REAL-TIME TRANSIT INFORMATION ACCURACY:

IMPACTS AND PROPOSED SOLUTIONS

A Thesis
Presented to
The Academic Faculty
by

Aaron Gooze

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in the
School of Civil and Environmental Engineering and the
School of City and Regional Planning

Georgia Institute of Technology
May 2013

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ACKNOWLEDGEMENTS

No achievement is ever completed alone, and proper acknowledgement of all of those who have supported me during this time is long overdue. I must first thank my parents for their support and words of encouragement throughout this process. While at times my work may have seemed strange or abstract, you were always interested my latest project and you were there for unconditional support.

In my leap back to graduate school, Dr. Kari Watkins was instrumental in providing numerous opportunities and substantial perspective during my time at Georgia Tech. Thank you for your advice and guidance and for allowing me to work with you on a wide variety of projects. It has been an honor and a pleasure to help you make your impact on Atlanta-area transportation issues.

I want to thank my advisor in the City Planning department, Dr. Jiawen Yang, who offered constructive recommendations on not just this research, but on transportation planning and finance in the U.S. and other areas of the world. In addition I want to thank my committee member from the University of Washington, Dr. Alan Borning. You provided valuable guidance during our work in Seattle and you have been a great champion of real-time transit information.

The research could not have been completed without the assistance of those who were involved on the OneBusAway project, including Brian Ferris, Scott Rose, Mark Hallenbeck and all of the people at King County Metro and Sound Transit. Thank you for taking the lead many years ago in progressing customer information and for continuing the push into the future.

Many thanks go out to my friends and colleagues in the Civil Engineering and City Planning departments at Georgia Tech. The people I’ve met and the perspective I’ve gained has provided me with relationships that will extend far beyond our time in graduate school.

Finally, I would not have reached this point without the continued support of my wife, Gillian Schauer. Whether it was a walk on the Beltline discussing statistics or the numerous weekend study sessions, you were there as an inquisitive mind and a motivating force as we embarked on our journey in Atlanta. I could not have done this without you and I look forward to where life takes us next.

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LIST OF ABBREVIATIONS

AVL	Automatic Vehicle Location
GTFS	General Transit Feed Specification
GPS	Global Positioning System
IVR	Interactive Voice Recognition
KCM	King County Metro
OBA	OneBusAway
SMS	Short Messaging System

SUMMARY

When presented in a practical format, real-time transit information can improve sustainable travel methods by enhancing the transit experience. Larger shifts towards public transportation have cascading effects on the environment, health and urban form. The research will identify the positive shift realized by the continued development of a set of real-time transit information tools, specifically in the Seattle region. In addition, it will analyze real-time prediction errors and their effects on the rider experience. Three years after the development of location-aware mobile applications for OneBusAway - a suite of real-time information tools - a survey of current users was conducted by the author in 2012 in order to compare the results to a 2009 study. The results show significant positive shifts in satisfaction with transit, perceptions of safety and ridership frequency as a result of the increased use of real-time arrival information. However, the research will also provide a perspective of the margin of error riders come to expect and the negative effects resulting from inaccuracies with the real-time data. While riders on average will ride less when they have experienced errors, a robust issue-reporting system as well as the resolution of the error can mitigate the initial negative effects. In response, the research provides a framework for a crowd-sourced error reporting process in order to improve the level of accuracy by means of a Transit Ambassador Program. Finally, a pilot program developed by the author is assessed against this framework and insight is provided within the context of the real-time information system.

CHAPTER 1

INTRODUCTION

For all of the benefits associated with public transit, the very notion of transit that is collective requires users to relinquish some control in their travel activity. They are beholden to the transit systems' particular route network, the schedule of its service, the spatial availability of the network and the comfort and convenience of the system. In many cases, this lack of control also results in increased travel times, waiting time and thus, frustration. For decades, riders have not made any strides in improving their situation while single-occupancy vehicle users realized a number of improvements in riding comfort, mobility and flexibility. However, in the digital age, there are an abundance of possibilities and potential with how transit service can be enhanced. Real-time transit information is an emerging tool to empower the transit rider to efficiently plan their travel activity and to take back some of that control they relinquished. Wait-times can be reduced, route selection can be optimized and in general, satisfaction with the transit system can be improved just with the answer to a simple question: When will my bus arrive? While a simple response is all that is necessary, the steps to provide an accurate response are extremely complex. From that perspective, the core objectives of this research are to not only expand on the evaluation of the empowering effect of real-time transit information, but to analyze the impact that inaccurate information can have on these underlying benefits and how best agencies can adjust in order to provide the most precise answer to that very simple question.

CHAPTER 2

BACKGROUND

To properly assess the impacts of real-time transit information, a thorough understanding of the role of public transit within the realm of transportation is appropriate along with assessing the functionality of automatic vehicle location systems in the context of public transit system operations.

2.1 Current Transportation Issues

Throughout history, urban regions have faced numerous issues related to the efficient movement of people and goods both within and outside of their boundaries. While technology has continued to progress in resolving propulsion challenges and researchers have advanced in understanding traveler behavior, four key issues have consistently been at the forefront for transportation planners: congestion, equity, safety and the environment. Recent analysis reveals the role that public transit has in this context, and the effectiveness that a properly operated system can have in addressing the underlying sources of the transportation problem.

2.1.1 The Role of Public Transit in Solving the Issues

<u>Congestion</u>

It is no surprise that the most efficient means of reducing congestion within urban areas is to decrease the total number of vehicles on the road by travelling collectively. This can take on the form of carpool usage, vanpool and demand-responsive transit; however the most effective means of leveraging collective transportation is via fixed-route public transit. The Urban Mobility Report of 2012 estimated that congestion in 2011 caused urban Americans to travel 5.5 billion hours more, with a congestion cost of

$121 billion. In that report, researchers calculated that yearly delay saved by public transit amounted to 865 million hours, or $20.8 billion dollars in travel costs while traffic operational treatments only saved 374 million hours and $8.5 billion dollars *(1)*. It is well understood that the transportation community cannot "operationalize" out of congestion and the most efficient means to allow for urban growth is to fully leverage the power of public transit.

Environment

With the noted benefits of reduced congestion via collective transportation, the environmental issues stemming from transportation can be addressed via public transit. A shift from single-occupancy vehicle trips to public transit trips inevitably reduces the total emissions produced on a per-trip basis along with the collective reduction in overall vehicle-miles traveled. The Federal Transit Administration released a report in 2010 that determined the pounds of carbon dioxide (CO_2) emitted per single-occupancy-vehicle were .96 per passenger mile compared to .45 per passenger mile for transit *(2)*. A report by ICF International in 2009 concluded that public transit saved roughly 37 million metric tons of carbon from being released into the atmosphere annually, or the equivalent of planting a forest the size of the state of Indiana *(3)*.

