perceptions and behavior amongst riders.

Satisfaction With Public Transit

We asked survey respondents whether their overall satisfaction with public transit had changed as a result of using OneBusAway. The results, summarized in Figure 9.4, show an overwhelmingly positive change in overall satisfaction as a result of using OneBusAway, with 92% of respondents

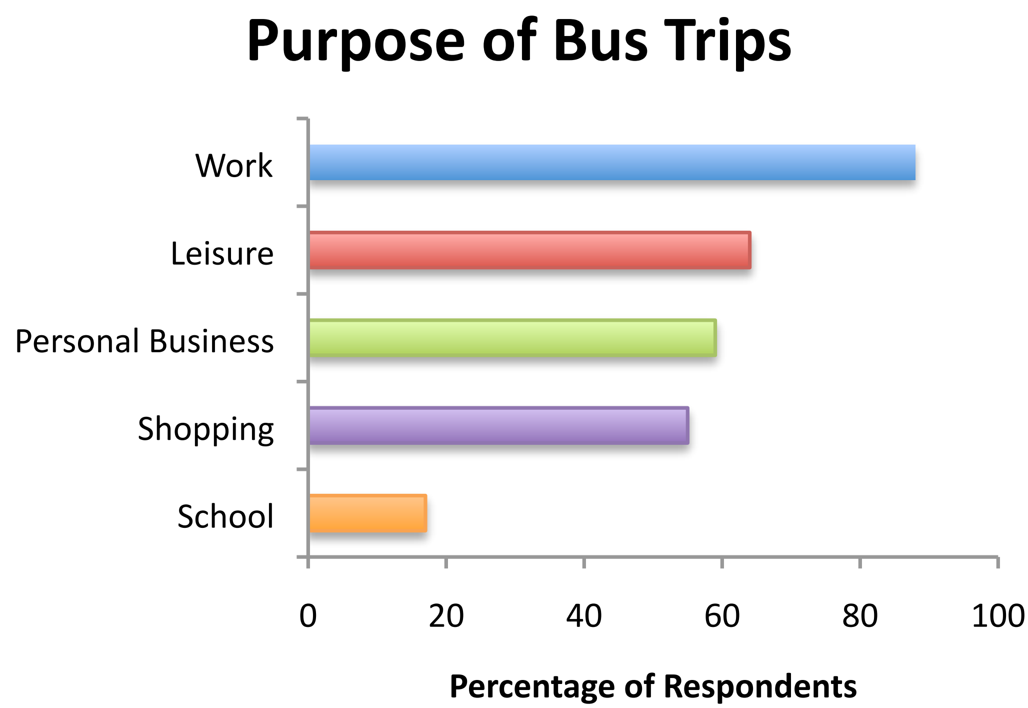

Figure 9.2: Purpose of bus trips as percentage of total respondents. Commuting to work was the most frequent response.

stating that they were either somewhat more satisfied or much more satisfied with public transit as a result of using OneBusAway. This is a remarkably strong effect from adding a relatively inexpensive technology to public transit.

To get a better picture of user satisfaction with public transit with regards to OneBusAway, we asked respondents to describe how their satisfaction had changed in a free-form comment. We had 418 responses, which fell into a small number of key categories. The most common response, mentioned by 38% of respondents, concerned how OneBusAway alleviated the uncertainty and frustration of not knowing when a bus is really going to arrive. A typical comment:

> The biggest frustration with taking busses is the inconsistency with being able to adhere

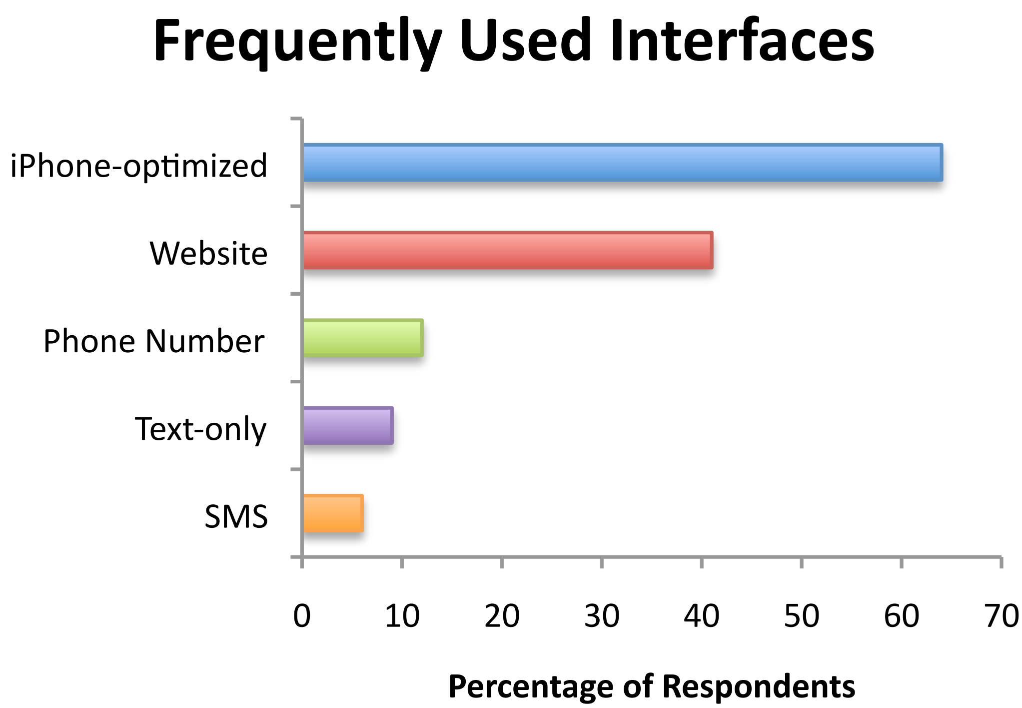

Figure 9.3: Percentage of respondents who frequently use the specified OneBusAway tool.

> to schedules because of road traffic. Onebusaway solves all of that frustration.

and

> I no longer sit with pitted stomach wondering where is the bus. It's less stressful simply knowing it's nine minutes away, or whatever the case.

The next most common response, mentioned by 35% of respondents, concerned how OneBusAway increased the ease and flexibility of planning travel using public transit, whether it be a question of which bus to take or when to catch it. A typical comment:

> I can make decisions about which bus stop to go to and which bus to catch as I have options for the trip home after work.

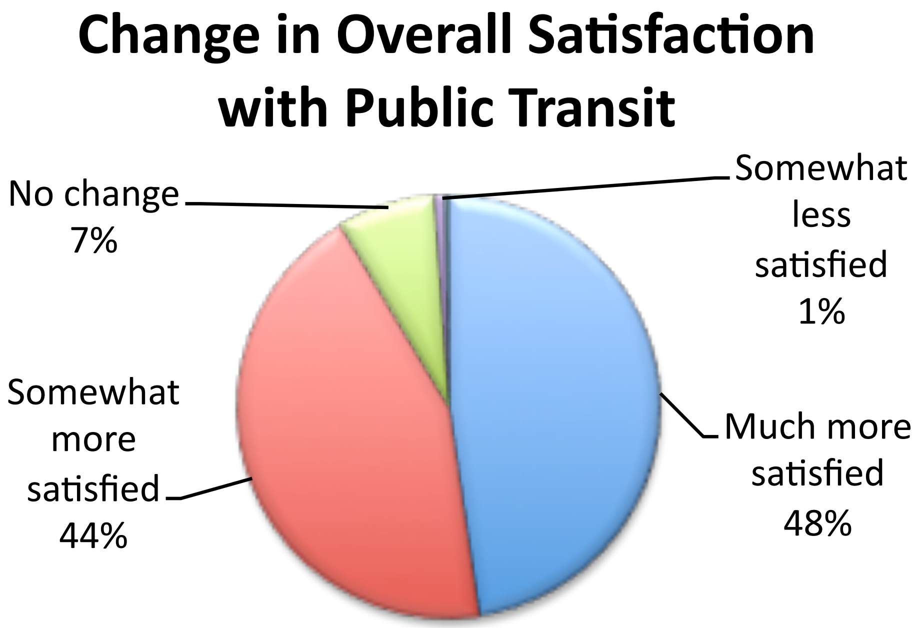

Figure 9.4: Change in overall satisfaction with public transit as a result of using OneBusAway. The change, as reported by respondents, is overwhelmingly positive.

and

> It helps plan my schedule a little better to know if I can take a little extra time or if I have to hurry faster so I don't miss my bus.

Other responses included saving time (25%) and the general convenience of OneBusAway tools (10%), especially in comparison to existing tools.

In addition to the comments describing changes in satisfaction with public transit, we also found that satisfaction was significantly negatively correlated with age among respondents ($X^2 = 24.615$, $p = 0.017$). That is to say, the younger the rider, the more increased satisfaction they have with public transit as a result of using OneBusAway.

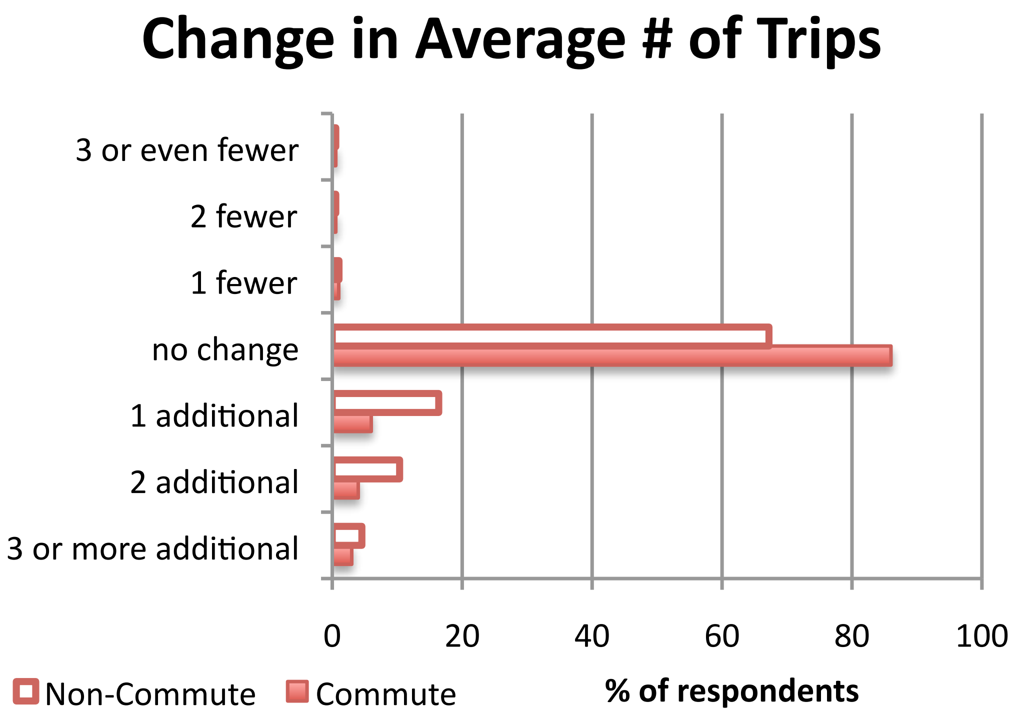

Figure 9.5: Change in the average number of trips per week among users of OneBusAway. Note the larger reported increase in non-commute (choice) trips.

Time Spent Waiting

We asked survey respondents if there had been a change in the amount of time they spent waiting for the bus as a result of using OneBusAway. Among respondents, 91% reported spending less time waiting, 8% reported no change, and less than 1% reported an increase in wait times. Regarding the relationship between satisfaction and wait time, we found that overall satisfaction with public transport is highly correlated with decreased wait time amongst survey respondents ($X^2 = 40.467$, $p < 10^{-5}$). These results are further confirmed by the user comments, noted in the previous section, that list time savings as a major reason for increases in overall satisfaction.

Number of Transit Trips Per Week

In addition to changes in satisfaction and wait time, we asked users how the average number of trips that the user takes each week has changed as result of using OneBusAway. We asked users specifically about the number of commute and non-commute trips they make. The results, presented in Figure 9.5, show an increase in the number of trips taken by OneBusAway users, with more gains in non-commute trips.

Access to Schedule Information

We also asked respondents how they typically find bus departure time information. While some 16% of respondents reported using the published schedule provided by the transit agency in either paper or online form, a full 73% of respondents indicated that they used OneBusAway to find out when the next bus will actually arrive, without consideration of the published schedule. The remaining 10% used some combination of the two, or else existing trip planning tools. This shift away from traditional static schedules has some important policy implications, presented in a later section.

Perception of Personal Safety

We asked users how their perception of personal safety had changed as result of using OneBusAway. While 79% of respondents reported no change, 18% reported feeling somewhat safer and 3% reported feeling much safer. This increase in the perception of safety when using OneBusAway is significant overall ($X^2 = 98.05$, $p < 10^{-15}$). We also found that safety was correlated with gender ($X^2 = 19.458$, $p = 0.001$), with significantly greater increases in feelings of safety for women.

We additionally asked respondents whose feeling of safety had changed to describe how in a free-form comment. Of such respondents, 60% reported spending less time waiting at the bus stop as their reason, while 25% mentioned that OneBusAway removed some of their uncertainty. Respondents specifically mentioned waiting at night (25%) or at unsavory stops (11%) as potential reasons they might feel unsafe in the first place. Respondents also described using OneBusAway to plan alternate routes (14%) or to help decide on walking to a different stop (7%) in order to increase feelings of safety.

A representative comment:

> Having the ability to know when my bus will arrive helps me decide whether or not to stay at a bus stop that I may feel a little sketchy about or move on to a different one. Or even, stay inside of a building until the bus does arrive.

and:

> Onebusaway makes riding the bus seem more accessible and safe. I can plan when to leave the house better and spend less time waiting at dark or remote stops.

These results are consistent with a 2006 King County Metro rider survey which found that 19% of riders were dissatisfied with personal safety while waiting for the bus after dark [24].

Walking to a Different Stop

We asked survey respondents how likely they are to walk to a different bus stop based on information from OneBusAway. While some 19% of respondents reported no change in their walking habits and 3% reported they were less likely to walk to a different stop, a full 78% reported they were more likely to walk to a different stop. We had not expected such a significant response regarding increased walking in the original survey, which is why we undertook the second survey to provide more detail about how and why walking habits had changed.

In the followup survey, we asked again how likely respondents are to walk to a different bus stop based on information from OneBusAway, and had an almost identical response (79% as more, 19% as no change, and 2% as less). We next asked respondents where they walk when they walk to a different bus stop. The results, shown in Figure 9.6, show that the most popular choice was to a stop on a different route, while stops further along or further ahead on the current route were picked less frequently.

We also asked respondents to classify why they walked to a different stop. Responses, shown in Figure 9.7, indicate that finding a faster route to their destination is the most popular reason. On average, OneBusAway users surveyed estimate that they walk 6.9 more blocks per week than before using OneBusAway (SD=8.2), with a median value of 5 blocks. The high standard deviation and multiple reasons given for walking suggests that our survey may capture multiple walking populations with different motivations to walk.

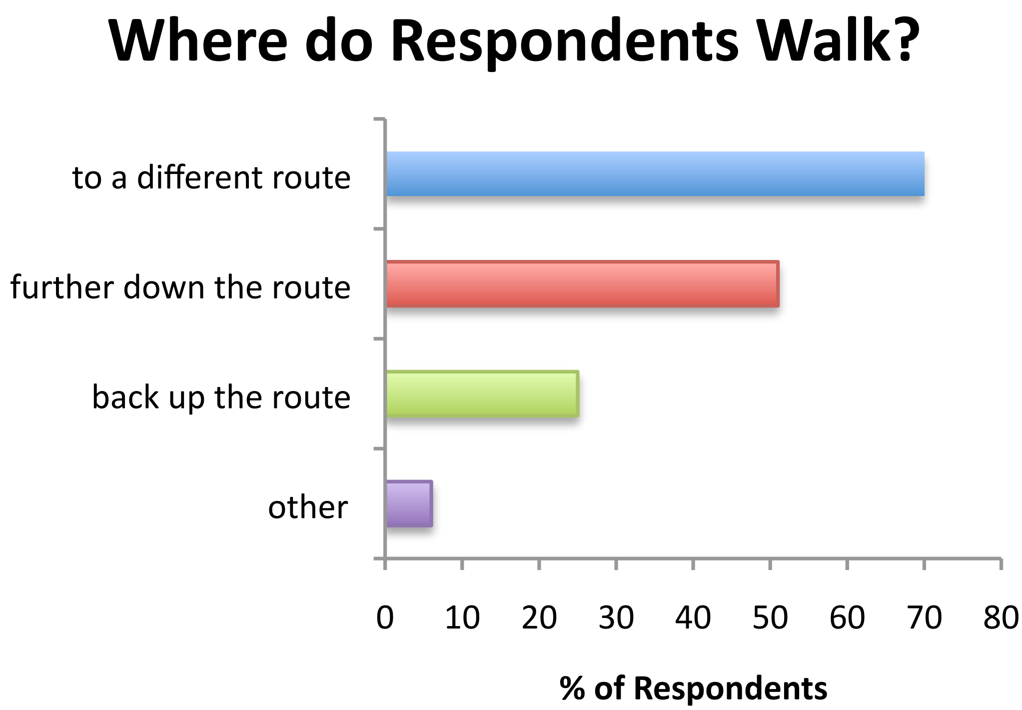

Figure 9.6: Where do respondents walk when they choose to walk to a different stop? Walking to a stop on a different route was the most frequent response.

Several respondents commented about OneBusAway not only increased their walking, but decreased the stress involved with the walk, especially the threat of being passed by the bus while in between stops. As one explained, "Before OneBusAway, I played what I like to call Metro Roulette: start walking to the next stop for exercise, and hope my bus didn't pass me by. Now, though I miss out on the adrenaline rush elicited by Metro Roulette, I can make an informed decision about whether or not to walk to the next stop..." Respondents also explained that OneBusAway lets them know the speed at which they must walk. "[It] helps me decide whether I need to run or walk to the stop."

Multiple respondents also commented about their decision to walk the entire distance to their destination based on OneBusAway information. "If I know a bus is a long time away from arriving,

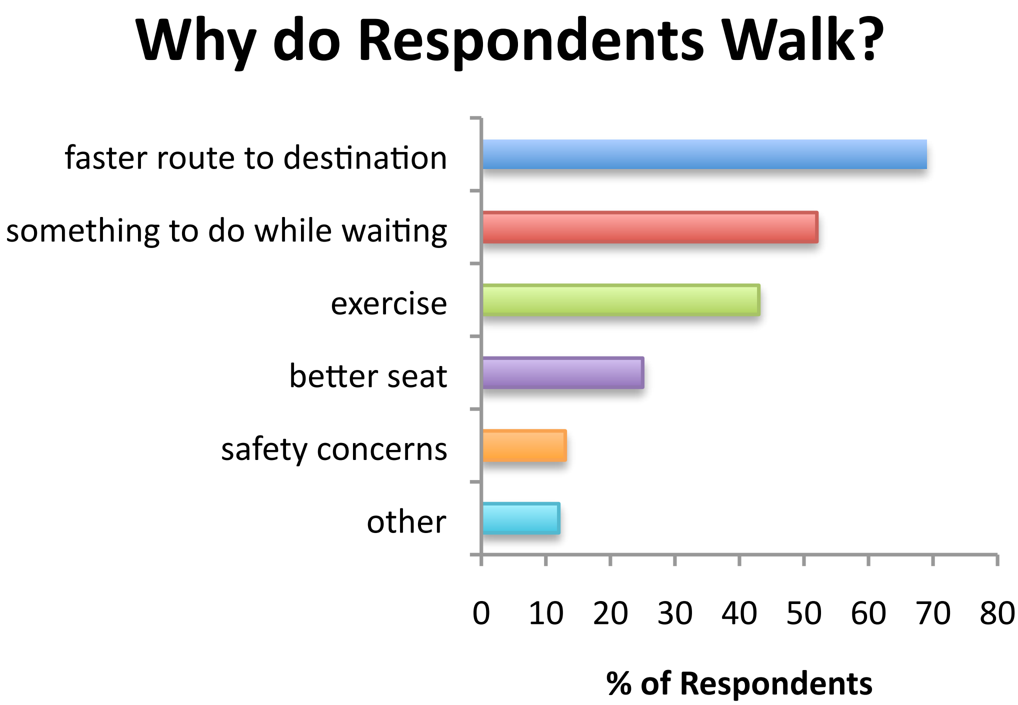

Figure 9.7: Why do respondents walk to a different stop? A faster route to their destination was the most frequent response.

I'll just walk to my destination if walking would be faster than waiting." This was particularly true in the case of transfers.

In the first survey, there were a tiny number of respondents who indicated they actually walked less due to OneBusAway than they otherwise would. This result struck us as strange initially, but we subsequently realized that users might be taking advantage of the real-time arrival information from OneBusAway to hop on a bus arriving shortly to save a trip of a few blocks that they would have otherwise walked. Some 26% of respondents in the follow up survey indicated that they do in fact take the bus for short trips for which they previously would have walked based on information from OneBusAway, but overall the balance is more walking.

Additional Feedback

The survey included an additional free-form response question asking users if they had any specific problems with OneBusAway or any suggestions for improving OneBusAway. The biggest complaint by far concerned data reliability issues (25% of respondents). Respondents noted that real-time arrival information had not been accurate at one time or another, or that schedule data for a particular stop was incorrect. Beyond data issues, users had a laundry list of usability complaints and feature requests, including requests for native apps tailored to specific mobile devices, location-aware search, real-time trip planning, better management of frequently accessed stop information, and easier search.

Location-Aware Aspects of OneBusAway

In addition to direct evaluation of the utility and usability of OneBusAway in general from the survey evaluation, we compared the relative satisfaction of users of our location-aware tool with users of existing OneBusAway tools. Specifically, the survey results from the previous sections also include 15 out of 16 users of the at-the-time beta version of our location-aware iPhone application. As such it is useful to compare their responses to some of the overall responses from the survey.

Some key findings from the survey are summarized in Figure 9.8. As mentioned in the previous sections, a significant majority of users were more satisfied with public transit as result of using existing OneBusAway tools, reported that the amount of time they spent waiting for transit was reduced as result of using existing OneBusAway tools, and were more likely to walk further as a result of using OneBusAway tools.

While the general results were quite good, the results for the location-aware tool were possibly even better:

- 90% of the users were more satisfied with public transit as result of using existing OneBusAway tools, while a full 100% of users of the location-aware tool were more satisfied.

- 90% of users found the amount of time they spent waiting for transit reduced as result of using existing OneBusAway tools, while 93% of users of the location-aware tool experienced a reduction in wait time.

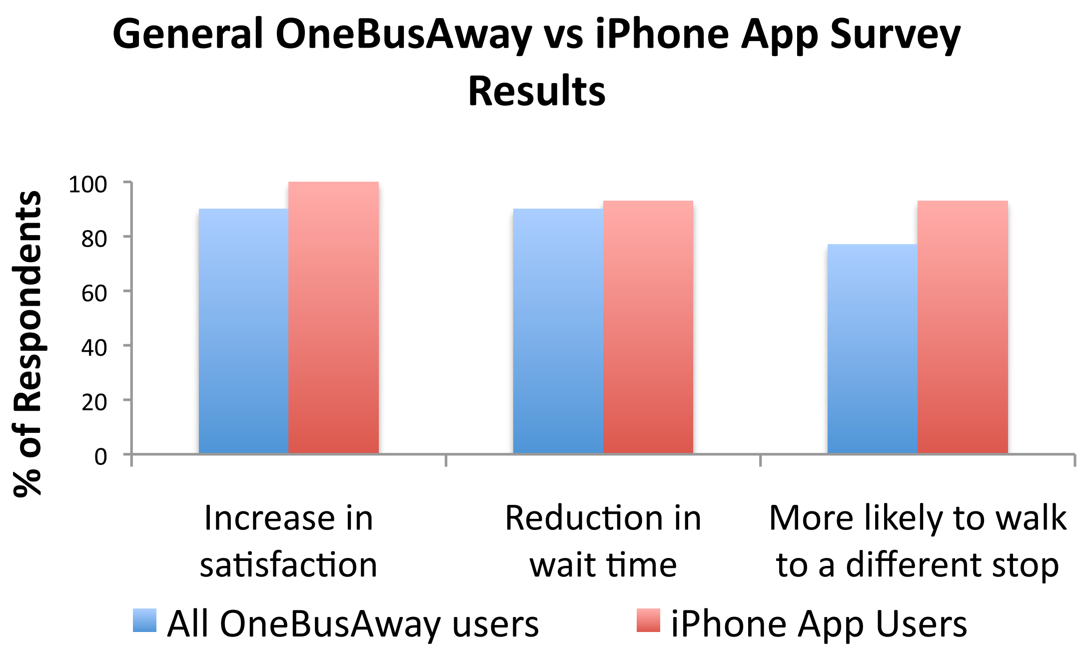

Figure 9.8: Results from a survey of 488 OneBusAway versus 15 iPhone native application users with respect to transit satisfaction, time spent waiting, and likelihood of walking to another stop.

- 77% of users were more likely to walk to a different stop based on information from existing OneBusAway tools, while 93% users of the location-aware tool were more likely to walk to a different stop.

The results suggest that the location-aware version of OneBusAway might even improve the results for satisfaction, waiting time and likelihood to walk, but at that time we did not yet have a large enough sample size for this result to be statistically significant. The potential increase in the number of users who walk to a different stop using the location-aware application is interesting, especially in light of the location-aware capabilities of the app and the potential health benefits of more walking. There is an opportunity for future work to gather data for a significantly larger number of riders through a follow-up survey now that our location-aware tool has been released and is in general use.

9.4 Discussion

Before we discuss the results from our surveys, we must note a few important caveats. First, the survey results are self-reported, which can call into question the reliability of responses and limits the potential strength of claims we can make using response data. Second, we do not have a control group of users who have not heard of or used OneBusAway or other real-time arrival information tools, which limits the strength of claims we can make regarding changes in behavior resulting from the OneBusAway tool. Despite these limitations, we believe the results from the survey, bolstered by qualitative comments from survey respondents, make a strong case for the value of systems such as OneBusAway.

Specifically, survey respondents indicated a number of positive outcomes as a result of their usage of OneBusAway: increases in overall satisfaction with public transit, decreases in wait time, increases in the average number of weekly transit trips (non-commute especially), increases in feelings of personal safety, and increases in likelihood of walking. Of these outcomes, only satisfaction and feelings of personal safety are subjective measures. The remaining outcomes concerning wait time, number of transit trips, and distance walked come with the caveat that they are self-reported statistics rather than being direct measurements of behavior.

The reduction in wait time is especially interesting in this regard. We believe this reduction is a combination of actual reductions in wait time, along with reductions in perceived wait time. Previous studies have shown that fixed real-time arrival signage induces reductions in perceived wait time for transit riders [21], and it is likely that a similar effect holds for users of our system. We performed a user study exploring this issue in more detail, outlined in Chapter 11 and covered in depth in [105]. Regardless of how much of the reduction in wait time is perceived and how much is actual, survey results show a strong correlation between reported reductions in wait time and an increase in overall satisfaction with public transit.

The increase in number of trips per week is a potentially important finding for policy makers looking to boost usage of public transit. Again, the exact increase is hard to quantify with only our survey results due to potential self-reported bias, but the larger increase in non-commute trips makes intuitive sense as riders have more flexibility in this area to make gains in weekly ridership. Comments support the notion of more non-commute trips as well: “While my work usage was pretty much on a fixed schedule, OneBusAway has made impromptu trips much more convenient," "The OneBusAway app makes me feel more comfortable with spontaneously changing trip plans," and "Better able to fit in quick purchasing trips."

Our survey results also indicated that for some of our users, feelings of personal safety play an important role in using public transit, and that OneBusAway can help address concerns in this area. Despite the improvements brought by OneBusAway, we feel there are some real opportunities for addressing this issue further in a value sensitive way [32] to provide riders with additional tools and resources. For example, information tools could help riders form ad-hoc transit social networks that could provide support and safety in uncomfortable situations.

The reported increase in walking is notable, because there are health benefits from increased walking, independent of whether the users are walking for exercise or just to get to their destinations faster. As we have noted before, the self-reported number of additional blocks walked by respondents is probably not an accurate measure of actual walking. However, quantitative and qualitative results from the survey paint a strong picture that users of OneBusAway have the additional flexibility and confidence they need to walk to a different stop when they so choose.

Beyond using OneBusAway to support more walking, people are using OneBusAway in other ways as well. One user comments:

> OBA makes [it] much *much* easier to avoid standing room only busses by letting me know there's a follow up bus right behind the current full bus.

Other users commented as well that they were using OneBusAway to decide whether it was worth getting on a crowded, standing room-only bus or if they should wait for the next bus in a few minutes that will be mostly empty. Like predicted arrival time, the number of available seats on a bus is another important piece of information which we would like to make more visible in transit systems. We have already talked with agencies about allowing drivers to note when their vehicles are full in an automated way so that riders can avoid a packed bus. This can help the transit system overall by discouraging bus bunching, the phenomena where a bus gets stuck in a vicious cycle of running late, causing it to pick up more passengers, causing it to run even later, and so forth. Often an empty bus will be just a few minutes behind.

Some design principles that have served OneBusAway well include: quick access to information when and where it is needed, service across a variety of interfaces (primarily on mobile devices), and methods for accessing arrival information when away from the actual stop. These principles are also relevant for other real-time traveler information tools.

A significant number of survey respondents reported issues arising from the reliability of the underlying data feed, pointing to an area in which design improvements are needed for both OneBusAway and other applications for this domain. The underlying real-time arrival information used by OneBusAway is definitely not 100% accurate, as tracking vehicles and predicting arrival times in dynamic urban environments with changing traffic conditions is an on-going area of work for both academic researchers and commercial vendors. Specific opportunities exist for presenting the inherent uncertainty of arrival information in an appropriate way to users, as discussed in Chapter 5, and also for leveraging the crowd to help improve the accuracy of arrival information, as discussed in Chapter 8.

Chapter 10
TRANSPORTATION CHOICES COALITION STUDY

To better evaluate how OneBusAway changes transit usage, we conducted a major field study during the summer of 2010 in partnership with Transportation Choices Coalition (TCC), a transit advocacy group located in Seattle. The study attempts to look at how a variety of intervention strategies might encourage new and choice riders to use public transit in the Rainier Valley region of Seattle. With the opening of Link Light Rail in the area in the summer of 2009, the transportation options available to residents had changed and we believed there was an opportunity to encourage increased ridership. After an initial survey and focus group evaluation, a study was designed where participants would receive a number of incentives to use public transit: a subsidized transit pass, initial training in the use of public transit, email reminders, and a rewards program with local businesses. In addition, half of the participants would be instructed in the use of OneBusAway, while the remaining participants would serve as a control group. The separation between the non-OneBusAway control and OneBusAway experimental group would hopefully allow us to more accurately measure the impact of OneBusAway on transit ridership without some of the issues of self-reported data with no control group from our previous evaluations. The program, dubbed "Seattle on the Move", was launched with 100 participants, as recruited by TCC. In this chapter, we will discuss the details of the study, the results, and their implications for OneBusAway.

10.1 Initial Survey and Focus Group Evaluation

In order to get a better feel that for the challenges that must be met in encouraging further usage of public transit in the Rainier Valley, TCC conducted a phone survey of 200 residents of the region. The survey was long, at 57 questions, and covered a wide range of topics, including current transportation usage, perceptions of public transit, and other issues.

As part of the survey, participants were asked to consider if various factors were more likely or less likely to have them consider riding transit. Factors covered a number of reasons riders typically mention as their justification for using public transit, including for example "owning a car is expensive" or "light rail doesn't get stuck in traffic". As part of the survey, we specifically asked participants to consider:

> New applications for your mobile phone can tell you when the next bus or train is coming in real time, so you never have to guess about schedules.

Some 58% of respondents said they would be more likely to use transit if such applications were available, while 32% said there would be no difference or they did not know. It is not clear why 10% of respondents said they would be less likely to take transit if such an application was available. To put these numbers in perspective, the most-postive response came for:

> Light rail doesn't get stuck in traffic. That means you get around faster than driving.

with 70% of respondents saying they would be more likely to use public transit after taking this factor into consideration. The least-positive response came for the following:

> Owning and operating a car is expensive, averaging six hundred dollars per month for insurance, maintenance, gas, and car payments, and that is without parking costs. Riding transit every day is about eighty dollars a month, a savings of five hundred dollars.

with only 55% of respondents stating that this factor would make them more likely to use public transit.

In addition to the phone survey, TCC also conducted a number of focus group sessions with residents of the Rainier Valley to go into more depth regarding there perceptions of public transit. The questions, and many of the responses, were generally similar to those in the phone survey. However, as part of the focus groups, we also created a OneBusAway introductory video that describes what the service offers and how to use it [74]. Overall, the response to the video by focus group participants was overwhelmingly positive, with many participants stating they would definitely use such a service.

We had wanted to ask survey participants about their mobile phone usage, specifically their usage of the phone versus SMS versus mobile internet. Unfortunately, the question was cut from the final survey. However, we did ask focus group participants to get a more anecdotal idea of phone usage. Of the focus group participants, all reported having a mobile phone, with 80% stating they used their phone for texting. Only 20% of the participants mentioned having mobile internet or app-phone capabilities.

10.2 Study Design

As we were working within the framework of the larger TCC Seattle on the Move program, the parameters of our study were largely determined by the resources and goals of the overall program. Specifically, 100 participants were recruited in the Rainier Valley region of Seattle. Participants were recruited primarily via community meetings, word of mouth, flyers, and through partner organizations. Recruitment focused on finding participants who were new to transit, and while there were certainly a large number of car users in the group, a number of existing transit riders were ultimately included in the study as well, as we will discuss in further detail below. The study ran for three months during the summer of 2010.

10.2.1 Incentives

As part of the program, a number of incentives were devised to get participants using public transit. First, each rider would be given an ORCA transit pass that included an introductory balance sufficient to make two round trips using public transit each week. The ORCA transit pass is a smart-card-based product from our regional transit agencies that allow for riders to pay their transit fare without cash. Secondly, each participant would be given a brief orientation on how to use the ORCA pass to pay for public transit usage. In addition, a general guide on how to use public transit in Seattle was provided on the Seattle on the Move website. Participants were also given discounts at a number of local businesses in the area if they showed their transit pass, and they received weekly emails about places they might visit using public transit. Finally, participants were asked to commit to making at least two trips per week using public transit as part of program participation.

The Seattle on the Move website showed participants a running total of how many trips they had made that week, as well as how many trips they had made total. The estimated savings in both dollars and carbon emissions of those trips was displayed as well, using basic cost-of-usage and CO_2 calculators comparing transit to car trips. The goal was to incentivize more trips by emphasizing the cost and environmental savings of taking public transit. Additionally, participants were also shown the current trip count average for the TCC study participant group as a whole, with the idea being to incentivize riders to make more trips if they were falling behind their peers.

It is worthwhile to examine these incentives within the framework of general techniques used in persuasive technology. A recent summary analysis of models and techniques used in eco-feedback programs across environmental psychology and HCI [34] highlights a variety of methods that persuasive technologies use: information / prompting, goal-setting, comparison, commitment, incentives / disincentives versus rewards / penalties, and finally feedback. It is interesting to note that many of these strategies were used in the TCC study:

- *Information and prompting* was used in the form of introductory tutorials and guides on how to use public transit along with regular emails reminding subjects to participate.

- *Goal-setting and commitments* were used by asking each rider to commit to taking at least two additional trips using public transit each week.

- *Comparison* was used when we presented participants with both their aggregate trip count and the average aggregate trip count of all participants.

- Finally, a number of *incentives* were used including the subsidized transit pass and special deals with local businesses.

10.2.2 OneBusAway and Trip Counts

A primary goal of the TCC study was to evaluate how the addition of OneBusAway changed actual transit usage in riders. While the survey evaluation discussed in Chapter 9 suggested an increase in transit trips taken as result of OneBusAway usage, the results were self-reported, calling into question their accuracy. The TCC study presented an opportunity for a more accurate evaluation.

Specifically, part of the study included the distribution of an ORCA card transit pass to each participant. The ORCA card is a contact-less smart card transit pass that keeps an electronic record of each use. By examining the card usage, we could get a much more accurate picture of transit usage than what is otherwise possible with self-report data.

For the study, the primary experiment and control groups would be those who had been exposed to and instructed in the use of OneBusAway and those who had not. By examining the ORCA card trip counts at the completion of the study, we hoped to get a more accurate picture of how OneBusAway changes transit usage over time. While it would have been desirable to have a separate experimental versus control group for each of the incentives offered in the study to evaluate their relative contribution to any measured change in transit usage, our participant pool was too small to give significant results if we subsampled the group any further. Also note that additional effort was made to make sure members of the non-OneBusAway control group were not accidentally exposed to mentions of OneBusAway at their initial orientation or during any other point in the program, as described below. Of course, we cannot isolate a participant completely, so there remains a chance that they might learn about OneBusAway through some other channel. A follow up survey at the end of the study period asked all participants about their usage of OneBusAway to identify any control group members who might have learned about the tool. Indeed, seven participants from the control group reported in the follow up survey that they had used OneBusAway.

Though the bulk of OneBusAway usage comes through our mobile apps for iPhone and Android, as well as through our website, we suspected that participants in the Seattle on the Move program would skew more towards usage of the OneBusAway phone IVR and SMS interfaces. As noted in Chapter 5, those two interfaces are tricky to use, due to the limited modality and location-aware functionality of these interfaces. To help minimize that pain, we took a number of steps to help potential users of these tools in our study. First, we made note of each participants' mobile phone number where available and automatically preconfigured the default geographic search area to be the Rainier Valley within the OneBusAway system. Second, we made the stop number at each transit stop more visible by placing a vinyl sticker at each stop in the Rainier Valley with the stop number clearly and legibly printed with a label printer. Recall that the phone IVR and SMS interfaces work best when the stop number is easily found. This task involved biking to some 800 transit stops in the Rainier Valley and applying the labels by hand! Note that OneBusAway was not itself mentioned on the stickers, as to avoid tipping off our control group and also to avoid incurring the wrath of the local transit agency. As our third and final effort, a OneBusAway introductory video was shown to participants (described below in Section 10.2.3) that highlighted the phone and SMS interfaces.