Equity

Besides the congestion and environmental benefits, public transit provides equitable mobility and accessibility for all citizens, regardless of one's ability to own and operate an automobile. As of 2012, a report by the American Automobile Association calculated that the average yearly expense of owning and operating a car was almost

$9,000 *(4)*. Contrast this with a typical yearly expense of roughly $1,200 for monthly transit pass expenditures[1]. In addition, numerous reports have detailed how minority groups have a higher propensity to not have access to a vehicle while people with disabilities and no ability to operate a vehicle rely solely on public transit for their mobility needs *(5)*.

<u>Safety</u>

Finally, the benefits of increased safety realized by the usage of public transit should not be understated. Motor vehicle accidents are the cause of the highest percentage of deaths amongst age groups 44 and below and the accident rate on a per-vehicle-mile basis is far higher for single-occupancy vehicles as compared to public transit *(5)*. In addition, older adults are at a greater risk of accident while driving behind the wheel while public transit provides mobility with a higher safety level for this aging population.

2.1.2 Automatic Vehicle Location Information Role in Transit

With the understanding of the role that transit can play in solving core transportation issues, the role of automatic vehicle location information (AVL) within public transit provision is a suitable next step in assessment. There are three core aspects

[1] As sampled from the top 10 largest U.S. transit agency monthly pass programs

of public transit in which real-time vehicle location information plays a pivotal role: operations support, planning and customer information *(6)*.

<u>Operations support</u>

Case studies and research of systems asserts that the knowledge of vehicles' locations allow transit agencies to operate in a more efficient and cost-effective manner *(7)*. AVL information is still relatively new with many strides made within the last 10 to 15 years in GPS technology development and the expansion of the availability of the GPS satellite system *(8)*. With the aid of this information, transit agency operations managers can efficiently manage the fleet in real-time, making operational decisions based on a vehicle's schedule deviation, its location and its current speed of service *(6)*. In addition this provides improved response for any on-the-street maintenance issues that may arise as managers are able to view a vehicle's location the moment that a breakdown occurs with no comparative delay to the previous voice-radio relay response systems.

<u>Planning</u>

In addition to the benefits provided for the day-to-day management of the system, real-time vehicle location offers support for transit planning purposes. Archiving each vehicle's location information in a database format allows agencies to accurately assess a particular route's performance metrics such as on-time adherence, speed variation and deadhead mileage occurrence. This allows transit planners to develop future service changes based on historical information that is easily collected from each vehicle. Additionally, the information gained from the AVL systems can automate complicated reporting processes for the National Transit Database system, thus relieving agency staff to dedicate their limited time to other activities *(9)*.

Customer Information

Finally, emergence of vehicle location information in real-time provides new avenues for agencies to convey information to the riding public via enhanced customer information systems. Riders now have the ability to view a particular vehicle's exact location in order to more efficiently plan their trip. In addition, agencies can provide enhanced information from the location data such as the expected delay of a particular route or the street deviation of a trip due to traffic disruptions or adverse weather conditions. This improvement in customer information from the era of printed fixed schedules benefits all riders who seek to make the most informed decisions when embarking on their travel activities.

The following chapter will assess the state of real-time information and its expansion due to these benefits while providing an in-depth assessment of previous research related to real-time information impacts on the riding community.

CHAPTER 3

LITERATURE REVIEW

3.1 Expansion of Real-time Customer Information

With the increased need for real-time vehicle information within the public transit realm, agencies have aggressively expanded the usage and complexity of their real-time systems. Early AVL systems utilized sign-post beacon placements as a means of determining vehicle locations automatically along the route. These systems were first installed as early as 1968 with expansion throughout the U.S often via federal demonstration funds. Due to the large investment required and inconsistent results, adoption was slow and by the late 1980’s and early 90’s, a small percentage of agencies in North America were utilizing AVL technology. By the mid 1990’s with the advancement of Global Positioning System (GPS) technology and the rapid decline in price, transit agencies were now able to deploy AVL systems with relatively low cost and higher levels of accuracy. Indeed, a longitudinal study revealed that by 2000, there had been a 259% increase in the number of agencies utilizing AVL technology as compared to 1995 *(10)*. By 2000, 88 transit agencies had AVL systems while 142 were planning deployment *(11)*. While it is unknown at this time the exact number of agencies with real-time information deployed, the emergence of the “open-data” movement is exhibited by the 234 agencies in the U.S. currently with publicly available GTFS feeds, however not all of these agencies provide open real-time information *(12)*.

Real-time Customer Information Systems

Within the realm of real-time customer information, a number of methods exist in which to disseminate it with variations in the cost and complexity of the data capable of being transmitted.

Variable Message Stop Displays

This technology was the first instance of real-time information provision as agencies relayed vehicle location data from internal systems to message display signs permanently placed at transit stops. This method is still widely used with many large agencies, especially at major transfer stations, rail stations and other high-trafficked areas of a transit system. The cost can often be high due to the hardware and installation required along with the continued maintenance during the life of the system *(13)*.

Web-based Information

With the expansion of internet usage among riders, providing real-time information via web-based technologies has increased due to the low-cost nature of the medium. Web-based methods allow riders to obtain information in their home, at work or on any web-enable mobile phone. The hardware is often provided by the user themselves via their own personal computers or mobile devices and as such, agencies are only required to supply the underlying web server and data.

SMS

Adoption of cellphone technology has allowed agencies to provide basic vehicle location data to customers via short messaging systems, or SMS. This allows riders to send a simple request via text, with an automatic response from the agency regarding the vehicle location and expected arrival time. Again, the hardware medium is supplied by the riders themselves and the agency is only responsible for ensuring the provision of information to an SMS request.

IVR

For those riders with no SMS-capable phone or with visual-impairment, integrated voice recognition systems provide riders with the same level of real-time information. While often more expensive than website or SMS deployments, IVR systems provide equitable access for all riders to the real-time information system.

Mobile Applications

Within the past four to five years, the rapid increase in smartphone usage has allowed agencies to leverage this improved technology as a means of delivering real-time information in a more customized location-aware basis at a much lower cost *(14)*. Typically, the agencies do not develop the mobile interface internally, but rather they provide the data for third-party developers to create and distribute native applications for all platforms. The term “open-data” in this context refers to the agency’s publication of their real-time vehicle locations in a standardized format. This method of information dissemination has truly unleashed the potential of real-time information, of which quantifiable benefits have begun to emerge.