10.2.3 Study Components

All study participants were invited to a mandatory initial orientation as part of participation in the program. At the orientation, participants filled out a brief entrance survey that asked a number of questions about their current transit usage, their level of access to a mobile phone, their potential familiarity with transit tools, and basic demographic information. Once completed, participants were given a brief tutorial on the usage of their ORCA transit pass and other Seattle on the Move program resources. Finally, the participants received their ORCA card and were sent on their way.

Participants were additionally assigned to a OneBusAway or non-OneBusAway experiment group at orientation. Specifically, the first 25 participants at orientation were assigned to the non-OneBusAway control group. The next 25 were assigned to the OneBusAway experiment group. The remaining 50 participants were similarly partitioned. We chose this partitioning scheme, as opposed to randomized assignment, because each OneBusAway experimental group member was additionally asked specific survey questions about OneBusAway and shown a brief tutorial video introduction to the use of OneBusAway [74]. In order to not accidentally cross-contaminate non-OneBusAway control group members, the two groups were partitioned to make it easier to keep the two separate during orientation. Also note that the split was not exactly 50-50 in practice, but instead 48 in the OneBusAway experimental group and 52 in the non-OneBusAway control group

During the course of the study, participants were sent email reminders about discounts at local businesses for Seattle on the Move participants, emails about specific trips that could take that week using public transit, and pointers to other Seattle on the Move resources, like our online transit guide and trip counts. Additional care was taken to make sure members of the OneBusAway experimental group, who were given encouragement to try OneBusAway through emails and mentions in the transit guide, were kept separate from members of the non-OneBusAway control group, who did not receive emails and whose online transit guide automatically removed all mentions of OneBusAway when viewed.

Age	Percentage
18-25	5%
25-35	20
35-45	21
45-55	22
55-65	23
65-75	3
75-85	1
Other	5

Table 10.1: Age distribution of study participants, as a percentage of the entire group.

A follow up survey was administered at the end of the study period that attempted to assess the impact of the various study incentives. As mentioned above, all participants were asked about their usage of OneBusAway during the course of the study in order to identify any participants in the non-OneBusAway control group who had found out about OneBusAway.

10.3 Study Results

10.3.1 Summary of Participation

Overall, 55 women and 45 men were recruited for the study, with a broad representation of both age and race, as detailed in Tables 10.1 and 10.2. The age distribution includes In addition to the 100 initial recruits, we had an additional 250 participants on a waiting list for open spots. Though we met our goal of 100 participants for the program, ultimately only 93 of the participants would actually take at least one trip using public transit. There is no indication that the remaining seven participants took any part in the program after the initial recruitment, so we have excluded them from our results and analysis. Additionally, only 59 of the participants completed the post study survey. While completion of the initial survey was required for participation in the program, we did not have a similar incentive for completion of the exit survey, leading to our diminished response rate.

Race	Percentage
American Indian or Alaska Native	1%
Asian	10
African American	8
Native Hawaiian or Other Pacific Islander	1
White	67
Other	5
Not specified	8

Table 10.2: Race distribution of study participants, as a percentage of the entire group.

Though we attempted to recruit new potential transit riders, we ended up with more of a mix between existing car users and public transit users. Specifically, only 47% of our participants reported using their car to drive to work, school, or to run errands three or more times a week. By the same measure, 37% of participants reported making three or more of the same trips each week using public transit.

In terms of technology access, 86% of our participants had access to a mobile phone. Only 57% of our participants additionally made use of SMS text messaging and an even smaller 37% had an internet-enabled phone. This result seems to match our initial estimates of relatively widespread access to a mobile phone, but less access to SMS and even less access to an internet-enabled phone.

10.3.2 Trip Counts

As discussed in Section 10.3.1, these results concern the 93 participants who made at least one trip using public transit during the course of the three months study and the smaller group of 59 participants who actually completed the post-study survey.

In terms of raw trip count, some 1540 trips were taken using public transit, walking, or biking during the course of the study, with 1421 of those trips taken using public transit. The total trip count equates to an average of 14.8 trips per participant and a combined savings of almost 4 tons of CO_2 and 1,500 gallons of gas. Those are commendable numbers for the Seattle on the Move program at large, but what of the effects of OneBusAway?

Here the results are not as encouraging. Of the 93 participants who took at least one trip, 41 ended up being in the OneBusAway experimental group and 52 were in the non-OneBusAway control group. Of those groups, OneBusAway users average 15.7 trips and non-OneBusAway users average only 15.0 trips. While OneBusAway has a slight edge, the difference is not statistically significant.

Of the 59 participants who completed the exit survey, only 36 answered whether they had used OneBusAway or not during the program. Of those, 15 were in the OneBusAway group and 21 were in the non-OneBusAway group. Of these participants, OneBusAway users made an average of 18.7 trips while non-OneBusAway users made only 17.5 trips on average. Again, a slight lead for OneBusAway, but the difference is not statistically significant.

We notice our first statistically significant difference in trip counts in a place that is not too surprising. Members of our initial car-driving group (drove alone to work, school, or ran errands 3 or more times a week, N=42) made an average of 11.3 trips per week, while everyone else took 18.6 trips per week (N=49). That is a statistically significant difference (P=0.003), but we would of course expect existing car drivers to make less transit trips than everyone else, which includes existing transit users.

If we take a deeper look at participants with a high initial car usage, one differentiator on trip count seems to be trip planner usage. Participants in this group who reported regularly using a trip planner tool (N=15) took on average 18.0 transit trips during the course of the study, while those who had not (N=3) took only 4.7 trips. This is a statistically significant difference (P=0.046).

Regarding the set of participants who did not have a high initial car usage, those who used OneBusAway took an average of 18.8 transit trips during the study (N=5), while non-OneBusAway participants took only 13.3 trips (N=11). Though this difference seems again to favor OneBusAway, it is still not sufficiently significant (P=0.359). It is also worth noting that everyone in low initial car usage group reported using a trip planner during the course of the study.

10.3.3 Incentive Evaluation

Though we had no formal quantitative evaluation of how the various program incentives effected transit usage, the post-study survey asked a number of qualitative questions that would gives us some idea of the effectiveness of the various incentives.

One question asked participants to "Please let us know if you agree or disagree with the statements", where the statements were:

- The ORCA card I received motivated me take more transit trips.
- The ORCA Card I received made it easier to use transit.
- OneBusAway makes it more convenient to use transit.
- Seeing my weekly trip count, and that of other participants, motivated me to take more transit trips.
- The On the Move orientation provided me with information that helped me use the ORCA card.
- The On the Move Guide at the website helped me make more transit trips.
- Emails and updates from On the Move motivated me to take transit, walk or bike more.

As summarized in Figure 10.1 and 10.2, the results overwhelming point to the popularity of the ORCA card in both motivating more trips and making transit easier, along with the value of the initial program orientation in demonstrating the use of the ORCA card. OneBusAway also had a positive impact, with more than 37% of respondents reporting a positive impact from OneBusAway and only 3% reporting a negative impact. Of course, this result includes ALL study participants, not just OneBusAway users. When we consider the 15 post-study survey respondents who indicated they used OneBusAway during the course of the study, *all but one* indicated that they agreed that OneBusAway makes it more convenient to use transit.

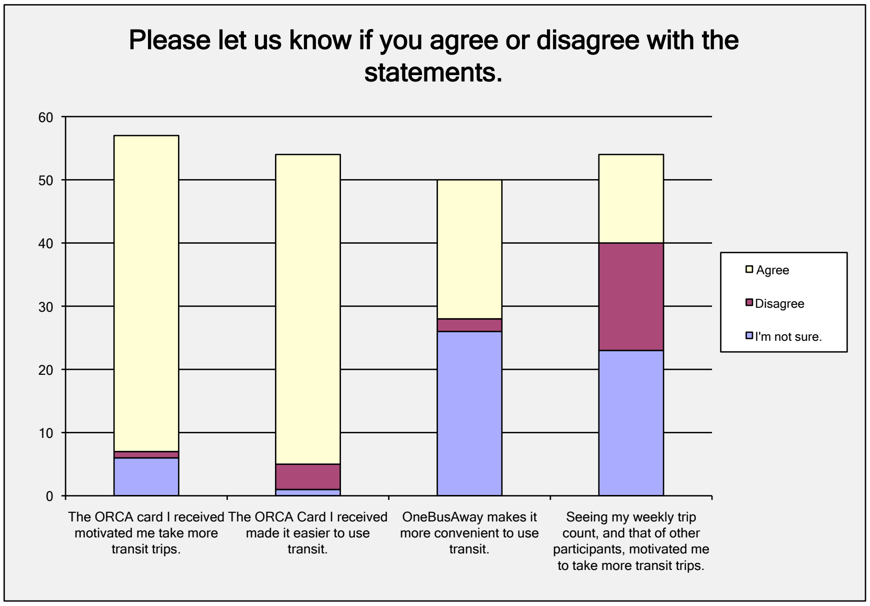

Figure 10.1: Post-study survey evaluations of the TCC program demonstrate the value of the subsidized transit pass and, to a lesser extent, OneBusAway.

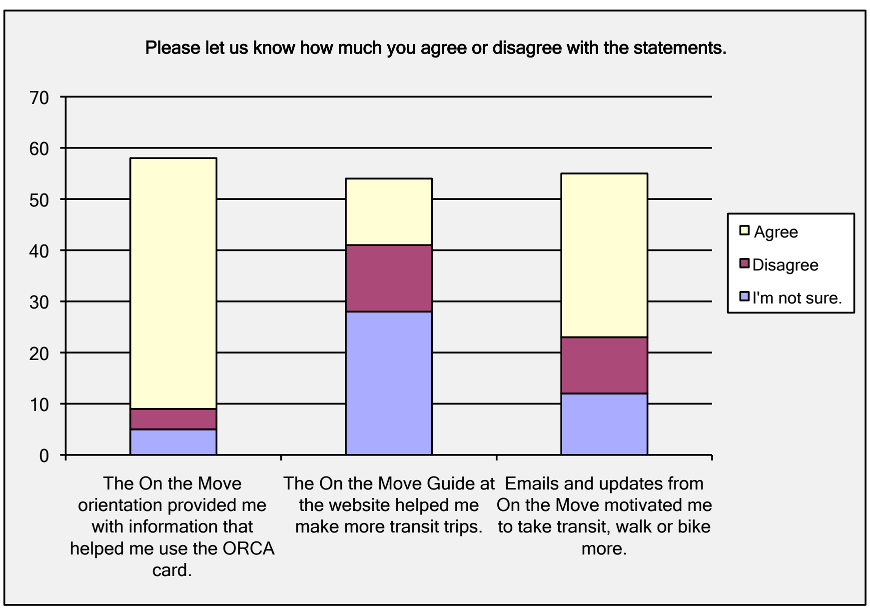

Figure 10.2: Post-study survey evaluations of the TCC program demonstrate the value of the initial program orientation and, to a lesser extent, follow-up emails.

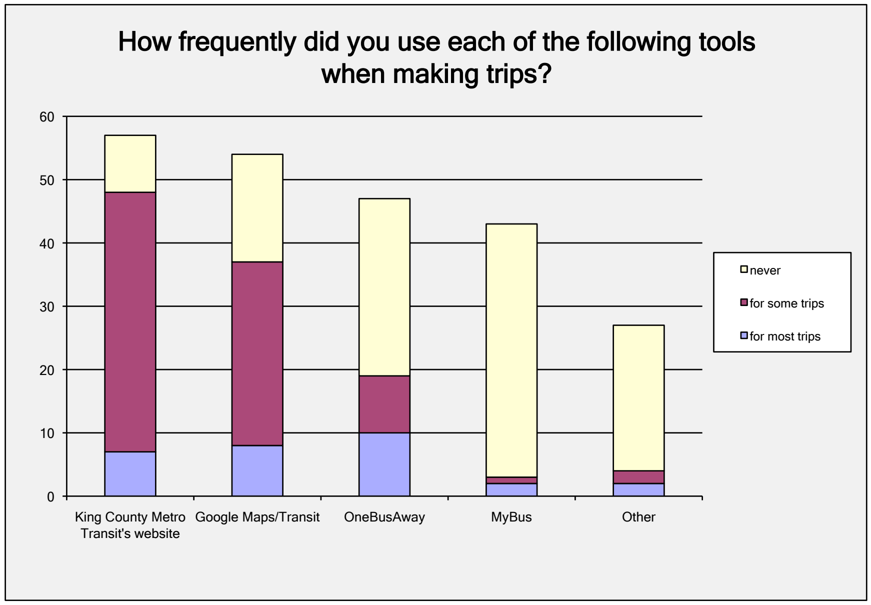

Figure 10.3: Post-study survey evaluations of the TCC program demonstrate the value of trip planning tools.

Interestingly, neither the online transit guide nor the online trip counts fared well in our evaluation. We can confirm from server logs that the Seattle on the Move website was not frequently accessed. User profile pages, which contain the active trip counts and to which the participant is automatically forwarded when they visit the site, only received 381 visits over the course of the study, where a visit is a series of hits over the course of a sesion. The transit guide page received only 216 visits and the local business rewards page only 159. Clearly, participants were not frequently visiting the site.

As we discussed in the trip counts results section, trip planning tools also seemed to play an important role for participants. As illustrated in Figure 10.3, participants were asked to rate how often they used tools like King County Metro's trip planner, Google's trip planner, OneBusAway, and other tools like the older MyBus real-time tracking tools. Participants indicated a healthy usage of trip planning tools over the course of the study, outweighing the use of OneBusAway.

In other post-study survey results, 90% of respondents indicated that they were likely to continue using their ORCA card after the study's completion. Only 24% of respondents took advantage of discounts offered at local businesses as a part of the program. Finally, respondents were asked about their feelings towards car ownership. While 17% asserted that they do not own a car and 20% said that it was not important, the remaining 63% indicated that car ownership was still somewhat or very important.

We close with a few feedback quotes from some of the study participants:

- "The program is a great idea because I would probably have driven on many of the trips for which I used transit."

- "I enjoyed the ease of the ORCA card. It did inspire me to take the train. I hope to keep that up"

- "I loved hearing about the OneBusAway bus locator program. It really helped! Thanks."

The Seattle on the Move program was clearly of value to some of the participants.

10.4 Study Discussion

All told, while the TCC study was well liked by participants, it was not a clear win for OneBusAway. Clearly, the program participants made a significant number of trips using public transit, though it remains to be seen if those gains as sustainable. The subsidized transit pass played a large role in motivating many of the trips, as indicated by the post-study survey results. It would be interesting to see what happens when the subsidy goes away. Unfortunately, we do not have access to post-study trip count data to make this evaluation. However, if the post-study survey results are to be believed, the simple act of teaching participants how to use the ORCA card seems to have had a significant effect. Given that the ORCA card has an anecdotal reputation for being confusing to use years after its launch, this result might not be too surprising.

Regarding OneBusAway, when we set out to design and implement this study, the goal was to measure concretely the change in transit usage that OneBusAway might encourage. Towards that goal, while OneBusAway users had slightly higher trip counts in a number of places throughout the study, none of the difference were statistically significant enough to say with certainty that

OneBusAway was responsible. It is hard to say if a larger overall population size or strong post-study survey response rate would have been enough to make the results more certain. However, there is potentially a story to be told in the data.

Specifically, we saw the gap between OneBusAway and non-OneBusAway usage grow amongst existing transit riders. At the same time, usage of trip planner tools amongst existing car users was shown to statistically increase the average trip counts amongst participants. It has long been a complaint against OneBusAway that our tools are geared more towards existing transit riders and are not as helpful to new riders. A big part of the problem is that OneBusAway does not have a trip planner component of its own. While real-time transit info is useful for transit riders who already know how to get where they are going, new riders need more direction about which bus or train is appropriate for getting them where they want to go. This might explain the seemingly less pronounced impact of OneBusAway on new transit riders in the study. Clearly, encouraging a mode-shift from car to public transit is difficult under the best of circumstances. That said, we can clearly be doing more to help new riders with OneBusAway tools, with the addition of a trip planning component being a high priority. We discussed these issues and more in Chapter 6.

Though our attempts to impact trip counts using OneBusAway in the TCC study were modest at best, we think the overall study technique has merit. Specifically, our success with using ORCA data to accurately measure trip counts suggests this method as a promising avenue for gathering trip counts for a wider selection of OneBusAway users. We know that ORCA records are kept for an extended period of time. Since we also know the rough date when a user started using OneBusAway, we hope to look at trip counts before and after to see how OneBusAway changes frequency of transit use. However, there are challenges. There are strict rules and regulations about how ORCA trip data can be used in order to protect the privacy rights of transit riders. We are still exploring potential solutions that maintains rider privacy while still allowing us to access aggregate trip count information.

Chapter 11
WAIT TIME AND WALKING

In Chapters 9 and 10, our evaluations showed that users of OneBusAway were more satisfied with public transit, used public transit more frequently, and even felt safer when using public transit. We also found indications that users of OneBusAway spent less time waiting for public transit and walked more as result of our tools, but we only had self-report evidence to support these claims. In this chapter, we discuss work that we have undertaken to address these two claims in a more quantitative fashion by observing and measuring these effects directly.

11.1 Wait Time

In a controlled experiment, my colleague Kari and I set out to measure two aspects of waiting for public transit: actual wait times and perceived wait times. Public transit research has shown in the past that the amount of time that riders actually spend waiting for a bus or train is often shorter than the time riders *perceived* they have waited. Research has also shown that fixed real-time arrival signage can bring the actual and perceived wait times closer together [21]. We hope to show that the same effect holds for mobile tools like OneBusAway. We also hypothesize that riders who use OneBusAway will spend less actual time waiting for public transit than riders who do not.

To evaluate these hypotheses, we constructed an experiment to measure both the difference between perceived wait time and actual wait time, along with the relative difference in actual wait times, for regular riders and users of OneBusAway. I will give a general overview of the study here, while the full details of the study are described in [105]. We constructed the study by picking a number of stops located near and around the University of Washington campus. At each stop, we deployed two study examiners, each with a specific task. The first examiner was based at the stop itself. The examiner's task was to periodically survey individual riders waiting at the stop, asking the following series of questions:

- How long have you been waiting for the bus?

- Did you use some form of real-time information to time your arrival at the stop today?
- Which route are you waiting for?

The second examiner positioned him or her self near the transit stop where they would have an unobstructed view of people arriving at and departing from the stop. The examiner's task was to record the time at which each rider arrived at the stop, the time at which the rider departed on a bus, and additional notes about distinguishing features of each rider. These additional notes would help the second examiner keep track of all riders waiting at the stop, such that when the first examiner interviewed one of the waiting riders, the rider could be matched to the data collected by the second examiner.

In this way, we collected four key data-points for the riders:

- How long had they actually been waiting for the bus?
- How long had they perceived to have been waiting for the bus?
- Had they used OneBusAway or some other source of real-time information?
- How long did they wait at the stop in total before their departure?

Care was taken when surveying the rider about their perceived wait time. Many riders were tempted to immediately check their watch when we asked them how long they had been waiting, which we quickly asked them to avoid. Riders also had a habit of rounding to “5 mins” or “10 minutes”, so we made a point of asking them specifically, to the minute, how long they thought they had been waiting. We also made a point of asking riders who had been standing at the stop for five or more minutes. This evaluation might have made it tricky to catch riders who may be using OneBusAway to reduce their wait times to a very short interval.

With this data, it was now possible to test our hypothesis comparing actual and perceived wait time, along with the effect of real-time information from OneBusAway on that perception. Additionally, we could compare total wait time between riders who had used or not used OneBusAway for their trip.

In total, 655 usable rider surveys were completed. Of those, 111 were from riders who had used some form of real-time information to plan their trip, including OneBusAway. For riders who arrived at the bus stop having used traditional methods, such as a schedule, map, trip planner or other static informations sources or simply showing up at the stop, our results show that the perceived wait times and measured wait times for these riders is not the same. On average, these riders perceive that they are waiting 0.83 minutes (15%) longer than they actually are. For riders using real-time information from OneBusAway, the hypothesis that the perceived wait time is equal to the measured wait time cannot be rejected. The measured difference of 0.32 minutes (6.7%) between perceived and measured wait time is not significant (P=0.1884). Additionally, riders using real-time information say that their average wait time is 7.54 minutes versus 9.86 minutes for those using traditional bus arrival information, a statistically significant difference of 31% (P=0.000). For further details on these results and the corresponding analysis, see [105].

We have demonstrated that OneBusAway does indeed reduce wait times, both perceived and actual, for OneBusAway users. Additionally, we have shown that OneBusAway users spend less time waiting for the bus overall.

11.2 Walking

Just as we have done for wait times, we wish to further explore the result from Chapter 9 indicating that OneBusAway users had reported walking more as result of using the tool. Towards that end, I developed a data collection application that runs on Android phones to collect location, motion, and transit data over the course of the day. Using that data, we can perform activity inference to extract transportation mode information. From these activity traces, we hoped to identify distance walked, time spent waiting for transit, and other measures. Our goal was to deploy the activity data collection application to a large set of users to evaluate how OneBusAway changes their walking behavior. In the following sections, I describe the data collection application, the activity inference component, and the proposed evaluation.

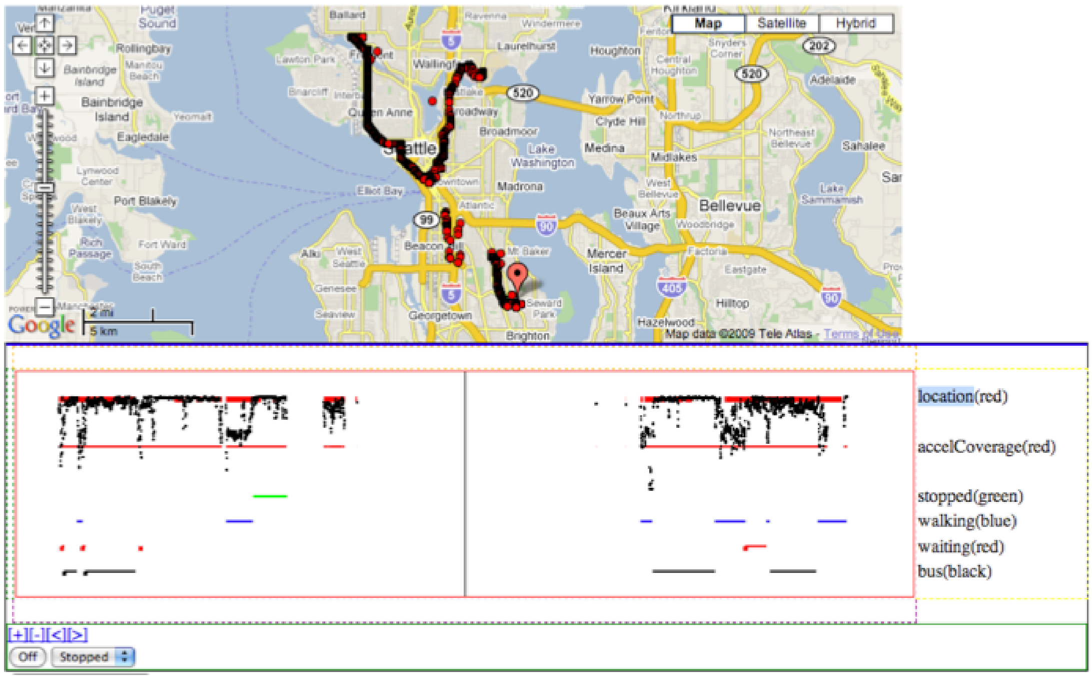

Figure 11.1: Data collection visualization showing collected location and motion data, along with activity annotation data, over the course of a day.

11.2.1 Data Collection

I developed an Android application to collect raw activity data for a user carrying the phone, in the form of motion data from the accelerometer, location data from the GPS sensor, augmented with WiFi and cell-tower localization, and finally, real-time information about buses currently in transit near the user's location. The application runs as a background service on the phone so that it can unobtrusively record data as the user carries the phone from place to place. The application also includes an activity annotation feature for the user to periodically label their current activity, such as "walking", "waiting", or "on a bus". The annotation feature is used to collect ground truth label data for training the activity inference algorithms described in the next section. The periodic annotations collected by a user do not sufficiently label all the trace data, so we use a data annotation interface to go back and apply complete activity labels to the entire trace. Figure 11.1 demonstrates the data visualization and annotation interface, showing data for a full day, including location data, motion data, and full activity labels.

A naive approach to collecting location data using the GPS sensor on the phone would be to simply keep GPS on all the time, but this quickly drains the battery on the phone. Instead, I keep the GPS off by default and use a simple accelerometer-based motion detector to detect sustained periods of motion. If more than six consecutive seconds of motion are detected, we turn on the GPS sensor and keep it on until the GPS detects that the user has not moved more than 20 meters in the last minute. This approach keeps the GPS sensor off for the bulk of the day when a user is just sitting at their desk at work or sitting at home, even ignoring some minor fidgeting by the user. However, when the user starts to walk some place, the sustained motion detector will trigger the GPS, which will remain on until we have detected that the user has stopped moving.

In practice, this technique captures the majority of typical transportation usage scenarios, where a user typically starts by walking to their car or to the bus. It is also efficient enough to keep the data collection program running all day without completely killing the battery. In practice, this method will have false positives, such as when a user gets up to go to the bathroom with the phone in their pocket, and also true negatives, such as a user stuck in particularly bad traffic.

As an implementation note, the real-time motion classifier is implemented using a single binary decision stump with accelerometer variance as the input feature to detect movement. Accelerometer variance is computed over a one-second window. Instead of storing raw accelerometer values in the data trace, we actually store the output of this simple motion classifier instead.

11.2.2 Activity Inference

The goal of our activity inference system is to take the raw, unlabeled sensor data from the phone, as described in the previous section, and generate a complete activity labeling for the data trace. Here, activity labels include “walking”, “waiting”, “in a car”, and “on a bus”, along with details about which particular bus was used and the departure and arrival stops. These high-level activity labels will allow us to compute summary statistics about distance walked and time spent waiting for a bus, which will be useful for quantitative evaluations of OneBusAway.

Since we are just using our inference algorithm for computing summary statistics, we do not need to run the algorithm in real-time as the data is collected. Instead, we can run it offline after a data trace has been completed, running inference on the entire trace at once. The inference algorithm runs in two phases.

In the first phase, a low-level motion classifier attempts to classify segments of the activity trace into one of three motion classes: “stopped”, “walking”, and “vehicle”. Specifically, motion features, such as average velocity and accelerometer variance, are computed from raw location and accelerometer motion readings on a 10-second interval. A simple LogitBoost classifier is used to classify each interval.

The results of the classifier are a bit noisy, especially around transition points from one motion state to another. For our train-and-test evaluation corpus of over of 12-hours of trace data collected and annotated for a single user, the low-level motion classifier was 86% accurate in identifying the correct motion class for a particular interval. If we examine the places where the classifier showed confusion, the bulk of the errors occurred around motion state transition points, such as the transition from waiting for a bus (“stopped”) to riding the bus (“vehicle”). These transition points are difficult to accurately annotate as to where one state stopped and another started even for a trained human annotator, so some confusion is to be expected here.

An important property of the low-level motion classifier is that while the transition points might be noisy, it very rarely fails to miss a transition completely. For example, the classifier might be inexact in finding the transition from waiting at a bus stop to riding the bus, or it might insert some spurious regions of “walking” or “stopped” for a bus ride that is moving particularly slow. However, it will not often fail to find the transition between two different vehicle segments, even if they are only separated by a brief period of motion. This property of not missing low-level motion transition points is one we will take advantage of in the next phase of the inference system.

In the second phase of the inference system, a high-level motion classifier attempts to refine the low-level motion types inferred in the first phase and to further distinguish between different vehicle types for the low-level “vehicle” state as either “car”, “bike”, or “bus”. In the case of “bus”, we also reason about which specific vehicle the rider was on. We use a Conditional Random Field (CRF) to perform the inference.

To construct the CRF, we first merge contiguous motion state segments from the first phase. Specifically, we merge consecutive 10-second segments of trace data if their inferred motion states are the same. This merge step produces a series of intervals of trace data where each interval has the same inferred low-level motion state. Coming back to our previous discussion about the properties of our low-level motion classifier, the inferred intervals generally match the actual intervals in the ground-truth labeling, except for small regions of incorrect intervals that can be introduced at points where the inference is uncertain, such as near transition points. What is critical is that intervals are not often missed completely.

We will treat the high-level motion state of each of these larger intervals as the hidden state in our CRF. The CRF will have the power to reassign the motion state of a particular interval, which will allow it to clean up spurious intervals introduced in the low-level inference. However, while the CRF can "join" intervals by reassigning the motion state of consecutive intervals, it cannot "split" an individual interval into smaller intervals, which is why it is critical that the underlying low-level motion state classifier favor finding too many intervals as opposed to too few. This over-segmented interval approach will allow us to compute aggregate features over intervals, which can number from 10-20 for a typical trace, that would not be possible if we attempted to reason directly about the motion state of the hundreds of individual small segments that we considered in the first phase.

We use the following features in the CRF:

- **Low-Level Motion Classifier** - We use the average weighted output of the low-level motion state classifier for a particular trace interval as a feature. When the low-level classifier is less certain, the CRF will have the ability to reassign motion state based on other features.

- **Nearby Bus** - The data collection program periodically stores information about buses actively in transit near the user's current location at the time the trace was collected, as pulled from OneBusAway. If a particular bus is, on average, near a user for most of a trace interval, there is a good chance the user might be riding that bus.

- **Board Near a Stop** - Transitions to and from a bus are likely to occur near a physical bus stop.

- **Bus Transitions** - It is unlikely that a user will be on a particular bus, then temporarily exit the bus for a short period of walking or waiting, only to re-board the bus again. This feature will help eliminate spurious walking or waiting intervals introduced in the middle of bus rides.

CRF parameter learning and inference are done in the standard way: conditional pseudo-log-likelihood gradient optimization and loopy belief propagation, respectively.

11.2.3 Evaluation

While I have implemented, trained, and tested the inference system described above using hand-labeled training data collected for my own travels throughout the city, the system clearly needs training and test data for a large set of users if it is to be evaluated in a serious way. Towards that goal, we intended to deploy our data collection application during the TCC study described in Chapter 10. Specifically, we had 20 Android phones donated from Google, along with subsidized calling and data plans for the phones, that we could give to participants to use during the study.

Unfortunately, we were only able to convince 5 participants to carry the phone for the duration of the study, with only a few of the participants collecting a usable amount of data. While that is data that we can use to further refine the inference system, it is not enough to make any hard claims about the system or about users of OneBusAway regarding their walking patterns.

We have explored the possibility of including our data collection functionality in the OneBus-Away Android application in order to open up data collection to a wider population. The challenge here is that we do not have a control group to compare against. One option is to start the study with riders when they first install the OneBusAway application and see how their behavior changes over time, the idea being that their regular transit habits likely would not change immediately with the introduction of OneBusAway, but might induce a more gradual change over time. These potential studies are left as future work beyond the scope of this dissertation.

Chapter 12

CONCLUSION

I have presented my dissertation on the value of real-time transit traveler information systems, demonstrating a number of widely deployed tools and evaluations of those tools that show their utility. Specifically, I have described the OneBusAway system, which provides real-time riders tools across a variety of devices and interfaces. I have also presented a principled prioritization scheme for helping to decide which features to implement next for OneBusAway in a value-sensitive way. I have demonstrated a real-time mobile trip planning tool and also a method for crowd-sourcing the detection of errors in public transit data. Finally, I have presented evaluations that show OneBusAway improves satisfaction with public transit, reduces wait times, increases transit usage, encourages walking, and improves perception of safety among riders.

All told, the OneBusAway system is having a meaningful impact on more than 50,000 public transit riders each week, as of this writing (Summer 2011). We now present a number of policy implications that a system like OneBusAway raises for transit agencies, developers, and riders moving forward. As I move forward myself, I look forward to continuing to work to improve the public transit experience for riders the world over.

12.1 Policy Implications

Real-time arrival information using fixed signage is relatively accepted as a means to increase ridership by reducing rider anxiety, increasing the perception of reliability and presenting an image of a modern transit system [83]. I have shown that many of these aspects hold for OneBusAway as well, in addition to other positive outcomes. This demonstrates that providing real-time arrival information on mobile platforms is a worthwhile investment for transit agencies, because the benefits to riders and the agency can far outweigh the costs. These results raise a number of interesting policy questions and implications for agencies, developers, and riders moving forward.

12.1.1 Headway-based Service

Public transit service can be scheduled in two different ways. The most common is a fixed schedule, where the agency sets a specific time when a particular bus will be at a particular stop. Another method is headway-based service, where the agency simply states that a bus will serve the stop approximately every N minutes. In the transit service planning industry, 10 minutes has long been considered the barrier between schedule-based and headway-based service. A recent study found that at 11 minutes, passengers begin to coordinate their arrivals rather than arriving randomly [83]. This is consistent with earlier studies documenting random versus coordinated arrivals. Therefore, at a time between buses greater than 10 minutes, passengers want a schedule to coordinate their arrival times. However, as described in Section 9.3.2, with the introduction of real time information such as OneBusAway, we have shown that users more frequently refer to real time information than to schedules to determine when to wait at the bus stop, with 73% of OneBusAway users no longer using static schedule data at all. This is important for transit service operations because a significant amount of time is lost in attempting to maintain reliability for scheduled service — planners must build a certain amount of slack time into the schedule. One study found the slack ratio to be 25% in Los Angeles [26]. With headway-based service, supervisors use real time transit data to maintain a certain amount of time between buses, rather than attempting to maintain a schedule, thereby allowing more efficient deployment and saving slack time [112]. This savings in running time can reduce agency costs to provide the same level of service on a transit route.

Tools like OneBusAway can help here. By providing riders with tools to see the real-time arrival information for transit vehicles, agencies could switch to headway-based service with a less-frequent service interval, perhaps at 15 minute headways instead of 10. The agency would enjoy additional scheduling efficiencies from headway-based service, while riders would have the information necessary to coordinate their arrivals. Care must be taken, however, in that not all rider populations are served by tools like OneBusAway, and their needs must be balanced in such service changes.

12.1.2 Fixed Real-Time Signage versus Mobile Tools

In addition, the investment in website and phone-based real time transit information can also save an agency substantially in other deployment costs. As an example, Portland deployed their Transit

Tracker program in 2001 with information displays at transit stops, a webpage and more recently a phone system. The transit tracker signs at light rail stations and 13 bus stops in Portland cost $950,000 including message signs and conduit. The cost for computer servers and web page development was much cheaper at $125,000 [13]. Given the widespread availability of mobile phones and web access, providing real time transit information via a service such as OneBusAway could yield a substantial savings and more complete stop coverage for an agency over constructing real-time arrival display signs at even a few stops. More importantly, mobile tools can help riders make decisions about public transit where they need it most: before they have to walk out to the transit stop. With fixed signage, the rider has already committed to walking out to the transit stop by the time they receive information critical to route decision making. We recognize that there are access issues in moving away from fixed-signage to mobile-phone-based solutions, but as mobile phones become near ubiquitous, we believe there are reasonable options for helping riders who might not otherwise have access to a mobile phone. For example, programs exist to provide cell-phones with free SMS to low-income citizens. Innovative solutions for deploying low-cost real-time arrivals displays in coffee shops and other more convenient locations can also help address the cost and inconvenience of fixed-signage at the stop.

12.1.3 Other Barriers to Real-Time

We have shown in a number of ways how real-time public transit information can have a positive impact on riders, but there are a number of barriers keeping transit agencies from more widely deploying real-time tools. What is the hold up? There are two big issues at play: cost and standards.

12.1.4 Paying for Real-Time Systems

The first big issue is that real-time systems are not cheap. While developers can whip up some amazing software systems from little more than some open-source libraries and a few caffeine-fueled nights at the keyboard, public transit automatic vehicle location (AVL) deployments require physical GPS hardware and radio infrastructure that is not free. There have been some innovative projects working to provide an open-source AVL stack that helps reduce the cost to the agency. See, for example, `http://bustime.mta.info/`, a real-time transit vehicle tracker currently used as part of a single-route pilot for the B63 in Brooklyn by NYC MTA. The system, which I helped engineer, is open-source and aims to provide extremely low-cost vehicle tracking. However, even with innovations like the OneBusAway and BusTime projects, these systems still cost real money.

When budgets are beyond tight at many agencies, what can we do as a community? Step one is helping agencies make the business case for real-time. The more we can do to help convince transit agencies that real-time can be a cost-effective way of dramatically improving the public transit experience for riders, the better. This thesis is a step in that direction, but there is more that can be done. Specifically, our research has suggested that while real-time transit tools might increase the overall satisfaction with riders and reduce their wait times, the impact on increased ridership is less-pronounced. While one would like to think that rider satisfaction is an important metric for agencies, ultimately ridership numbers drive a lot of transit funding.

One possible way to help convince transit agencies, along with the other state and federal agencies that often control transit funding purse strings, is to make an economic argument around the value of public transit. Specifically, we have demonstrated that tools like OneBusAway can lead to a reduction in wait-times for riders. That saved time, when multiplied by thousands of riders and service days, adds up to significant time savings in aggregate, which has a real economic value. We justify investment in public transit systems by talking about the savings in congestion costs, fuel costs, and reduced commuting costs. Why not include the savings from reduced wait times in those calculations as well?

What about agencies that are convinced of the value of real-time transit information, but just do not have the resources to deploy a traditional AVL system? We have discussed a few of options in the crowd-sourcing space in Chapter 8 that may prove to be reasonable alternatives to a traditional AVL deployment.