3.2 Real-time Information Benefits

With the understanding of the previous environment and current state of real-time information, a large number of studies have assessed the benefits of providing real-time information to riders. Historically, these studies have utilized stated preference surveys and subsequent simulation techniques, however there have been recent gains in applying empirical analysis in formulating a more robust and valid assessment of the true benefits of real-time customer information. While a number of quality-of-service factors have been positively impacted by real-time information, the cascading relationship of three key aspects – wait-time, satisfaction and ridership - is highlighted in greater detail below.

Wait-time

Since the beginning of travel behavior analysis, researchers have attempted to quantify the added burden of out-of-vehicle travel time in comparison to in-vehicle travel time *(15)*. In many of these studies, the ratio of the traveler's perception out-of-vehicle time to in-vehicle time ranges as high as a factor of 2.5. Many travel surveys, when evaluated with multinomial logit modeling techniques reveal this bias of travelers against out-of-vehicle travel time *(16)*. Dr. Chandra Bhat of the University of Texas has devoted much of his research in part to mode choice and logit modeling and many of his studies have conveyed the large impedance present in out-of-vehicle travel time *(17, 18)*. Besides the variance exhibited between in and out-of-vehicle travel time valuation, a number of studies have measured the difference between perceived and actual wait-time at transit stops. Dr. Mishalani of Ohio State University assessed passengers of the campus bus system to compare actual versus perceived wait times at the bus stops without real-time information. He found that overall, customers over-estimated their wait time by 14.5% *(19)*. Regarding the impact of real-time information on perceived and actual wait-times, numerous studies have quantitatively assessed the impact of real-time information provision. As early as 1995, Dr. Thomas Reed performed a conjoint analysis to hypothetically gauge the effectiveness of real-time information on wait-time reduction. A study in 2006 showed a reduction in wait-time of 20% after the installation of real-time displays at stops in The Netherlands *(20)* while a study by Dr. Kari Watkins in Seattle utilized quantitative analysis to measure the difference between an observed rider's actual wait-time versus the perception of their wait-time. Her study determined that of riders who utilized real-time information, there was a 30% reduction in the perceived wait-time *(21)*. Finally, Dr. Dun Chen in 2012 evaluated the real-time information impact in the city of Taipei in order to develop a true economic benefit achieved via this technology. In this study utilizing logit-based modeling techniques, he estimated that there was an aggregate $80,000 economic benefit on a daily basis due to reduced perceived and actual waiting times *(22)*. These studies all revealed the general notion that real-time information was effective at reducing both perceived and actual wait times, an aspect of a traveler's journey that has a greater impact on mode choice than overall travel time.

Satisfaction

In general, reductions in wait-time are thought to be linked to overall satisfaction of a service, not just in public transit but in all service-related industries *(19, 23, 24)*. However, while the linkage between those two aspects in public transit are shown to have a strong relationship *(25)*, it is often difficult to directly link the provision of real-time information to an increase in satisfaction. The ability to control for a rider's underlying satisfaction level with transit itself along with a number of outside factors that drive their satisfaction level is required in order to isolate the true impact of real-time information. The Countdown System in London has conducted a number of studies since deployment of their real-time information displays. Much of the data has focused on improvements in customer's perceptions of service reliability and their reduced amounts of stress and wait times *(13)*. Studies of the Transit Watch system in Seattle during the early 2000's attempted to directly measure improvements in satisfaction with riders as a result of real-time information display installation. While researchers found that riders perceived the information as a benefit, they were unable to define a significant change in overall satisfaction with transit *(26)*. Dr. Dziekan and her research team sought to isolate the behavioral aspects of real-time information systems via direct studies and meta-analysis. They found that a number of factors related to real-time information had an impact on satisfaction, including improved perceptions of safety and reduced waiting times *(20, 27)*. Again, it was difficult to truly ascertain the impacts of improved customer information levels of satisfaction with transit. In 2008, Dr. Feng Zhang evaluated riders in the University of Maryland bus system in an attempt to bridge the gap between stated-preference and empirical analysis. Utilizing before-and after panel analysis, his study revealed through ordered probit modeling the significant relationship between use of the real-time information system and overall satisfaction with transit. A stronger relationship was observed directly in 2010, with the research conducted by Dr. Watkins and others at the University of Washington. A question from the study directly asked a user to state their change in satisfaction with transit as a result of utilizing the real-time information system. In response, over 92% of riders stated that they were somewhat or much more satisfied with transit due to real-time information *(28)*. Again, biases via stated preference questions must be taken into account, however it is promising to see the potential linkage between real-time information and rider satisfaction.

Ridership

How best can researchers relate an abstract idea of satisfaction from real-time information to improvements in ridership? As early as 1994, Abdel-Aty asked for the respondents' stated preferences to use transit and 38% said they would try transit if given real-time information. The study controlled for a number of socio-economic factors and commute patterns in order to isolate that factor and to provide a theoretical basis for the linkage between real-time information and ridership. Hickman and Wilson in 1995 provided a modeling framework in which to simulate traveler path choice based upon the provision of real-time information. While the simulations yielded modest results in the ability to improve traveler's travel time and variability, the provision of real-time information did have a significant impact on directing riders to a path in which arrival times were supplied. This early study highlighted the mode shift potential with the provision of real-time information. In 2007, Litman provided a summarization of transit agencies and the impact of real-time information on ridership, however almost all of the agencies were outside of the U.S. and many of their ridership impacts were conflated with other factors *(29)*. More recently, in 2008, Dr. Zhang and his research team conducted a number of studies of the University of Maryland shuttle system and the deployment of its real-time information system, which included variable message signs, a website and mobile-web portal along with SMS and IVR capability. A general transportation attitudes survey, a 1-day travel diary and a cross-sectional onboard survey all provided the data for the study, with surveys conducted six months before and one month after the real-time system deployment. Log-linear regression analysis was utilized to reveal the impact of the real-time system on monthly shuttle trips. This analysis actually revealed no statistically significant relationship between real-time information and changes in monthly ridership while it did reveal significant impacts on reducing anxiety and on increasing overall satisfaction with transit. A major drawback of this study however was the short time allowed for real-time information to realize its impact on riders as the study was conducted only a month after system deployment. In 2010, Dr. Watkins also evaluated the ridership impacts of real-time information in addition to the impacts on wait-time perceptions. The survey of Seattle-area riders revealed that 20% of respondents claimed to take at least 1 or more additional transit trips per week due to usage of the real-time information. While this change may have been affected by self-report bias, it is valid to note the presence of a perceived shift in transit trips, or the behavioral change in the propensity to take transit. Whether that resulted in actual changes in transit ridership was not a primary focus of the study. In addition, the study was based on a real-time information system that had not yet deployed mobile location-aware applications, and thus the effects were the result of web-based, SMS and IVR technologies only.