12.1.5 Real-Time Data Standards

The second big issue is that there is no *de-facto* standard for real-time transit information. Google deserves a lot of credit for establishing GTFS, which has driven the availability of schedule data in a standard form and the hundreds of interesting applications and tools that this schedule data has enabled. We are seeing a lot of similar innovation in the real-time application space, but the lack of an open, widely used data standard for exchanging real-time information has usually tied a particular application to a particular transit agency or geographic region. A real-time data standard could really break this open. But what should a real-time standard look like? Who should it target?

I would argue that in the open transit data space, there are two classes of consumers of real-time transit data: direct consumers and aggregators. By direct consumers, we typically mean basic mobile apps that make a direct call to a transit agency's real-time transit data source, typically a simple web API call about a specific stop, and display that info directly in the app. Think simple iPhone apps in this space. Contrast this with the aggregators, the name I use for the class of applications that consume real-time and schedule data from potentially multiple agencies and integrate it into a new form that has more capabilities than what is provided in the raw data from any one agency. Think users like Google, HopStop, and OneBusAway itself in this space. I think the real-time data standards that would be designed for these two classes of consumers would look very different.

It helps to contrast the API needs of these two groups. Direct consumers are going to be looking for a high-level API that wraps up all the information they need into a few structured API calls that remove the burden of data processing from the client. In contrast, aggregators are going to be looking for a low-level API that provides closer access to the underlying data with methods that favor efficiency over convenience. As an example, a direct consumer API might provide information about a particular stop including all real-time arrivals and service alerts, while an aggregator API would provide low-level access to the real-time location of all transit vehicles and a stream of service alerts as they occur. The consumer API might favor request-response, while an aggregator API might also provide publish-subscribe. We can see the distinction between these two APIs within OneBusAway itself. The REST API we use to power our mobile apps, as described in Section 4.5, is an example of the first API while the raw real-time data streams we receive from agencies are an example of the second. We can keep outlining differences, but the good news is that we actually have good starting points for both styles of API already. Let us talk about an aggregator API first.

What many developers and agencies do not realize is that standards for real-time information already exist. The SIRI standard (`http://siri.org.uk`) is already being used by a number of transit agencies in Europe, and increasingly here in the States as well as discussed in Section 4.8, to exchange real-time transit operations data, including real-time vehicle locations, service alerts, and schedule updates. I think the SIRI standard is a good starting point in that it is an open standard, it covers many of the features we would look for in a real-time feed for aggregators, and it is actually being used by agencies. Like any standard, there are certainly rough spots, and while I think we need to understand more about the governance of the standard before moving forward, I think SIRI is a good place to start the discussion.

It is worth briefly mentioning APTA's TCIP standard. Though TCIP is similar in spirit to SIRI, TCIP has little in the way of actual adoption as far as I can tell. While I hear occasional rumblings that APTA wants to put more resources into TCIP, I think these resources might be better spent helping agencies work with a standard that has a bit more traction, like SIRI. Add into this space the various vendor-specific protocols and data export capabilities already available in vendor AVL systems that might serve as the basis for a standard. Should we be creating an additional real-time standard in this space? I am inclined to reuse what already exists as opposed to creating a new standard, not-invented-here syndrome aside.

What about direct consumer applications? While I think applications built by aggregators are going to provide the majority of coverage in the transit app space, I think the direct consumer APIs are still important because they are more accessible to developers who wish to tinker with data and they allow an agency to quickly get an app up and running with their new real-time data. The direct consumer API space is a bit trickier, however, because there is no existing standard that is an obvious choice to build from. A number of agencies provide web-based REST-ish APIs that are similar in spirit but we are not to the point where a user can swap a URL in an iPhone app to start accessing data for their agency. There are other complications when it comes to handling multiple agencies with interleaved data but no interleaved API. That said, I think we should still define an API that will be useful to the community in this space and there are active discussions taking place to make that happen.

12.1.6 Open Transit Data

In the discussion above about transit data standards, one point should be clear: sharing open transit data in ANY format is a win for agencies and riders. OneBusAway is just one example in a growing list of innovative transit applications running on a variety of mobile platforms, made possible by forward-thinking transit agencies that have made their routes, schedules, and real-time arrival information available via public APIs. For these reasons, we encourage other transit agencies to include real-time arrival information in their transit systems and to publish this data, along with static schedule data, through public APIs so applications like OneBusAway can help make public transit work better for the riders who use it every day.

12.2 Acknowledgements

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A big thanks goes out to all of the users of OneBusAway for providing valuable feedback and suggestions, both in our formal surveys and in many other forums. They are the reason I do this work.

A special thanks goes to my colleague on the OneBusAway project, Kari Watkins. Kari has been a great partner on the project and I think our work has shown that the whole of our efforts has been greater than the sum of the parts.

Finally, thanks to my wife, Amy, who has been there for me on both my best days and my worst. More than anything, she puts up with having to ride the bus everywhere with me. What more could you ask?

Appendix A
VALUE SENSITIVE DESIGN ANALYSIS APPENDICES

A.1 Stakeholder Table

Conceptual analysis of direct and indirect stakeholders, along with relevant values, and benefits and harms of potential technological systems.

	Benefits	Harms	Values
riders			
"typical" rider?	Decision support		Efficiency
age:			
children	Decision support	Privacy invasion by nosy parents, parents may blame OBA if something goes wrong	Efficiency, Safety, Privacy, Accountability
teens	Decision support	Privacy invasion by nosy parents, parents may blame OBA if something goes wrong	Efficiency, Privacy, Accountability
parents with children	Decision support, extra confidence and control		Efficiency, Privacy
older riders / elderly	Decision support, extra confidence and control	Complicated gadgets that can confuse seniors, issues with print size	Efficiency, Dignity
choice:			
captive rider	Decision support	Become reliant on the system and reduce interaction with others, Economic pressure of getting an iPhone since other riders have it	Self-image, Dignity, Efficiency, Community
choice rider	Decision support	Become reliant on the system and reduce interaction with others	Efficiency, Community
gender:			
female	Check for creeps that ride the bus	Label people that seem sketch	Safety, Efficacy, Privacy, Trust, Community
male	Check for hot babes that ride the bus!	Label people that may not enjoy the attention	Safety, Efficacy, Privacy, Trust, Community
socio-economic:	Save time	Pressure to buy iPhone	Efficiency
commute	Save time	Become reliant on the system and reduce interaction with others	Community, Trust, Efficiency
non-commute	Save time, learn how to get to different places	Become reliant on the system and reduce interaction with others	Community, Trust
access issues:			
blind	More confidence, independence, autonomy	Less communication with other people, less communal feeling	Community, Self-reliance, Efficacy
deaf	More confidence, independence, autonomy	Less communication with other people, less communal feeling	Community, Self-reliance, Efficacy
deaf-blind	More confidence, independence, autonomy	Less communication with other people, less communal feeling	Community, Self-reliance, Efficacy
cognitive	Decision support	Reliance on the system	Trust, Dignity
wheelchair	Check for open spots	People may avoid routes with wheelchairs or say wheelchair spots are full when they aren't	Efficiency, Fairness
crutches / cane	More time to catch bus		Efficiency
people with accessories:			
bike	notification of room for their bike	people could falsify info to prevent loading of bike (takes time)	Trust
suitcase	pick-up connection - could get picked up in real time from stop		Trust
strollers	notification of room for stroller	people could falsify info to prevent loading of stroller (takes time)	Trust
groceries			
wheelchair	notification of space for wheelchair	people could falsify info to prevent loading of wheelchair (takes time)	Trust, Dignity
multimodal:			
bike, park & ride, walk, zi	wait at home for next bus	entry to park and ride lots may experience peaks as everyone gets in 5 mins before the bus	Efficiency
non-riders:			
car	Avoid bus-heavy routes because buses are slow	Increase bus population that slows drivers	Efficiency, Fairness
bike	Avoid bus-heavy routes because buses are slow and polluting	Increase bus population that slows bikers and has them breathe exhaust	Efficiency, Health
walk	Options for walking part-way	Increase bus population that has them breathe more exhaust	Efficacy, Health
private employer shuttle	Cover sparser areas		Efficiency
potential:			
high vs never-gonna-happen	Gauge difficulty of actually riding bus	Do not see the direct community benefits due to lack of first hand experience	Community, Sustainability
parents of children and teen	Security, safety	Privacy invasion	Safety, Privacy

drivers/operators	Less questions to answer about transfers	More aware and proof of late bus - will on-time performance be linked to evals / pay?	Privacy, Accountability
	Less anxious / happier riders if they have information at hand	Responsible for failed information – "OBA said you were coming in 5 minutes and I almost missed my bus."	
		Could require more from them – push a button for bike presence or overcrowding	
		Higher ridership means more people to deal with – first time riders don't know the drill	
part-time or those unfamiliar with route	Resource to tell riders if they don't know how to find an address requested		Community
other transit agency employees			
general manager	Access to excellent tools without spending resources	Agency could be held accountable for inaccuracies or not working tools	Accountability
	Seen as progressive to riders	Have to change systems and possibly reorganize to acquire data in timely matter	
	Happier riders	Have to find funding for data exchange and system changes	
	Greater ridership = more money and bigger agency		
Planners & Schedulers	Possible changes to how shceduling is done	Possible changes to how scheduling is done	
gis / data-source people	Access to excellent tools with minimal work	Have to provide means for data exchange	Accountability
		Have to address issues with data	
		Feeling that UW can "do it better"	
field supervisors			
dispatch operators			
community			
businesses and services (served by transit)	More visibility through trip planner tools		Access
	More business if riders know they have time to kill before a bus		
businesses and services (NOT served by transit)		No equal access to resources	Access
employers whose employees (may) use transit	Less parking required if employees switch to transit	Pay for transit passes	Access
	Work longer hours by standing at stop less time, arrive to meetings or work on-time more often	Expected to have a car to get around during day if commute is via transit?	
	Happier employees are more productive	Employees spend too much time playing with tools	
transit advocates	More and happier transit riders make them look good	May run out of things to advocate for? ;-)	Access
advocates for other stakeholders	See above	See above	Access
citizens of region	More usable transportation options – increase accessibility, increase property values	Have to pay for creation and maintenance of tools with taxes	Community
	Increased transit use gets people into society – more interaction, more people means safer streets	Government and peer pressure to use transit	
		Gentrification	
elected officials	See citizens – benefiting them gets them re-elected	Have to find funding for tools	Accountability
everyone on earth	Increased transit use can improve sustainability, global warming, reduce pollutants		

A.2 Cultural Probe Instructions

Instructions for subjects participating in our cultural probe experiment with members of the King County Metro Transit Advisory Committee (KCM TAC).

Future Directions for OneBusAway: Identifying Needed Transit Traveler Information Tools

Brian Ferris, Kari Watkins and Yegor Malinovsky, University of Washington

The OneBusAway transit traveler information system has existed as a service for transit riders for over a year (visit http://onebusaway.org). Although the more than 5000 daily users indicate that the system has been a success, the aspirations of the OneBusAway team are much bigger. We hope to develop an information system that can be relied on by transit riders throughout the region and beyond in the many situations they face while using public transportation.

The underlying goal of OneBusAway is to reduce the burden of using public transportation and thereby increase rider satisfaction and increase transit ridership. To date, the tools offered are based almost completely on our own experience as riders, rather than a comprehensive look at the potential user base. Because the developers of OneBusAway represent only a few types of riders on the transit system, we must expand our knowledge of riders' values and desires for information in order to achieve our goal.

In order to get a better idea of the kinds of tools we should be considering, we intend to conduct interviews and surveys of several stakeholder groups. The intent of these interviews is to obtain information about how rider tools may affect these parties. In addition, we plan to investigate several existing documents, such as transit agency rider and non-rider surveys, to include the "potential rider" point of view in the analysis. The final product will be a rating system to rank the potential tools and enhancements to OneBusAway in order to prioritize the future directions of the project.

Today, we are leaving you with a packet of goodies. We hope you will have fun with this exercise while also letting us know your thoughts about being a transit rider. Please try to fill out your goodies within the next month (by early December), so that we may use them as part of our study.

Your goody packet includes:

- 12 postcards
- A map with sticky dots and a crayon
- 10 TOP 5 lists

Each pre-stamped addressed **postcard** has a different emotion that you may experience while navigating the transit system. We ask you to fill them out as one of these emotions seems appropriate during your transit trips and then pop them into a nearby mailbox. In filling out the cards, we ask that you leave off any identifying information that would make you feel uncomfortable with the process.

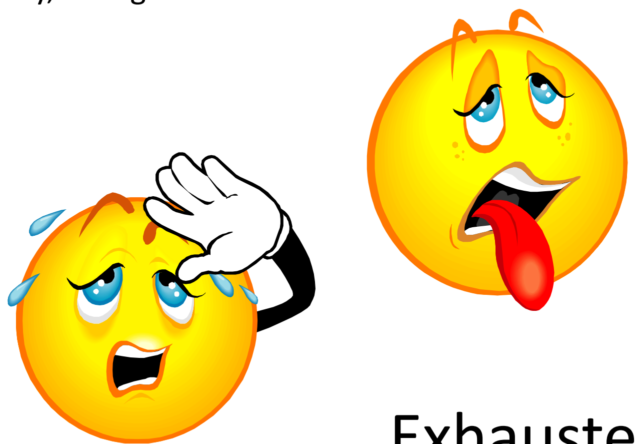
The **map** is for you to show us where you often go and can't easily go using transit. More instructions can be found on the map. The **TOP 5 lists** are similar to the questions you were asked tonight in the group interview. We'd like you to ponder what you said and heard and give us your thoughts about the good, bad and ugly of transit use as well as what might make it easier and better all around. Once your map and TOP 5's are done, put them in the pre-stamped envelope and pop them in the nearest mailbox.

Thanks for your help!

A.3 Cultural Probe Postcards

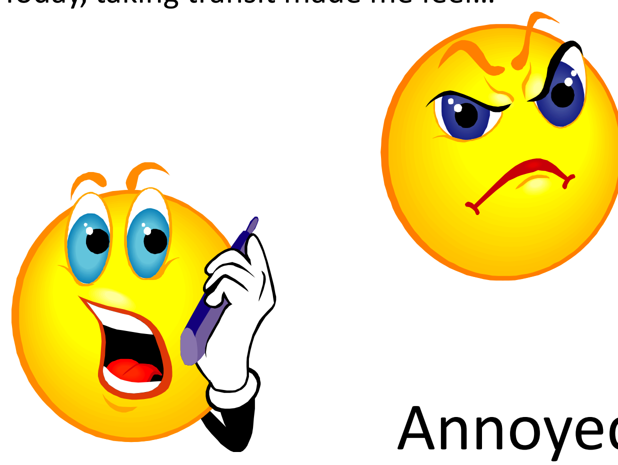
A part of the cultural probe was the following set of postcards that riders could use to describe situations where public transit triggered a particular emotion.

Today, taking transit made me feel...



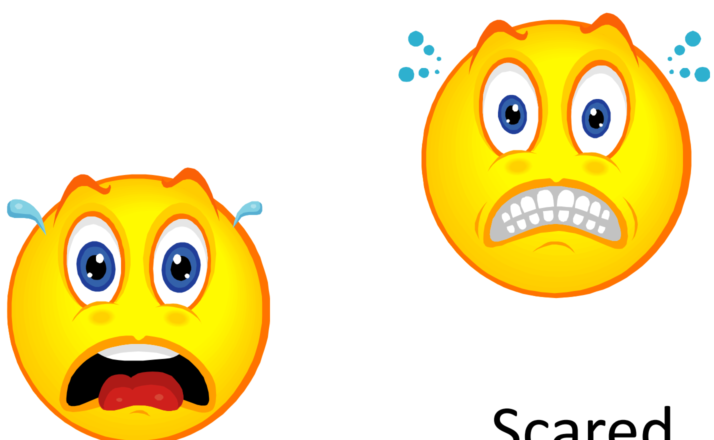
Exhausted

Today, taking transit made me feel...



Annoyed

Today, taking transit made me feel...

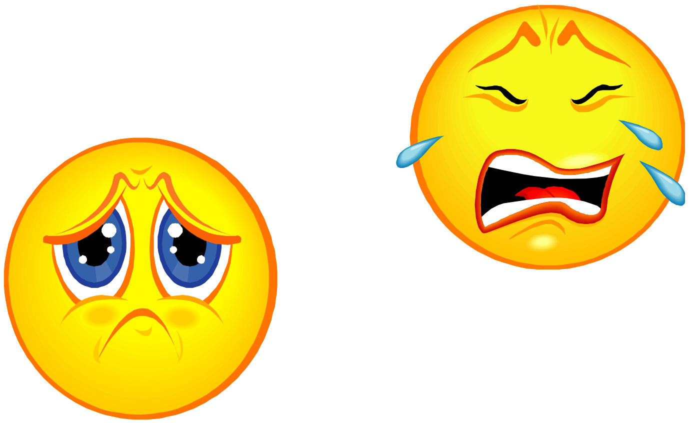


Scared

Today, taking transit made me feel...

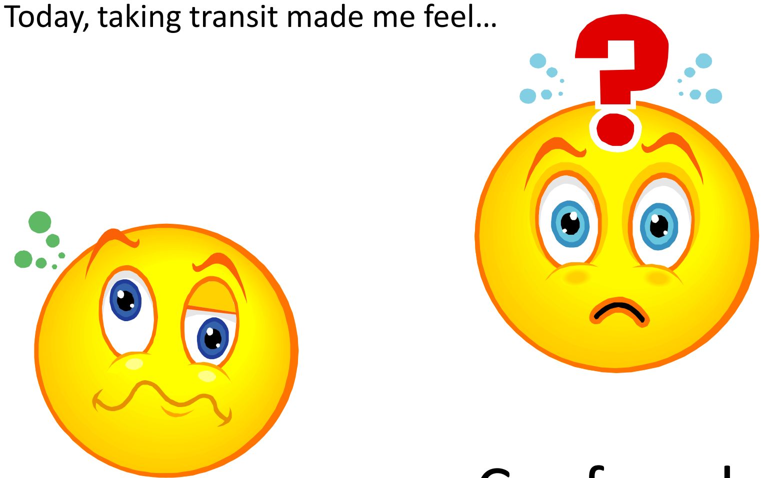
Angry

Today, taking transit made me feel...



Disappointed

Today, taking transit made me feel...



Confused

Today, taking transit made me feel...

Calm or Peaceful

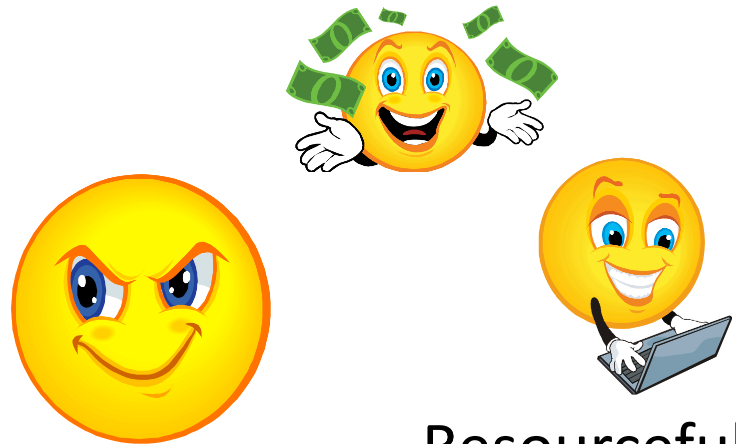
Today, taking transit made me feel...