In, 2011, Dr. Lei Tang and Dr. Thakuriah sought to build on these previous stated preference and simulation-based assessments of real-time information by applying an empirical framework to the analysis. The team evaluated Chicago Transit Authority (CTA) ridership changes stemming from the phased deployment of their real-time information system. Controlling for a number of outside factors such as gas prices, employment levels, weather and other socioeconomic variables, the research team evaluated longitudinal ridership data from 2002 to 2010. Within that time period, from 2006 to 2009, the CTA deployed real-time information on a route-level basis. The research team compared ridership data for each route from one year before real-time information became available on that route to a year afterward, while those routes with no real-time information served as the control group. The regression results yielded a significant coefficient for the provision of real-time technology, on the order of 126 additional riders per weekday per route. This constituted between 1.8-2.2% of additional riders based on average weekday ridership totals of the system. The authors sought to obtain more details regarding this impact by evaluating the ridership change differences between routes in both a spatial and temporal context. Those routes that implemented real-time information earlier in the process saw a lower ridership increase than those routes deployed in later years. The authors hypothesized one possible reason was due to the increased system-wide adoption of the technology by riders who had experienced it with other routes. Thus, the later routes in the system most likely had riders who were already familiar with the technology and were more adapt to adjust their ridership behavior upon deployment of their particular route. Along these lines, one major shortcoming of the study as noted by the authors was the arbitrary one-year cutoff point in which to measure ridership gains. With noted technology adoption patterns *(30)*, analysis with a longer time-period would most likely yield even larger ridership impacts. In addition, mobile location-aware applications were not fully deployed until late in 2009 and most likely the adoption rate did not increase until a time period outside of this study.

3.3 Research Needs

Indeed, as noted by many of the previously described studies, there exist a number of gaps in the existing research related to the true impacts of real-time information. This stems from the temporal constraint present in many studies in which their evaluation periods were too soon after the deployment of the real-time information systems. In addition, due to the recent development of mobile location-aware applications and the rapid adoption of these devices, none of the studies were able to capture the effects of the additional features present with native mobile applications. That said, the impacts measured on wait-time, satisfaction and ridership all were assessed under the assumption of a suitable level of accuracy within the real-time information systems. A large amount of research has been devoted to improvements in the algorithms underlying the real-time predictions. The seminal work conducted by Dr. Dan Dailey and others at the University of Washington was vital in enhancing the level of accuracy with vehicle location predictions, specifically in the Seattle region *(31, 32)*. Researchers in Korea sought to apply systematic adjustments to address data collection errors, information processing errors and random arrival errors *(33)*. An additional step involved the work of Dr. Mazloumi and his research team as they attempted to improve prediction methodologies by fully incorporating current traffic flow data within the real-time information process *(34)*. The commonality in all of these, however, was an assumption that errors in real-time predictions negatively impacted riders. While this basic assumption is sound, the magnitude of the effect is still not understood and has not been evaluated in a systematic method. With the rapid expansion of real-time information, researchers have sought to quickly measure and assess the benefits of the system in order to aid in policy decisions. Yet understanding the cascading effects of inaccurate predictions is just as necessary to guide an agency's development of its real-time information system.

As such, the primary objectives of this research stem from two divergent yet related concepts. While significant additional benefits exist when real-time information is provided in a mobile location-aware application, those benefits will be adversely affected by issues of data accuracy. The following chapters address this hypothesis and provide for a solution to the issues currently affecting transit agencies and their real-time information systems.

CHAPTER 4

REAL-TIME INFORMATION BENEFITS AND IMPACTS

4.1 Methodology

4.1.1 Background to the Situation

In the Seattle region, a number of local and regional agencies provide transit with the largest provider, King County Metro (KCM) handling 305,000 of the roughly 487,000 region-wide average weekday trips[2]. Beginning in the early 1990's, KCM installed roadside signpost beacons as a means of automatic vehicle location monitoring with upwards of 300 signposts in operation and coverage of an estimated 90% of the schedule time points in the system *(7)*. This early and revolutionary system provided data which allowed University of Washington researchers to develop a web-based portal called MyBus as a means of providing real-time information to riders *(32)*. This system not only displayed vehicle location information, it utilized a fully-developed algorithm with which to provide predictions on vehicle arrivals. Even with these revolutionary advances, the system was still somewhat underutilized due to the difficult user interface and lack of customization. In response, beginning in 2007, a PhD student at the University of Washington, Dr. Brian Ferris along with Dr. Kari Watkins and Dr. Alan Borning began to develop a set of tools to provide this real-time information in a user-

[2] Per 2012 fourth quarter ridership statistics from www.apta.com

friendly format. The program, now called "OneBusAway" (OBA) initially provided real-time transit predictions for the greater Seattle region via a custom-built website, a short-messaging service (SMS) and an Interactive Voice Recognition (IVR) system. Since deployment it has realized a significant increase in both functionality and use, with over 100,000 unique weekly users[3]. In conjunction with development of the technology, the research team conducted a survey in 2009 to better understand the user experience of real-time information provided by OneBusAway and the effects the information had on safety, time spent waiting and overall satisfaction *(28)*. At that time, the native mobile applications were still under development and almost the entire user base was accessing the real-time information via the desktop or mobile-optimized websites, or the SMS and IVR systems. The development of native applications for the iPhone and subsequently the Android and Windows phone platforms during 2009 and 2010 provided users with an enhanced level of customization, information and mobility. Riders now had location-specific real-time information along with enhanced map-based functionality with which to plan and adjust their travel. It should be noted that for the first three years, the entire development and implementation of the system had been conducted by University of Washington researchers and use of OneBusAway had only grown via word-of-mouth and grassroots expansion. In that sense, the OneBusAway product was always seen as a community supported product, with direct outreach from the UW team to the riders

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[3] Figures based upon correspondence with S. Morris Rose, the OneBusAway administrator in 2012

throughout the development period. The role of the agencies throughout had always been in supporting the provision of the vehicle location data in coordination with the MyBus system developed at the University of Washington. Not until a contract in August of 2011 did the three main transit agencies in the region - King County Metro, Sound Transit and Pierce Transit – provide financial support for the OneBusAway system. Beginning in late 2011, King County Metro began to convert its legacy signpost beacon vehicle location system to a GPS-based system. This process proved to be much more problematic to the OneBusAway real-time system as previously thought as the customization of OneBusAway to the legacy system was not built to handle the new GPS-based feed. In addition, there appeared to be issues related to the GPS-system itself, both with the vehicle reporting and the adherence prediction technology tracking systems. This assortment of change throughout the system cascaded to the information provided to riders as they were experiencing significant decreases in accuracy of the real-time predictions *(35)*. The rider community expressed a growing amount of frustration via online blog postings and email feedback to the OneBusAway team *(36–38)*.