Happy

Today, taking transit made me feel...

Smart

Today, taking transit made me feel...



Resourceful

Today, taking transit made me feel...

Helpful

Today, taking transit made me feel...

____

A.4 Cultural Probe Map

A part of the cultural probe was the following map that riders could use to describe their use of public transit.

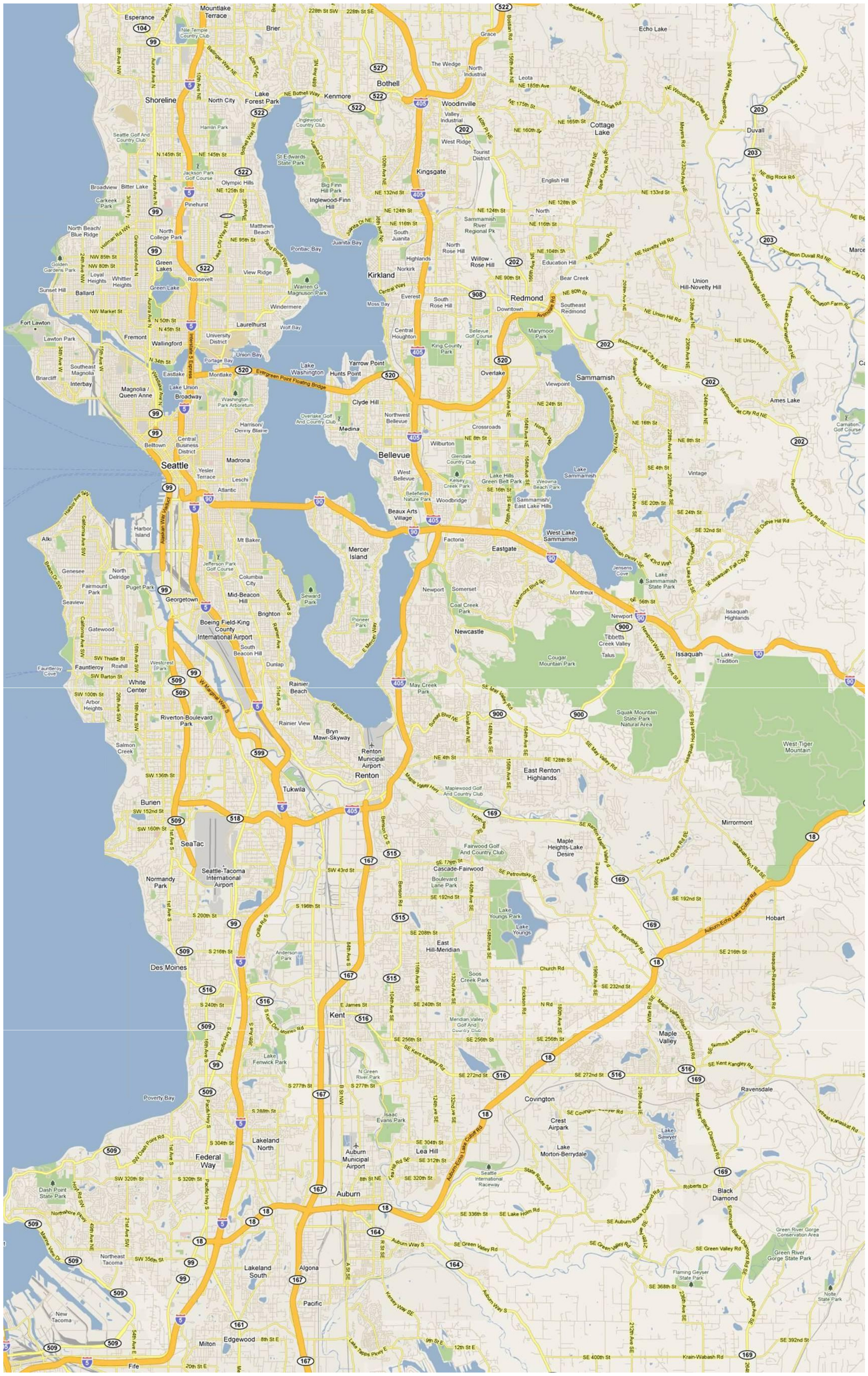
Place a **blue** dot near where you **live.**

Place a **yellow** dot near where you often go by bus to **work or school.**

Place a **green** dot near where you often go by bus for **entertainment or shopping.**

Place a **red** dot near where you'd like to go by bus, but **can't.**

If you feel some areas of King county are **inaccessible by bus** from where you live, color them with the crayon below.



A.5 TAC Meeting Notes

Notes from the KCM TAC group meeting.

Transit Advisory Committee
Group Forum Comments
November 9, 2009

Like about Transit
No driving
Less $ for parking
Feel good
Time to read / space out
People-watching
Flexibility
Designated driver
Part of community
Cheaper than driving
Explore new areas
Education for children
Greener than driving
Pace for seeing surroundings

Dislike about Transit
Other passengers
Takes time
Grumpy drivers
Uncertainty
Security
Smells
Noise – cell phones / people
Carrying stuff – dog
Limited schedule
Poor bus stops
Seattle-oriented – no cross-town trips
Unpredictability
Bad weather
Delays / schedule
Bus coughing
Poor connections
Routes don't get where you want to go
Connectivity
Waiting without covers
No special lanes away from traffic

Unique about how they ride
Occasional rider
Bike and bus
Multiple options / routes, but none perfect
Only option – no car
Short and long trips
Accessing service of Metro when riding
Ride with kids
Choose housing and work around transit

Needed Information
Real arrival time (not schedule) and destination time
Trip Planner with logical landmarks
Maps to give spatial orientation (route maps not so good – only show roads route is on)
Touch screen map → schedule

A.6 Cultural Probe Survey Responses

Summary of survey responses for subjects participating in our cultural probe analysis of the KCM TAC.

Appendix: Summary of Responses from King County Metro Transit Advisory Committee Cultural Probe

Best Things About Public Transit

- Not driving - traffic, weather, crazy drivers, stress
- Other activities - Relaxing, nap, read, studying, etc
- The challenge of trying to take the bus
- People watching
- Helping other people with where they are trying to go
- Minimize environmental impact
- More social activity - can tack with fellow passengers, children, community connection
- No parking hassles
- It's egalitarian
- It's built-in exercise
- Don't have to own a car
- Riding the bus is fun
- Inexpensive for seniors to ride
- Economic benefit of maximizing transportation infrastructure

Worst Things About Public Transit

- Use of smaller buses on less-used routes
- Better timing of buses to help reduce wait time when transferring
- More frequent buses - evenings, weekends
- Get rid of rude, surly drivers
- Transit schedules customized for non-commute riders
- Dedicated ROW for buses
- More express busses
- Long trips
- More bus shelters
- Missing connecting buses by just a minute or two
- Long wait times - evenings, weather
- P&R routes only during commute hours
- Getting stuck in traffic jams, game traffic
- Fix bumpy roads, bouncy buses
- Violence / disturbances on the bus
- Better information systems - downtown, transfer points
- ORCA system - complicated, confusing
- Better relationship with city council (Seattle)
- Unpredictability, unreliability
- Germs on the bus - coughers
- Poor usability - requires a lot of knowledge to use the system
- Off board payment
- Having to listen to people's private conversations (cellphone,etc)
- Loud, rowdy passengers
- Young people give up their seats to pregnant women, small children, elderly
- More east-west service
- Faster buses
- Politically driven resource allocation - doesn't make sense
- Lack of funding
- Rules at public agency inhibit innovation and nimbleness

Information Needs For Using Public Transit

- More frequent buses - evenings, weekends
- Trip planner doesn't make it clear which stop to get off at or where to catch a bus
- Trip planning for primary and return trip
- When will a bus be crowded
- Better maps: where you are getting off the bus, especially for new areas, street-level detail
- Issues with address lookup in trip planner
- Not aware of other available tools for trip planning, transit
- Which routes go on which streets downtown?
- Quickest / simplest route to my destination
- Inside bus: reader boards / announcements for each stop
- Maps of entire system for planning trips to new places
- On a crowded bus or rainy day, don't know which stop to get off at
- Map representation of trip planning results
- More real-time information
- Better stop and shelter signage - nearby transfers, stop number, schedules, address / intersection of stop
- Tools for people without smart-phones
- How often a bus runs and when it stops running
- KC Metro's schedule pages default to weekday even on Weekends
- Mobile device hard to use when traveling with child

Tips And Tricks For Using Public Transit

- Use bike racks for bike+bus
- Through routes to avoid a transfer
- Transfers are cheaper than paying twice
- Will often take a longer single trip instead of a shorter transfer
- Bring something to do while waiting, riding - especially for children
- Have a backup plan - routes, itinerary, etc
- Pack efficiently and appropriately
- Find a stylish wash&wear hairstyle
- Sight-seeing with my grandson

Favorite and Usable Websites

- Seattle Public Library
- New York Times
- Google
- EarlyMusicGuild.org
- Metro KC
- babycenter.com
- kuow.org
- bing.com
- streetsblog.org
- Seattle Transit Blog
- Alaska Air
- Amtrack

A.7 Postcard Responses

Summary of postcard responses for subjects participating in our cultural probe analysis of the KCM TAC.

Happy	Angry	Annoyed	Confused	Resourceful	Smart	Helpful	Other
Rode **brand new** CT Swift - Opening Ceremony	**Surly driver** (Rt 66) did not respond to 'Good Morning' and did not call out stops - did not apologize when sudden jerk made passenger almost fall.	The 271 Bus to Issaquah **left** the Eastgate P&R 2 minutes **earlier** than the scheduled time so I **missed the bus** - it was driving away just as I got to the P&R sidewalk.	Trying to **help** a **tourist navigate** tunnel ORCA **machine**	Loved parking costs. Much **cheaper** to take transit.	I succesfully completed a "treacherous" wordoku on the bus	I was able to offer my cell phone and **directions** to young boy who was meeting his coach for a ride. He had to **walk** a short distance once he got off at the Eastgate P&R, but after our **talk**, he knew **exactly where to go**.	WET!
Because I made **excellent connections** without even planning the trip. **No long waits** at any bus stops. Also, I got to **chat** with my sister-in-law on my way to swimming.							
I took the earliest 554 bus into Seattle for a run with friends, then took the 550 bus to Bellevue to do some shopping and the 271 home..and all went very **smoothly** in spite of the rainy, blustery wearther. I had **several bags** by the time I was going home and had a bit of a walk to get to my doorstep but still **felt it was** a **good** way to get around.							

A.8 Map Responses

Summary of map responses for subjects participating in our cultural probe analysis of the KCM TAC.

	Central	West Seattle	Bellevue	University	Ballard	Redmond	Auburn	Renton	Bothell	Green Lake	South Seattle	Shoreline	Northgate	Kirkland	Far East
Live	X														
Work						X									
Shop	X	X			X					X	X				
Can't Go		X													X

	Central	West Seattle	Bellevue	University	Ballard	Redmond	Auburn	Renton	Bothell	Green Lake	South Seattle	Shoreline	Northgate	Kirkland	Far East
Live		X													
Work											X				
Shop	X	X									X				
Can't Go		X		X								X			

	Central	West Seattle	Bellevue	University	Ballard	Redmond	Auburn	Renton	Bothell	Green Lake	South Seattle	Shoreline	Northgate	Kirkland	Far East
Live							X								
Work	X														
Shop	X														
Can't Go															

	Central	West Seattle	Bellevue	University	Ballard	Redmond	Auburn	Renton	Bothell	Green Lake	South Seattle	Shoreline	Northgate	Kirkland	Far East
Live													X		
Work	X			X											
Shop				X	X				X	X			X		
Can't Go									X						

	Central	West Seattle	Bellevue	University	Ballard	Redmond	Auburn	Renton	Bothell	Green Lake	South Seattle	Shoreline	Northgate	Kirkland	Far East
Live			X												
Work															
Shop	X		X	X						X					
Can't Go								X						X	X

A.9 Bus Operator Interview Results

Summary of bus operator interview results, as part of our VSD analysis.

Operator Interview Results
December 9 and 10, 2009

1. What are the five best things about driving a bus?
   - Social interaction
   - Independence
   - Leave job at work
   - Time for own projects
   - Range of puzzles to solve
   - Independence
   - Meet people wouldn't normally meet
   - See neighborhoods I wouldn't see – have bought houses in areas I drove
   - Love inner city and the diversity on those routes – makes the job interesting

2. What are the five worst things about driving a bus?
   - Damned if do, damned if don't interaction with management
   - Health effects
   - Extreme stress – cognitively
   - Schedule – very early, very late or split
   - Draconian rules including a 180 page contract and a 200 page policy & procedures
   - Each base interprets rules differently

3. What would you change about driving a bus given the chance?
   - Give operators authority, autonomy, and training to resolve problems themselves in the course of the day and respect those judgments
   - Manage as if people not robots
   - Ergonomics
   - Interaction of those delivering service into the planning process
   - Access to better information for drivers – maps / routing, ability to help people plan trips, locations of nearby buses for transfers
   - ORCA system – too old, too many steps
   - Get rid of speedometer and give me ahead / behind schedule
   - No mirrors – give me cameras – would narrow the bus and give me the ability to back up easier. Buses get stuck because they can't back up.
   - Give me a tablet PC with all the info I need to serve the public
   - Fare structure – feds have a lot to say about it, but it needs to be simpler
   - Way routes are scheduled
   - Could provide service better for less money with things like BRT
   - Need less political interference – politicians want a bus or a P&R that requires a bus even if no one rides it

4. What would you leave the same about driving a bus?
   - The people
   - Planners and schedulers are top drawer given their constraints
   - Metro reaches out to the public well as long as politicians stay out of it

- Don't get rid of the trolleys – they are quieter, cleaner and serve downtown efficiently - underappreciated

5. What kinds of information do riders ask for?
6. How frequently do you get these types of questions?
    - Destinations – at least few times per day depending on the route
    - Schedules – at least few times per day depending on the route
    - Routing – at least few times per day depending on the route
    - Social interaction
    - Where is the # XX bus? – mostly in downtown, especially routes with many new riders / tourists – probably hourly downtown
    - How do I get to YY? – mostly in downtown, especially routes with many new riders / tourists – probably hourly downtown
    - "When will I get to downtown?" or "When will I get to the U-District?" on an hourly basis – at least 2 to 3 per trip
    - Where does your bus go? To which, I always ask where they need to go

7. What kind of information should KC Metro provide to riders?
    - Info to serve traveling needs (trip planning type things)
    - Suggestions on entertainment accessible by transit
    - Ways the public can impact the service they are provided, including how to interface with Metro
    - Course for drivers to learn routes to inform passengers when they ask questions
    - The rules of the road, such as employee rights, should be posted
    - Fare information, how to pay, how much to pay
    - Rider alerts – but they need to be effective – announce known closures - interactive system to get the word out
    - Riders need to know if the bus is not coming and why
    - An interior next stop announcement sign could also alert people that the connecting routes are running severely behind

8. What types of things do you currently have to do while operating a bus?
    - Check that the doors are closed and no one is running up
    - 6 sets of mirrors and front window
    - Check mirrors every 7 seconds
    - Blind spots are an issue – constantly checking everywhere
    - Pull out of zone carefully to avoid cars, people
    - Drive cautiously to be able to brake in time
    - Escape route – driving safely – reaction time – can't stop quick with standing passengers
    - Lane changing is hard because people try to get around you at the last minute
    - Pulling into a zone, you have to look back at people on your bus and your right mirror not to bonk people waiting
    - See if someone needs a lift and pull to correct place to be able to use it, then tie them down as inconspicuously as possible to preserve their dignity
    - Watch when opening the door
    - Check paper schedule and look at ORCA (not supposed to) to see behind / ahead
    - Have to pay attention to people too
    - No route maps

- Fares at stop – if don't pay, scripted words to say
- Press buttons for certain passes or fare violations
- Would help if could integrate information flows so could ignore or do it while rolling

9. Pretend for a minute that you had to press a button to indicate something about the bus, such as it is standing-room only, your bike racks are full or your wheelchair spaces are taken, do you think you could safely do this while operating the bus? Why or why not?
10. What percentage of the time do you think you would remember to do this?
    - Everything is a trade-off
    - There is no "downtime" while operating, so it has to take the place of something else
    - Wouldn't remember (very small % of time)
    - Yes, I would have the ability to do it safely and I could remember. I think maybe 70% of drivers would remember to do it.
    - Depends on when I have to push it, but yes, I could and I would remember if I knew what it was used for
    - If a driver doesn't feel it's important, they won't bother – like the fare evasions – need to see the benefit to the agency or to me as a driver
    - Agency needs to communicate back how data is used to the drivers

11. Do you think the additional effort of you having to press buttons on the console for such information would be worth the information it might provide to customers? Why or why not?
    - Can't respond real-time anyway
    - False info is abundant
    - It could help a driver get back on schedule
    - Need 100% accuracy for such things or information is useless
    - Drivers might press it just to avoid stopping even if not full
    - YES & NO – some would take advantage and stay at their desk but for people on the street wouldn't help

12. How frequently do you think you are running hot (early)?
    - Depends on route / time period
    - Very infrequently running hot
    - Sometimes new route and not on-time all day – have to learn the route
    - I don't run hot – I work to prevent it
    - Not everyone cares, but good drivers work at it, not just things you can do about being early, also things about being late
    - Only on holidays
    - Sometimes purposefully start a couple of minutes late to make sure don't run hot

13. What do you do if your bus is running hot (early)?
14. How frequently do you XXX (list answers in 12)?
    - "Jump out and hit a garage sale"
    - Sometimes you don't know if you are hot
    - Some drivers purposefully run really late at the beginning to "have to catch up" because they don't want to run hot
    - Don't drive real slow sometimes because it's not very safe, but sometimes it is OK
    - Pull over & sit – they want you to do it before the zone, but that's too hard – there's no space

- Drivers always know the schedule well enough to know if they are hot
- I "drag my feet" until the point where people notice – you can use traffic lights, make complete stops and pause before you open doors, make sure everyone is seated before you drive
- But if it doesn't work, you have to sit somewhere and time passes so slow – a minute feels like forever when you know the passengers on the bus are impatient for you to drive

15. Do you feel that bus drivers would be more likely or less likely to adhere to the schedule if passengers were aware of when the bus came early? Why?