As such, this situation presented a unique opportunity to significantly contribute to the immense amount of research already conducted on real-time information impacts. The timing of the previously conducted survey in 2009 offered the ability to measure the temporal shift in rider attitudes towards OneBusAway, with the added benefit of directly measuring the change due to the native mobile application deployments. More importunately however was the opportunity to accurately assess the existence of issues of data accuracy and to measure the impacts on riders due to this decrease in information reliability.

4.1.2 Survey Design

Based on this situation, the main goals in the survey design included two key elements: measure the shifts in rider perceptions from 2009 and analyze the impacts of inaccurate real-time information on the rider experience.

From a structural perspective, the first 22 questions were identical to those in the 2009 survey, as a means to facilitate direct year-to-year comparison. The new survey added an additional 9 questions, related specifically to data accuracy issues. In order to ensure consistency between the two survey years, the original 22 questions were left in the same order and were placed at the beginning of the survey to prevent any influence of the data accuracy questions on the original responses. The survey was instituted over a 30 day period through an online web-based form. Participants were recruited via the OneBusAway website and social media platforms (Facebook, Twitter) along with postings on the SeattleTransitBlog website, a popular transit-focused community blog *(39)*. An alert was also posted via the iPhone OneBusAway application service-alert system to notify users of the survey and a link was provided to allow users to conduct the survey with their smartphone. From these outreach methods, a total of 5,074 participants responded over the course of the survey period. It should be noted that roughly 180 respondents were pulled from the initial notices posted on the OneBusAway website and social media outlets, while an additional 430 participants responded to the SeattleTransitBlog notice. The original 180 respondents might be classified as "OneBusAway Power Users", in that they regularly check updates on the developer's website on new application features. Meanwhile, the 430 participants gained via the SeattleTransitBlog may be classified as "Transit Enthusiasts" as they exhibit a strong passion towards public transit information and growth. The remaining roughly 4,460 participants were collected via the iPhone alert notice. Potential survey bias in the results because of these participant recruitment methods is discussed in later sections.

4.1.3 Demographics of Respondents

In order to provide context to the responses, the demographic statistics of the survey participants were compared to the transit rider population of the King County Metro system and to the 2009 survey population. A survey conducted in 2010 by King County Metro provided the most recent snapshot of the riding populace. A comparison of the survey results is highlighted in Figure 1.

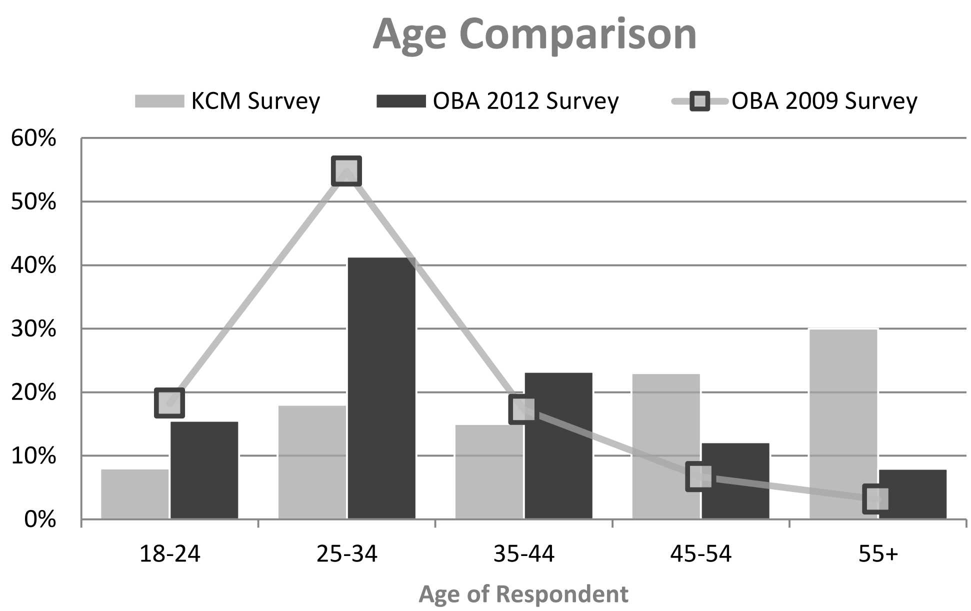


Figure 1: Age distribution of rider population vs. survey population

The distribution of age ranges for the OneBusAway survey is noticeably younger than that of the general rider population; however the variation exhibited in 2012 is less than that of the 2009 survey. This can be attributed to the deployment pattern of OneBusAway and its origins as a university-developed product, in which penetration to older riders has been slower to take hold. While the age distribution revealed some discrepancy of representation, the pattern of income distribution was more in-line between the survey and the general population as shown in Figure 2.

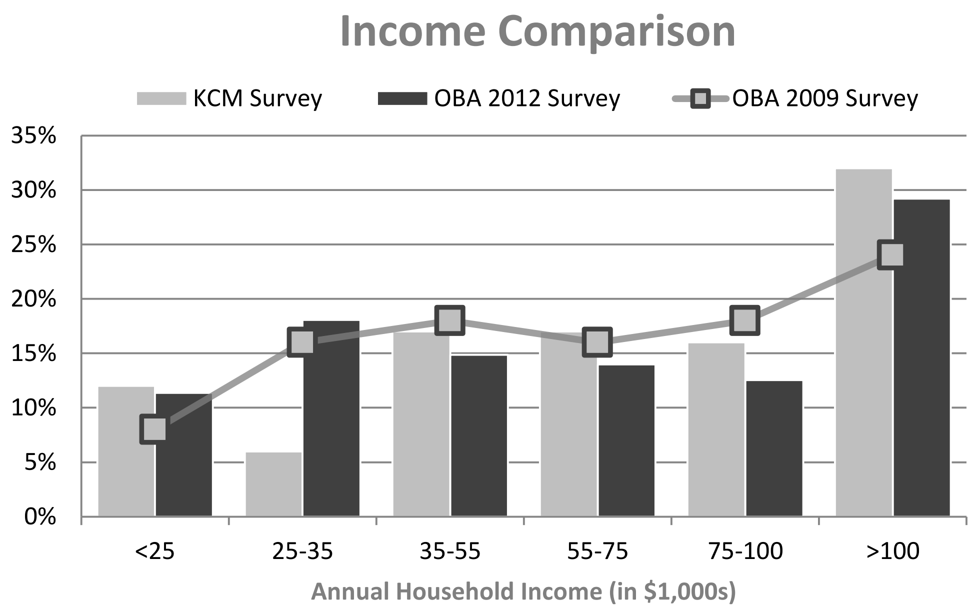


Figure 2: Income distribution comparison between rider survey and OBA survey

The spike in $25,000-$35,000 of the OBA survey population can most likely be attributed to the large student representation in the sample and the average salary earned by research students in that range *(40)*. In addition, while the KCM rider population is almost exactly split between males and females, the 2012 survey respondent population had a slightly larger amount of males, with 55% of the responses.