- People get on the first bus even if another is sitting at the stop
- Not sure info is useful except in limited circumstances unless sign on bus with "overloaded" to tell riders that I'm not picking up
- No difference – drivers already know without the info
- Metro is taking out the schedule maintenance, so there are less available coaches to slide in when a bus is really late
- If you are late, you can run reds and pull out when passengers still sitting down
- By cutting out recovery time, accidents may go up, because drivers will be under pressure to make up the difference
- Some routes, they run hot early in the route because they know they will get behind later
- Recognition of on-time status may help running hot, but hurt late buses, because drivers won't purposefully run early
- Recovery time is critical – shouldn't be taking it out
- If running hot, drive slowly if possible without stopping traffic
- If really hot, pull over and stop for longer period
- Small % might be better about running hot, but not many
- There is already public pressure to stay on time
- Drivers would definitely adhere more
- Passengers already tell you when they get on, but more people would know

16. What do you think about the vehicle location data that King County Metro collects?

- AVL is abysmally inaccurate
- AVL is inaccurate – drivers sometimes do creative routing between stops for good and bad reasons, but it messes up the AVL
- I'd like to see contract language about protection for drivers when the GPS comes about
- GPS is going to expose some things KC Metro allows that may be considered unsafe, such as letting drivers take measures to get back on schedule or allowing them to follow more closely downtown because it's just not possible leave the spacing you legally should.

17. Are you aware that this information is available to the public through KC Metro's Tracker and through OneBusAway as a countdown to your arrival?

- Yes
- Yes
- Yes

18. Do you think that this information is of value to the riders? Why or why not?

- Not of value – can't get enough information from it
- The driver adjusts the schedule, so they may end up back on time

- If you have choices, like in the city, it's great, but most stops don't have anything to use your time while you wait
- Yes – they can plan their time better
- Yes

19. Do you think that providing this information about your on-time status is a violation of your privacy? Why or why not?
    - No violation with privacy
    - Purpose to which it is put might violate though, because of false assumptions with a random collection of data
    - No violation of privacy – it's part of the job
    - Perhaps a countdown would be better without the "late" "on-time" or "early"
    - No, it's part of the job. We're there to serve the public.

20. What if the information were available about the % of on-time arrivals for your trip given historical data? Is this a violation of your privacy? Why or why not?
    - Historic collection IS a violation
    - It is public info – can get it – but maybe shouldn't be too easy for typical rider
    - (seemed to change mind about privacy violation midway through) "Information is an unavoidable consequence of working for transparent agency"
    - Would put drivers in jeopardy
    - Emphatically "NO" not a good idea
    - On-time performance statistics could lead to discipline and trouble with the union
    - Plus it could lead to problems with the public getting in a driver's face "Why are you always late?" when it may have nothing to do with them
    - Yes, that is a violation because it puts too much pressure on the driver for things they can't help – we are in the public eye, not the bad traffic or the poor scheduler

21. What about an application that rates the stations, routes or even drivers
    - Rate my route / driver – like it if done anonymously
    - Not tied to discipline
    - Delivered and received anonymously
    - Really like "rate my XX"
    - Don't like the idea, because it exposes information to people who may not use it the right way
    - Some guys could say "I gotta ride that bus – create some hell"
    - One of the good things about the job is that every day is a clean slate – don't stop that process
    - I like the aspects that would put pressure on management - buses went from weekly swab out to now 34 days between – that's not cost savings, that's bad service
    - Wouldn't be a bad thing to let grumpy drivers know that they public seems them that way

21. Sharing certain information may be detrimental to the quality of service on bus routes or the satisfaction of bus drivers. Do you feel that there is information that is best to be kept confidential? In other words, what is important not to share?
    - Aggregating and identifying with individual is a problem
    - Stalkers – physical harm / harassment of driver
    - Anything employee didn't ask for

- Discipline record should be kept private because you don't know the story behind the data
- Historic on-time performance is asking for trouble

22. Do you think there are any other benefits you would receive from different types of rider information?
    - "You might actually get drivers to ride!"
    - Driver access to the information would be great
    - Expand to countdown to 1 hour for inside the coaches, so that we can always see the next arrival for every bus (some are only hourly) or if it's not running right now
    - Metro would really benefit if we could track issues in zones, including deleting or implementing based on passenger opinions
    - Maybe it would help work with the schedulers – their performance would be rated too although the public doesn't see them
    - Not much as a driver, it's nice to have an informed public, but someone will always misuse it

23. Do you think there are any other harms you would receive from different types of rider information?
    - I wonder if customer service would feel threatened by some of this information
    - Public privacy is an issue with the ORCA card
    - Information is great, but we really need transit-only lanes – forget light rail, buses can do a better job, but you have to give them the same treatments – losing the tunnel to LRT is not progress
    - May impact schedulers too
    - There's always someone who will shout in your face and someone who will misuse the information

A.10 Rider and Non-Rider Survey Results

Summary of rider and non-rider surveys, as part of our VSD analysis.

Rider / Non-rider Survey Notes

King County Metro 2006 Rider / Non-Rider Survey Final Report, Northwest Research Group (2007)

Rider Satisfaction

Very	Very+Somewhat	
70%	95%	Personal Safety Waiting in daytime
69%	95%	Driver operates safe / competent
69%	92%	Ability to get information from routes / schedules
60%	95%	Driver courtesy
58%	93%	Personal safety related to conduct of others in daytime
56%	91%	Driver helpfulness with route/stop info
51%	89%	Personal safety at park-and-ride lot
50%	81%	Number of transfers to make
49%	86%	Numbers of stops bus makes
49%	78%	Ability to get parking at park-and-ride
45%	86%	Availability of seating
41%	87%	Inside cleanliness
41%	81%	Where bus routes go
37%	78%	On-time performance
35%	76%	Time between buses / frequency
34%	77%	Security of car in park-n-ride
33%	74%	Travel time by bus
32%	73%	Personal safety on bus related to conduct of others after dark
28%	74%	Cleanliness of shelters
27%	71%	Wait time when transferring
25%	69%	Personal safety waiting after dark

Riders Experiencing Problems in last 3 months

42%	On-time performance
36%	Travel time by bus
34%	Wait time when transferring
32%	Time between buses / frequency
31%	Availability of seating
25%	Cleanliness of shelters
21%	Where bus routes go
18%	Ability to get parking at park-and-ride
18%	Inside cleanliness
15%	Personal safety on bus after dark
15%	Driver operates safe / competent
14%	Personal safety waiting after dark
14%	Driver courtesy
13%	Numbers of stops bus makes
13%	Number of transfers to make
12%	Ability to get information from routes / schedules
10%	Driver helpfulness with route/stop info
8%	Personal safety on the bus in daytime

6%	Security of car in park-n-ride
5%	Personal safety at park-and-ride lot
5%	Personal Safety Waiting in daytime

Top Priority for Improvement
Wait Time When Transferring
Cleanliness of Shelters
On-Time Performance
Personal Safety on Bus After Dark
Travel Time by Bus
Ability to Get Parking at Park-n-Ride Lots
Frequency of Service

Barriers to Using the Bus for Commute
71% Routes don’t go where you want to go
59% Have to transfer
58% Have to plan around bus schedules
58% Time to travel by bus
51% Frequency of service after 6 pm
46% Have to be at work / school late
43% Have irregular hours
41% Need a car in case of emergency
39% No bus stop near home
32% Inexpensive parking
30% No bus stop near work
28% Need a car for business travel
26% Need car for personal errands
24% Lack of park-n-ride parking
23% No access to park-n-ride lot
22% Crowded buses / no place to sit
22% Concerns about safety waiting
18% Behavior of others on bus
16% Not knowing how to use the system
13% Concerns about safety riding

Barriers to Using the Bus for Non-commute
60% Routes don’t go where you want to go
57% Have to plan around bus schedules
52% Time to travel by bus
49% Have to transfer
49% Frequency of service after 6 pm
46% Need a car in case of emergency
39% No bus stop near home
30% No access to park-n-ride lot
30% Lack of park-n-ride parking
29% Behavior of others on bus
24% Crowded buses / no place to sit
23% Concerns about safety waiting

19%	Not knowing how to use the system
19%	Concerns about safety riding

Sound Transit
In 2008, 31% walked, 35% bus, 17% drove, 10% dropped off, 1% carpooled and 3% of respondents biked to get to the service. After taking ST, 47% walked, 30% bus, 13% drove, 3% biked, 2% carpooled and 5% other.

Reason to use ST:
18% more convenient
18% cheaper
13% no car
8% no parking
7% more relaxing
7% faster
6% reduces traffic
5% gas prices
5% less stressful
5% helps environment
3% work/school pays
4% other

What would you change?
9% Increase frequency
6% More buses
5% More routes / trips to other places
4% Lower price
4% Too crowded / more seating
4% Better quality buses / update equipment
4% Better / improve scheduling
4% Extend hours
4% More trains / Link
4% Change drivers / get polite drivers
44% Give me more

23% said schedule reliability is better, 4% said gotten worse
52% said can usually count on trip time reliability, 42% said always, 2% said hardly ever
20% have occasional safety concerns, 2% have regular safety concerns, 77% have no concerns

Information Sources
44% website (up from 2007, same as 2006)
24% schedule books (about same)
12% stops (down from 2007, same as 2006)
7% on bus/train (lowest its been)
5% stations (about same as 2006)
3% customer service / phone (down)
5% other (up)

61% have used the website, most use website for schedules (94%)

Website improvements
5% make it easier
4% easier to navigate
3% combine with Metro & trip planning & less busy & easier to find schedules & easier to read maps & hard to find address
2% not all stops listed & hard to find rider alerts & better mobile
57% don't know + no comment

9% have signed up for rider alerts – 49% find them useful, 11% do not
16% were very interested in rider alerts and 33% were somewhat interested, 42% not interested

Chicago Transit Authority, "Traveler Behavior and Attitudes Survey CTA Riders and Nonriders", July 2001, Northwest Research Group, Inc., CTA Technical Report MR01-09

Demographics – women (58%), younger (50% under 35), commuters, income and ethnicity similar between rider and non, only 32% are transit-dependant

Purpose – half of trips are commute related

Factors affecting transit use –
65% begin work earlier or stay later then regular work hours at least some days
47% of commuters need a car for work at least some times
20% drop off or pick up children

Attitudes –
59% feel streets are very congested during rush hour, 31% feel moderately congested
87% enjoyed traveling by car while 55% enjoy traveling by transit

Recommendations –
Stop loss of transit-dependent riders when lifestyle changes
Improvements needed include cleanliness, on-time performance, safety and security, improved travel times, limited stop service, signal priority, bus-only lanes.
Focus on increased use for recreational and personal business trips
Incentive programs like guaranteed ride home, transit benefit programs
Non-riders face a lack of knowledge about how to ride, lack of comfort on transit

Figure 59: Ratings of Auto, CTA Rail, CTA Bus
Base: Total Respondents (n_w=2,768)

	Auto	CTA Rail	CTA Bus
Overall	8.11	6.97 (-1.14)	6.28 (-1.83)
Getting to your destination quickly and on time	**8.26**	6.87 (-1.39)	5.70 (-2.56)
Inexpensive to use	6.00	**7.17** **(1.17)**	**7.06** **(1.06)**
Easy to set your own schedule	**9.10**	6.39 (-2.71)	5.62 (-3.48)
Comfortable	**8.96**	6.12 (-2.84)	5.78 (-3.18)
Clean	**8.77**	5.76 (-3.01)	5.65 (-3.12)
Safe from crime	**8.16**	5.48 (-2.68)	5.70 (-2.46)
Transportation I know how to use	**9.09**	7.85 (-1.24)	7.50 (-1.59)
Allows me to get home in case of an emergency	**9.15**	5.87 (-3.28)	5.26 (-3.89)
Allows me to stop on my way to / from my destination	**9.09**	5.48 (-3.61)	5.82 (-3.27)
Easy to arrange	**8.89**	7.02 (-1.87)	6.16 (-2.73)
Transportation I am comfortable using	**8.87**	7.00 (-1.87)	6.53 (-2.34)
Insure other people won't bother me	**8.57**	4.80 (-3.77)	4.93 (-3.64)
Gets me to my destination the fastest way possible	**8.26**	6.57 (-1.69)	5.30 (-2.96)
Is consistent with the kind of person I am	**8.19**	5.64 (-2.55)	5.23 (-2.96)
Is relaxing	**7.45**	5.89 (-1.56)	5.58 (-1.87)
Minimizes my risk of being in an accident	5.86	**7.85** **(1.99)**	**7.06** **(1.20)**

Numbers shown in parentheses represent the difference in ratings between auto and rail and auto and bus, respectively.

Figure 70: Importance Factors When Making Mode Choice Decision
Base: Total Respondents (n_w=2,768)

	All Respondents	Frequent CTA Riders	Infrequent CTA Riders	Nonriders*
Getting to destination on time	9.00	8.85	8.85	**9.14**
Safe from crime	8.66	8.39	8.41	**8.91**
Getting to destination quickly	8.58	8.53	8.50	8.64
Getting to destination fastest way possible	8.55	8.54	8.41	**8.63**
Easy to set schedule	8.48	8.31	8.09	**8.75**
Able to get home in emergency	8.46	7.98	7.90	**8.93**
Get to destination feeling clean and fresh	8.45	8.21	8.09	**8.73**
Transportation I know how to use	8.38	8.23	8.24	**8.52**
Transportation comfortable using	8.34	8.20	8.00	**8.57**
Easy to arrange	8.25	8.00	7.99	**8.49**
Clean	8.18	7.81	7.97	**8.46**
Comfortable	7.88	7.52	7.59	**8.20**
Inexpensive to use	7.87	**8.13**	7.93	7.72
Have a place to sit	7.64	7.14	7.24	**8.07**
Good for the environment	7.55	7.66	7.58	7.48
Minimizes risk of being in accident	7.50	7.50	7.06	**7.70**
Won't be bothered by others	7.41	7.12	7.02	**7.73**
Availability of parking at destination	7.30	5.44	6.88	**8.34**
Relaxing	7.27	7.08	6.93	**7.52**
Ability to stop on way to / from destination	7.23	6.79	6.73	**7.67**
Gets one in right frame of mind	7.14	6.79	6.61	**7.54**
Doesn't contribute to traffic congestion	6.94	6.97	6.94	6.92
Cost of parking at destination	6.75	5.77	6.67	**7.23**
Don't worry about wear and tear on vehicle	6.55	6.42	6.44	6.64

On a scale of 0 to 10, where 0 is "Not At All Important" and 10 is "Very Important"
**Nonriders include Occasional Riders that did not ride in the week prior to survey.*

Ridership Survey 2007, San Francisco Municipal Transportation Agency, Key findings, Corey, Canapary & Galanis Research
Aspects of Muni would most like to see improved
37% on-time performance / more accurate schedule
26% more frequent service / longer hours
13% employee helpfulness / professionalism / discipline
12% overcrowding
10% service reliability (breakdowns, delays, bus doesn't stop)
10% vehicle cleanliness
10% better security / safety from crime
9% better vehicles / equipment
8% better enforcement of rules
6% more efficient spacing of buses

Rating of attributes (excellent or good)
69% Safe operation
58% Operator helpfulness
56% Feeling safe / secure from crime
56% Vehicle comfort
47% Vehicle cleanliness
41% Communication with riders
40% Service reliability
39% service frequency

46% have used MUNI's website
Of those, 44% check schedules (down from 2006), 31% look at maps of individual routes (down from 2006), 29% use the trip planner (up from 2006) , 25% use vehicle arrival predictions (up from 2006), 10% use system maps (down from 2006), 4% use service change announcements (same as 2006)

Washington Metropolitan Area Transit Authority, Final Operating Plan, Regional Bus Study, September 2003, Transystems
Improvements desired by bus riders
49% on-time arrival
31% more frequent service
25% longer hours
22% less crowding
13% closer bus stops
12% go more places
10% faster service
10% better shelters
9% schedule info / signage
8% better vehicle condition
8% lower fares
7% better customer service

Improvements desired by non-riders
30% better information
21% better shelters

18% more convenient stops
16% faster service
16% more frequent service
13% service to destination
13% comfortable buses
9% service to Metrorail
6% better reliability

Improvements needed in Information
More information at bus stops and rail stations
Subregional and systemwide maps
Better and more user-friendly information for tourists
More marketing

2008 BART Customer Satisfaction Survey, Corey, Canapary & Galanis Research
Highest rated:

- Map and schedule availability
- Bart.gov website
- On-time performance
- Timeliness of connections
- Reliability of faregates
- Access for people with disabilities
- Reliability of ticket vending
- Timely information about service disruptions
- Signs with transfer / platform / exit directions

Lowest rated:

- Restroom cleanliness
- Presence of BART police on trains
- Presence of BART police in parking lots
- Availability of space for luggage, bikes, etc
- Noise level on trains
- Condition / cleanliness of seats
- Enforcement of eating & drinking
- Clarity of PA announcements
- Condition / cleanliness of train floors
- Condition / cleanliness of windows
- Presence of BART police in stations

Biggest improvements in satisfaction were interior cleanliness (5.8%), interior free of graffiti (3.5%), escalator availability (3.1%), timely information about service disruptions (2.5%), and timeliness of connections (2.3%). BART introduced real time service advisories since the last survey and next bus info became available for MUNI and AC Transit. Biggest declines in satisfaction were eating and drinking policy enforcement (-5.7%), temperature on trains (-3.2%), availability of seats (-1.9%), noise (-1.8%) and presence of BART police on trains (-1.5%).

Things seen as important on quadrant chart (using 1996 as baseline):
On-time performance

Service frequency
Leadership in transportation
Transfer connections
Station state of repair
Seat availability
Train seat comfort
Available standing room
Delay information
Personnel helpfulness
Car interior cleanliness
Seat condition

RTD 2008 Bus customer satisfaction & travel characteristics, February 2008, Howell Research Group
Nothing to note

An Analysis of Public Transportation to Attract non-traditional Transit Riders in California, California DOT, April 2003

Two Most Important Choice Criteria / Importance of Mode Choice Factors (1 to 7)

35.2%	Personal Safety	6.33
33.3%	Reliable arrival time	6.14
27.5%	Convenience	5.82
24.0%	Flexibility	5.84
18.1%	Travel Time	5.58
13.4%	Traffic Congestion	5.24
10.1%	Cost of Driving	5.03
10.0%	Transportation at Destination	4.98
7.7%	Privacy	4.63
6.1%	Availability of parking	4.91
5.5%	Cost of parking	4.13
4.6%	Vehicle appearance / cleanliness	4.97

Perceptions of Public Transit (1 to 7)
5.3 Safe
5.0 Inexpensive
4.8 Provides frequent service
4.8 Clean
4.6 Travel Time is reliable
4.4 Travel Time is reasonable
4.0 Convenient
3.9 Flexible
3.8 People who are like me use it

Perception among non-users that they do not have convienient access to transit near their home / work (only 38.2% said they did have access), BUT 80% said they no little to nothing about routes and 86% said they know little to nothing about schedules.