One final comparison to the King County Survey that serves as a major factor regarding the interpretation of the results is the frequency comparison. The King County Survey summarized riders as “Regular Riders” if they took 5 or more trips per month or as “Infrequent Riders” if they rode between 1 and 4 times in the previous month. While the OneBusAway survey asked riders to state how many trips they had taken in the previous week, the results can be interpolated to a monthly total for comparison purposes.

As of 2010, the King County Metro survey stated that 57% of their riding population were “Regular Riders” as compared to 80% of the OneBusAway 2012 survey population. This noticeable and significant difference can be attributed to the survey recruitment methods as well as the underlying goal of the survey. The objective of the survey was only to reach users of the OneBusAway real-time information application. As such, it was unlikely that infrequent riders of the system would be using any real-time information, especially due to the lack of marketing surrounding the program.

A final check on the survey population is the usage of the various platforms utilized to access the real-time information. Respondents were asked to list the methods in which they access OneBusAway. These respondents were compared with usage statistics pulled from the OneBusAway server that logged pings from mobile phone devices, website requests and SMS and IVR usage. The comparisons are shown in Table 1.

Table 1: Comparison of platform usage

	2009 OBA Survey	2012 Actual Usage	2012 OBA Survey
iPhone	2%	40%	63%
Android	n/a	29%	11%
Windows Ph.	n/a	2%	1%
Website	84%	27%	22%
SMS	9%	<1%	1%
IVR	5%	2%	2%

While 40% of the OneBusAway user population accesses information via the iPhone native application, 63% of the survey population classified themselves as iPhone users. The noticeable drop in the amount of website users from 2009 to 2012 is shown by the decrease from 84% to 22% between survey years. As expected, the previously described iPhone alert notice produced an overall survey response rate that was strongly weighted towards iPhone users while all other platforms were underreported. While the interface of the iPhone application is functionally similar to that of the Android or Windows Phone, it is still important to review the results of the survey with this discrepancy in mind while additional interpretations of this bias will be addressed in later sections.

4.2 Real-time Information Benefits

Comparison of the survey results to the 2009 survey provides the basis to ascertain any shifts in rider experiences and perceptions three years after the initial roll-out of the real-time information application. As previously noted, native applications for the iPhone, Android and Windows phone operating systems now offer location-aware capability as a means of enhancing the user experience. Understanding the impact of these mobile applications on the overall rider experience is possible by measuring the shift within four key response variables: safety, wait-time, satisfaction and ridership.

Safety

Regarding safety, the key question proposed to riders asked if OneBusAway had any effect on their feeling of safety while waiting for a bus. Respondents were asked to rate their change on a five-point likert scale from “much less safe” to “much more safe”. A comparison between the 2009 and 2012 survey yielded positive results related to safety concerns as shown in Figure 3.

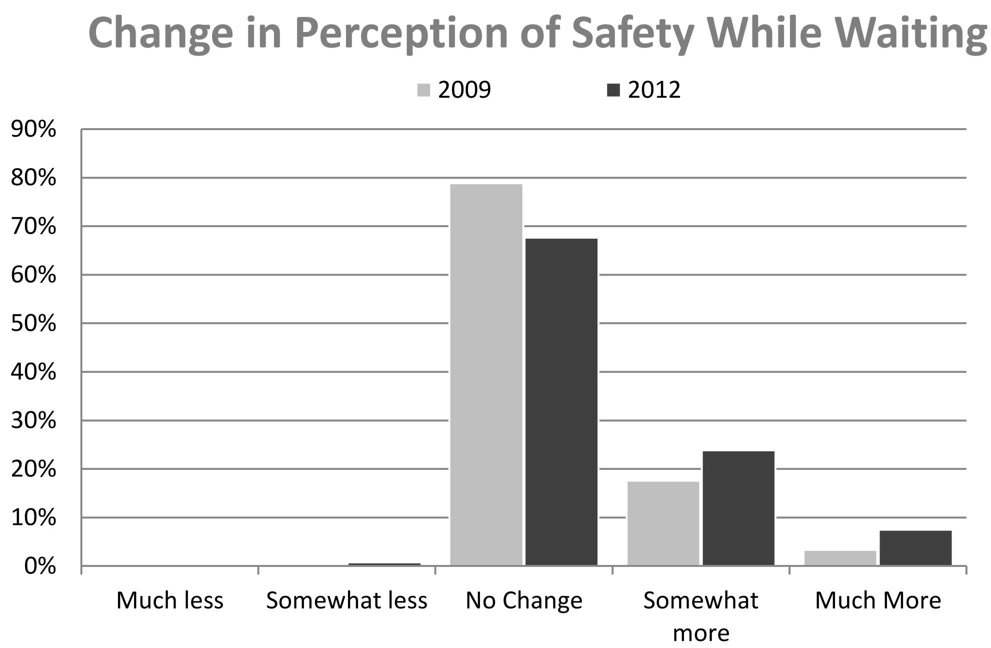


Figure 3: Perception of safety comparison

While 21% of respondents in 2009 stated that real-time arrival information made them feel "Somewhat" or "Much More" safe, over 32% in 2012 had the same positive shift in safety perception due to real-time arrival information, a significant change (*Kruskal-Wallis* X^2 = 21.2067, $p < .001$). The provision of the native applications may allow for a rider to wait inside a building for a longer period of time or the location-aware aspect of the mobile applications may provide for quicker results, and thus an enhanced ability for riders to feel in control of their situation.

Wait-time

The deployment of mobile applications actually showed no discernible change from 2009 to 2012 in the stated amount of wait-time by the respondents. While 91% of riders from the 2009 survey stated they spent "less time" waiting due to OneBusAway usage, the 2012 survey had 88% respondents with the same attitude. This inconclusive change can possibly be attributed to the broad nature of the question, in which only three options were provided: “less time, no change, more time”. Without a finer grain of detail, it is difficult to truly assess any noticeable shift in wait time due to mobile application deployment, however further detail was not possible due to the need to maintain consistency between the two survey periods. In addition, the high proportion of riders originally stating that they waited less provided little room for improvement in this metric. As such, it is still useful to note the broad impact on perceived and actual wait-time that real-time information can provide.