Why Not Use Public Transportation More Often

Speed/Convenience Issues	**28.9%**
Takes Too Long/Travel Time Longer	16.3%
Inconvenient/Not Practical-General	7.8%
Don't Like to Wait/Long Wait Time	4.6%
Too Many Stops/Don't Like Transfers/No Express Service	3.0%
Inconvenient in an Emergency	0.8%
Access Issues	**26.6%**
Routes Inconvenient/None Near Destination/No Direct Routes	11.5%
Transit Service Unavailable/No Access to Public Transit	10.4%
Bus Stops/Stations Too Far Away	5.7%
Flexibility/Control Issues	**22.6%**
Prefer Freedom/Convenience of Own Vehicle/Easier to Take Car	7.7%
Need Car During the Day/Need More Flexibility/Run Errands	6.7%
Need Vehicle for Work	3.7%
Transport Children to School/Day Care	3.7%
Transport Tools/Equipment/Supplies	1.8%
Want Control/Don't Like to Depend on Others	1.1%
Schedule Issues	**18.8%**
Schedules Inconvenient/Not Flexible/Doesn't Fit Schedule	6.5%
Unreliable/Runs Late/Concerned About Arriving on Time	5.4%
Not Late Enough/Not Early Enough	5.0%
Schedule Varies/No Consistent Schedule/Irregular Work Hours	2.2%
Not Frequent Enough	1.3%
Prefer Car/Prefer Walk/Ride Bike	**14.6%**
Have a Car/Prefer My Car/Like to Drive Car-General	12.6%
Prefer to Walk/Ride Bike	1.7%
Have Company Car/Work Pays for Car	0.5%
Travel Experience Issues	**11.1%**
Not Safe	4.3%
Don't Like People Who Use It/No Affinity with Users	2.7%
Prefer Privacy/Lack of Privacy	2.6%
Crowded/Noisy	1.7%
Not Clean/Uncomfortable	1.5%
Weather Issues	0.5%
Cost Issues	**3.3%**
Other	**8.9%**
Close To Work/Destination/Isn't Necessary/Live in Small Town	3.9%
Don't Know How to Use It/Need More Information	2.7%
Other	2.4%
Don't Like It/Never Used It/Not Interested/Don't Need It	**4.8%**
Currently Use Public Transportation	**5.9%**
Don't Know/No Reason	**0.9%**

10.1% said they plan to use transit in the future and 44% said they would consider it under the right circumstances (34% said only if no alternative and 10% said never)

Transit Non-user Survey: Restful Riding Rather than Stressful Driving, Center for Urban Transportation Research, University of South Florida, July 2002

- Bus stops need to be closer to origins and destinations
- Service improvements – lesser headways, reduced transfers and on-time performance
- Increased safety was a concern in larger cities – stops seen as unsafe at night, on the bus not typically a problem
- Reason why former riders no longer ride – automobile access
- Largest reason for not using transit was the convenience of the automobile
- Obstacles included hours of operation, reliability issues and the need to take multiple trips
- Lack of knowledge about route and schedules
- Need for flexibility
- Inconvenience of bus - bus frequency was above reasonable wait time of 15 minutes
- Route maps and schedules are confusing
- Positive = Bus is clean, safe and relaxing
- Individuals uncomfortable riding with other passengers, particularly those of another class
- Lack of control, knowledge and safety
- Car needed for children, errands and in case of emergency
- Unaware how to take the bus
- Length of time to take the bus

2004 Non-Rider Survey, Valley Metro, WestGroup Research Answers, April 2004

Aspect Liked about Transit in Other Cities if transit used elsewhere

Gets you anywhere you want to go	25%
Fast/frequent/every 15 minutes/on time	23%
Easy access/convenient locations/ practical/ easier than driving	19%
Convenience/easy (unspecified)	19%
Inexpensive/economical/no rental costs	10%
Didn't own, have or need a car/ only way to get around/ no choice	9%
No worries about parking	9%
Great/nice/good	6%
Avoid traffic congestion	4%
Clean	2%
Other	16%
Didn't like anything about it	7%

Dislikes about Transit in Other Cities

Nothing to mention/no dislikes	31%
Delays/long waits/slow	13%
Crowded	10%
Unsavory characters/safety concerns	10%
Inconvenient schedule/general inconvenience	6%
Dirty/smelly	6%
Limited destinations/didn't go right places	4%
Weather	3%
Parking	2%
Confusing/difficulty figuring out transfers	2%

Cost	2%
Too far away	1%
Other	9%
Don't know	11%

Top Reasons for not riding the Valley buses
40% Have a car
17% Bus inconvenient / not enough service
17% No bus in my area
11% Takes too long
8% Bus too far away
6% Need car for work
6% No need to go places
4% Changed jobs / moved / bus no longer convenient
4% Work and home too close
4% Retired
2% Safety
1% Need car for errands
1% Need car for daycare
1% Too much hassle

Reasons to consider taking the bus
55% Maintain air quality
43% Reduce street congestion
30% Save gas money
7% Conserve energy
6% Save insurance money
5% Save wear and tear
4% Safety / fewer accidents
3% Avoid driving stress
2% Use of riding time
6% No good reasons
10% Other
6% Don't know

Reasons driving is preferred
45% Independence / convenience
14% Takes too long by bus
12% Have kids / easier to transport
10% No bus service in area
7% Run errands / transport packages
7% Safer to drive
5% Everything is close by
5% Need vehicle for work
2% Age (elderly)
0% Value privacy / driving alone (past was 11%)
14% Other

5%	Don't Know

Circumstances for Considering Public Transit
25%	Get places in same amount of time
14%	Car broke down / did not have car
14%	Available in my area
6%	No transfers
6%	More convenient stops
6%	Saved rider money (gas prices went up)
3%	Adjustable work hours
3%	Rail instead of bus
3%	Service to sporting events
2%	Limited stop service
2%	Free parking at bus stop
1% each	Special discount, special lane for buses, employer discount, guaranteed ride home, evenign service

A.11 Results of Technical Brainstorming Session

Summary of our technical brainstorming session, as part of our VSD analysis.

Results of Technical Brainstorming Session
December 6, 2009

Social Engagement:
- Social networking applications - bus book club, mothers with kids, wordoku fans
- App to enable people who want to talk on the bus
- Bus Ambassador program - sticker - give up seat
- Rate my XXX - ride quality, driver nice, sketchy area, ability to read, people-watching, coughers (medical routes), talkies
- Political engagement website - petition city council member

Incentives:
- Website encouraging "bus games"
- Points at retailers for riding the bus
- Social games - 4 square (merit badges), give points if give up seat, give point for helping blind people, point for picking up trash
- Bus scavenger hunt - what can you get to using the bus
- Bus-driving video game
- Sponsorship program for auto-drivers to pay for transit-users to ride the bus
- App - "bored on the bus" - listing of apps that help when nothing to do

General planning tools:
- Calculator app - environmental impact, financial, social, congestion, compare to car cost or Zipcar cost
- Commute calculator tool - accessibility of transit route include travel time and amenities (only rail, only express), include weekend service accessibility
- Transfer optimization software
- Calculator tool - knows about deals to inform if senior or if pass is more

Trip Planning:
- BETTER trip planner - minimize transfers, which stop to get off at, where to catch bus (side of street), context on maps (zoomed in with street names), address look-up needs work, map of results, back-up plan, multi-stop itinerary
- Public information using historical data - chance of getting p&r space, on-time performance, crowding, safety information (crime & accidents),
- Mapping of bike facilities with historical use
- Trip planner with elevation data
- Phone trip planner - voice recognition
- Car-rider path – tells you when better off taking the bus due to congestion
- Integrating ORCA fares into trip planner
- Information about type of bus - low floor, etc to help with planning bringing luggage on, etc.
- Tools to encourage walking - multi-modal support - 30 min bike ride and then I want to take bus

Maps and Information Tools:
- First-time rider tutorials - how to ride, trip planners, ORCA system, OBA, bike on bus, give up seat, riding with kids
- Route maps need more street names, downtown only maps
- Customizable map maker / guides for certain places / demographics - neighborhood, parents, tourists (especially non-smart phone users)

- Where are bus shelters
- Information about evening frequencies
- Interactive information displays at key locations
- App to help Metro more easily print out timetables, maps of stops
- Transit schedule customized for non-commute riders
- Zip-car locations

Notification:

- iPhone ping when to get off, through-routing
- Tool to announce stops
- Real time data - park&ride spaces, next bus, seat availability
- Real time notification - crime & accidents
- New service notification app
- Last call notification
- Reroute notification
- Late bus notification
- Passing up passengers / full notification
- Agency notification of issues at stops, shelters
- Agency notification of where I can't go that I want to
- Website - demand locations for service
- App to notify driver to hold a bus for a transfer
- Hot running notification tool for drivers - amount time behind
- Weather app to tell when to take your rain coat
- Profiles that you can set up
- Bike & bus integration - bike racks full

Accessibility:

- More / simpler devices
- Hands-free operation of iPhone
- Access bus improvements
- Real-time arrival for Access buses, prediction of destination arrival time
- Stop & bus accessibilty information for wheelchair users
- Rate my route for Access
- Notes / SMS to dispatch or driver for non-speaking Access users
- Tools for blind / deaf-blind users
- Access routing tool for agency, with window of time arrival possible
- Senior aspects of each tool

Other:

- Testimonials on website
- Simulate APC data using OneBusAway requests
- Put money on ORCA card through app
- Donate app
- App to help transit agencies make data public - common license for access to data
- Photos of banned passengers on website

Appendix B

SURVEY EVALUATION APPENDICES

B.1 Primary Survey Artifact

The primary survey for OneBusAway user evaluation.

Your Tools Alan Borning (borning) Help

WebQ

OneBusAway Survey

Summary Build Results Preview

Add questions or general content to your survey by selecting an item from the drop-down menu and clicking **Add**.
View examples of question types.

Add item: Short response at end of survey Add

Print survey content Edit appearance

Page 1 Hide details Preview

General content

Edit Copy Logic Move Delete

We are researchers at the University of Washington who are trying to better understand how people use the OneBusAway real-time transit information system, and whether using the system changes their impressions of using public transit and how they use public transit. This survey will take about 15 minutes to complete. All your responses will be recorded anonymously.

At the end of the survey, you will be invited to enter a drawing for a $25 iTunes or University Bookstore gift certificate for people who participate in the survey. We will give out a total of two gift certificates. Entering the drawing is entirely optional, and there won't be any link between your responses on the survey and your email address for the drawing, to preserve anonymity.

If at any time during the survey you want to terminate your participation, simply close your browser window and your responses will not be recorded. Also, if there is any particular question you don't want to answer, just skip it and go on to the next.

You must be 18 years or older to participate in this survey.

If you agree to participate in this survey, please click the "Next" button to move on to the survey proper. If you don't want to participate please click "Cancel".

Join pages

Page 2 Hide details Preview

Multiple choice - one answer (menu)

Question 1

Edit Copy Logic Move Delete

Approximately how often do you ride the bus each week, on average? (If your trip involves a transfer, please count that as just one trip. However, count going to and returning from a destination as two trips.)

Label
Question 1.

- (•) Select one...
- ( ) I don't regularly ride the bus
- ( ) 1-4 times
- ( ) 5-8 times
- ( ) 9-12 times
- ( ) 13-16 times
- ( ) more than 16 times

Insert break

Multiple choice - multiple answers (check)

Question 2

Edit Copy Logic Move Delete

For what purposes do you take the bus? (Please check all that apply.)

Label

Question 2.

- ☐ work
- ☐ school
- ☐ personal business
- ☐ shopping
- ☐ leisure
- ☐ Other:

Insert break

General content

We would now like to ask a series of questions about the real-time bus arrival information available in OneBusAway and how you use it.

Edit Copy Logic Move Delete

Insert break

Multiple choice - one answer (menu)

Question 3

Has the number of bus trips you take per week for work or school changed as a result of using OneBusAway?

Edit Copy Logic Move Delete

Label

Question 3.

- ◉ Select one...
- ○ 3 or more additional trips on average
- ○ 2 additional trips on average
- ○ 1 additional trip on average
- ○ no change
- ○ 1 fewer trip on average
- ○ 2 fewer trips on average
- ○ 3 or even fewer trips on average

Insert break

Multiple choice - one answer (menu)

Question 4

Has the number of bus trips you take per week for other purposes changed as a result of using OneBusAway?

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Label

Question 4.

- ◉ Select one...
- ○ 3 or more additional trips on average
- ○ 2 additional trips on average
- ○ 1 additional trip on average
- ○ no change
- ○ 1 fewer trip on average
- ○ 2 fewer trips on average
- ○ 3 or even fewer trips on average

Insert break

Multiple choice - one answer (menu)

Question 5

Has using OneBusAway changed your overall satisfaction with using public transit?

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Label

Question 5.

- ◉ Select one...
- ○ much less satisfied
- ○ somewhat less satisfied
- ○ no change
- ○ somewhat more satisfied
- ○ much more satisfied

Insert break

Long response

Question 6
Following up on the previous question, if your overall satisfaction with using public transit has changed, please describe how:

Edit Copy Logic Move Delete

Label
Question 6.

Insert break

Multiple choice - one answer (menu)

Question 7
Is there a change in how much time you spend waiting for the bus for each trip as a result of using OneBusAway?

Edit Copy Logic Move Delete

Label
Question 7.

- Select one...
- less time
- more time
- no change

Insert break

Multiple choice - one answer (menu)

Question 8
Has using OneBus had any effect on your feeling of safety while waiting for the bus?

Edit Copy Logic Move Delete

Label
Question 8.

- Select one...
- much less safe
- somewhat less safe
- no change
- somewhat safer
- much safer

Insert break

Long response

Question 9
Following up on the previous question, if your feeling of safety while waiting for the bus has changed, please describe how:

Edit Copy Logic Move Delete

Label
Question 9.

Insert break

Multiple choice - one answer (button)

Question 10
How likely are you to walk to a different bus stop based on information from OneBusAway? (For example, you might sometimes walk further down the route if the bus won't be there right away; or you might walk to a stop on a different route; or you might just stay at the same stop in any case.)

Edit Copy Logic Move Delete

Label
Question 10.

- more likely to walk to a different stop
- no change
- less likely to walk to a different stop

Insert break

Multiple choice - one answer (button)

Question 11
How often do you use OneBusAway?

Edit Copy Logic Move Delete

Label
Question 11.

- multiple times a day
- once a day
- once a week or more (but less than once a day)
- rarely

never

Insert break

Multiple choice - one answer (button)

Question 12
How likely are you to use OneBusAway for trips to work or school?

Edit Copy Logic Move Delete

Label
Question 12.

- very likely
- somewhat likely
- not very likely
- never

Insert break

Multiple choice - one answer (button)

Question 13
How likely are you to use OneBusAway for trips for other purposes?

Edit Copy Logic Move Delete

Label
Question 13.

- very likely
- somewhat likely
- not very likely
- never

Insert break

Multiple choice - multiple answers (check)

Question 14
Which OneBusAway tools do you frequently use to access real-time arrival information? (Please check all that apply.)

Edit Copy Logic Move Delete

Label
Question 14.

- website
- phone number
- SMS interface
- iPhone-optimized webpage
- iPhone native app (current beta testers only please)
- text-only webpage

Insert break

Multiple choice - multiple answers (check)

Question 15
Which OneBusAway tools do you occasionally use to access real-time arrival information? (Please check all that apply.)

Edit Copy Logic Move Delete

Label
Question 15.

- website
- phone number
- SMS interface
- iPhone-optimized webpage
- iPhone native app (current beta testers only please)
- text-only webpage

Insert break

Multiple choice - one answer (button)

Question 16
How do you usually find out bus departure time information?

Edit Copy Logic Move Delete

Label
Question 16.

- I look at the published schedule, either a paper schedule or online.

I look at OneBusAway and find out when the next actual bus is without considering what the published schedule says.

Other:

Insert break

Long response

Question 17
Are there any problems you've encountered with using OneBusAway, or do you have suggestions for improving it?

Edit Copy Logic Move Delete

Label
Question 17.

Join pages

Page 3 Hide details Preview

General content

Demographic Questions

Edit Copy Logic Move Delete

Insert break

Multiple choice - one answer (menu)

Question 18
What is your age?

Edit Copy Logic Move Delete

Label
Question 18.

- Select one...
- 18-24
- 25-34
- 35-44
- 45-54
- 55 or older

Insert break

Multiple choice - one answer (button)

Question 19
Gender?

Edit Copy Logic Move Delete

Label
Question 19.

- Female
- Male

Insert break

Multiple choice - multiple answers (check)

Question 20
Are there any children in your household more than half of the week? (Please check all that apply.)

Edit Copy Logic Move Delete

Label
Question 20.

- under 6 years old
- elementary school age
- middle school age
- high school age

Insert break

Multiple choice - one answer (menu)

Question 21
Annual household income?

Edit Copy Logic Move Delete

Label
Question 21.

- Select one...
- under $20,000
- $20,000 - $40,000
- $40,000 - $60,000
- $60,000 - $80,000
- $80,000 - $100,000
- over $100,000

Insert break

General content

Edit Copy Logic Move Delete

Thanks for helping out!

In appreciation for your participation, if you would like to be entered in a drawing for a $25 gift certificate for iTunes or the University Bookstore, please send an email to survey@onebusaway.org to indicate that you took the survey and would like to be entered into the drawing to be held August 24. We will give out a total of two gift certificates. You can submit your responses to the survey without entering the drawing. There will not be any link between your data from the survey and your email addresses submitted for the drawing, to preserve anonymity.

Add item: Short response at end of survey Add

Save for later

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Questions or comments?
Contact us or email catalysthelp@uw.edu

B.2 Primary Survey Artificat

The follow-up walking survey for OneBusAway user evaluation.

Your Tools Alan Borning (borning) Help

WebQ

OneBusAway Walking Survey

Summary Build Results Preview

Add questions or general content to your survey by selecting an item from the drop-down menu and clicking **Add**.
View examples of question types.

Add item: Short response at end of survey Add

Print survey content Edit appearance

Page 1 Show details Preview

This is a very short follow-up survey to t...

Join pages

Page 2 Show details Preview

Logic added

Question 1
Do you use a wheelchair?

Join pages

Page 3 Show details Preview

Logic added

Question 2
How likely are you to walk to a different ...

Join pages

Page 4 Show details Preview

Question 3
What sorts of different stops do you walk ...

Insert break

Question 4
Why do you walk to different stops? (Plea...

Insert break

Question 5
Any comments on how your patterns of walki...

Insert break

Question 6
Are there ways in which using OneBusAway h...

Insert break

Question 7
About how many times total per week do you...

Insert break

Logic added

Question 8
Please estimate the net number of addition...

Join pages

Page 5 Show details Preview

Logic destination

Question 9

Insert break

Why are you less likely to walk to a diffe...

Insert break

Question 10
Are there other ways in which using OneBus...

Logic added

Question 11
Please estimate how many fewer blocks you ...

Join pages

Page 6 Show details Preview

Logic destination, Logic added

Question 12
Any comments on how using OneBusAway inter...

Join pages

Page 7 Show details Preview

Logic destination

Question 13
What kind of wheelchair do you use?

Insert break

Question 14
Please describe how using OneBusAway has c...

Join pages

Page 8 Show details Preview

Logic destination

---...

Add item: Short response at end of survey Add

Save for later

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Questions or comments?
Contact us or email catalysthelp@uw.edu

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