Satisfaction

As described from prior research, the linkage of real-time information to satisfaction has been difficult to measure. The question in the survey specifically asked “Has using OneBusAway changed your overall satisfaction with using transit?” In 2009, 48% of respondents stated they were “much more satisfied” with transit due to OneBusAway while in 2012, the percentage had increased to 51%. However, the shift is not significant as there was an increase in the amount of respondents stating a lowered amount of satisfaction due to OneBusAway in 2012 as shown in Figure 4.

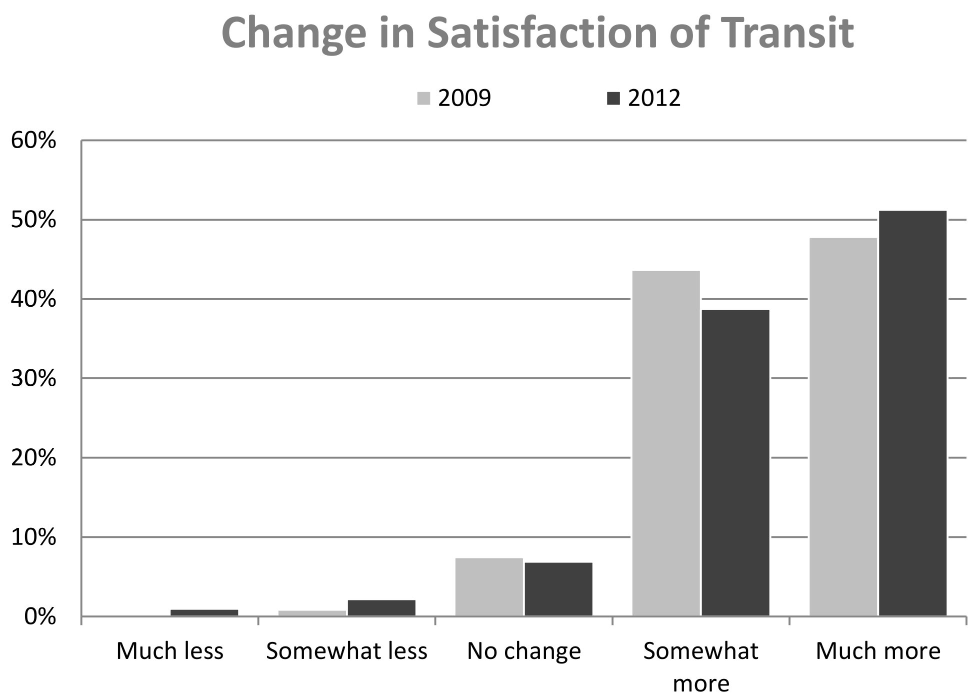


Figure 4: Change in satisfaction with transit due to OneBusAway

This strange phenomenon of inconsistent shifts in satisfaction will be discussed in greater detail related to data accuracy and impacts on riders. That said, while the survey revealed that real-time information continues to provide higher levels of satisfaction with transit, the shift due to mobile application deployment was possibly clouded by the increase of inaccurate prediction data.

Ridership

As stated in prior research, an improvement in perceptions of safety along with an increase in satisfaction can lead to an overall increase in trips taken via public transit. The survey asked respondents to state the change in their weekly ridership patterns as a result of using the OneBusAway system. Comparing responses between the 2009 and 2012 survey, Figure 5 and Figure 6 provide comparisons of the change in percentage of users who stated that they now take 1, 2 or 3 or more trips due to their real-time information use for both “Work or School” purposes as well as for “Other” purposes.

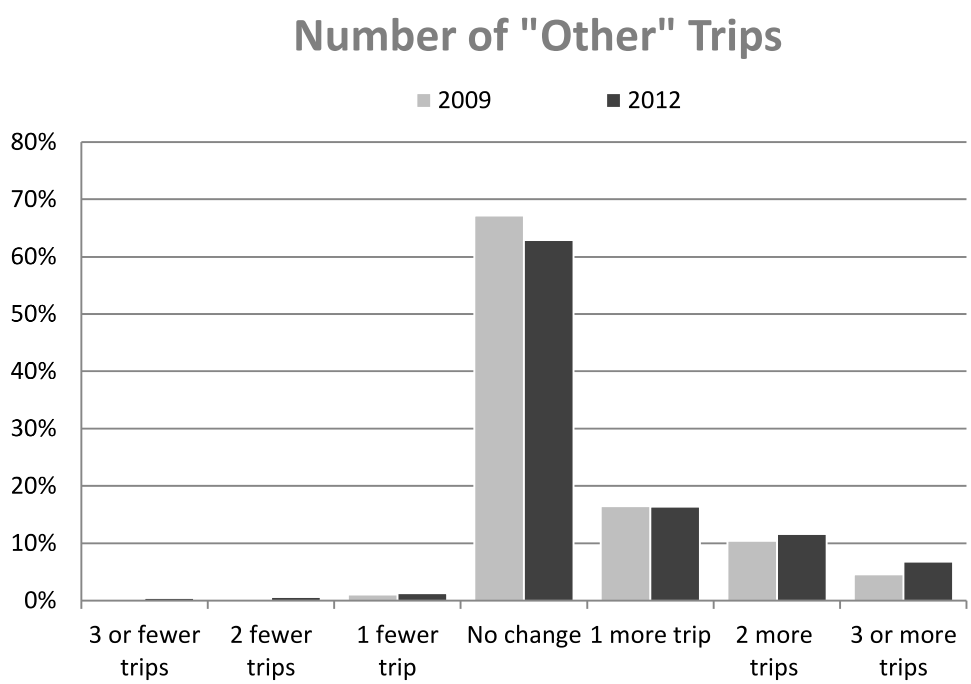


Figure 5: Change in weekly "Other" purpose transit trips due to OneBusAway usage

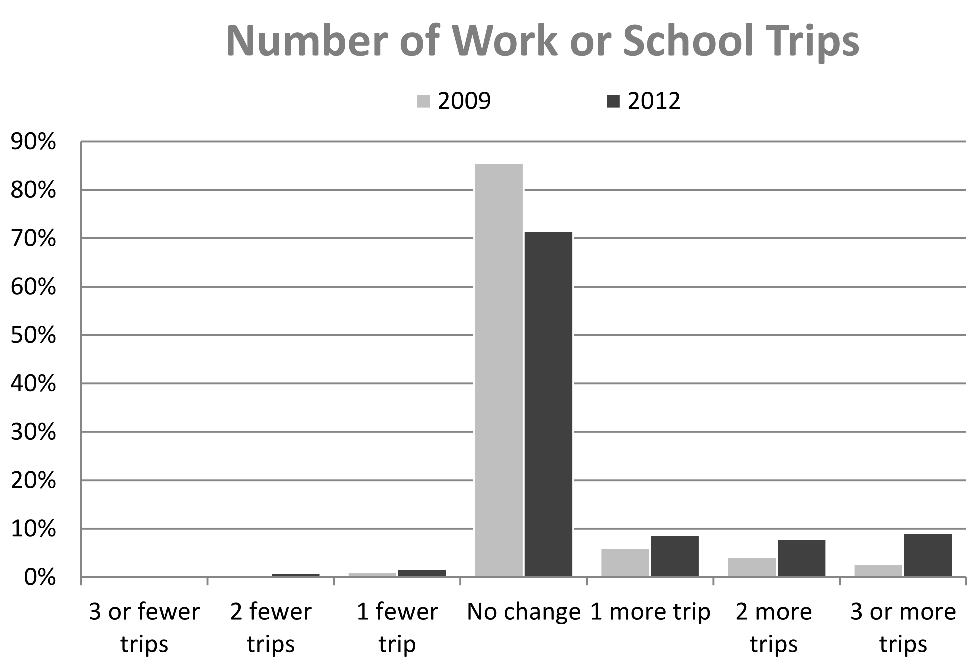


Figure 6: Change in weekly "Work or School" purpose transit trips due to OneBusAway

A consistent trend between “Other Trips” and “Work or School Trips” is the decrease in percent of respondents who stated that there was “no change” to the number of trips they took. The shift was highly significant in the “Work/School Trips” case ($X^2 = 42.8434$, $p < .001$) while in the “Other Trips” case it was significant at greater than 90% confidence ($X^2 = 3.1569$, $p < 0.1$). The larger shift in work/school trips could be caused by the notion of enhanced travel time reliability with real-time information provision. These trips most likely require a higher level of on-time reliability as compared to “other” trips, therefore riders may feel more empowered to utilize transit for work or school trips due to the ability to adjust their route choice with real-time updates. While the change in ridership is based on a stated-preference, it provides further support to prior research regarding the potential benefit to transit agencies and the community when real-time information is provided. For example, even if 5% of the riding populace in reality adds 1 additional trip per week, for a transit agency the size of King County Metro with 300,000 weekly riders, it can account for upwards of 15,000 additional weekly trips.

4.2.1 Usage of Schedule information

In comparison to user satisfaction and ridership changes, the percentage of real-time users who utilize the application as their main source of schedule and route information has realized the greatest change over the past three years. As Figure 7 shows, a much larger percentage of respondents stated that they referred to OneBusAway for schedule data in the 2012 survey compared to those respondents from 2009.

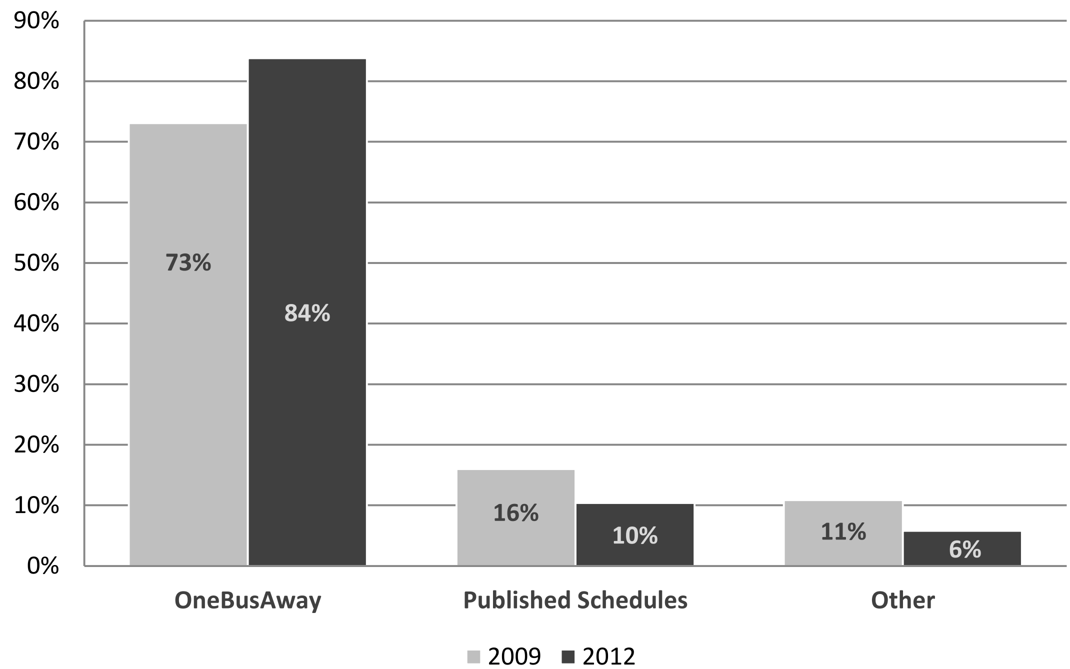


Figure 7: Primary method used for obtaining schedule information

The importance of this finding was noted in the previous 2009 study as it highlighted how a growing percentage of users relying solely on a real-time information environment could provide transit agencies with the underlying support to adhere to headway-based rather than schedule-based service *(28)*. A conversion to this form of scheduling however would either require almost 100% adoption of real-time information by riders or a decrease in headways in order to ensure that riders without real-time information did not wait longer than if a schedule had been provided. Furthermore, achieving that adoption rate may never be attainable, and thus any decision made regarding schedule and real-time information provision must take into account all riders in the system. That being said, this result lends credence to the role that third-party applications play within the transit information realm and the focus that transit agencies should have on providing accurate and detailed information in this open-data environment as a means of supplementing their internal provisions.

4.2.2 Summary of Shifts in Perceptions

The results from the real-time benefits portion of the survey showed a strong positive effect of the real-time application on rider satisfaction, trip frequency and safety perceptions. With the addition of location-aware mobile applications, satisfaction with transit along with the number of transit trips increased significantly when compared to the responses from the original survey in 2009. Again, it should be noted the survey bias present as a result of the oversampling of iPhone users along with self-report bias inherent in the methodology of the survey. However, this provides further evidence of the substantial impact that real-time mobile applications can have on the rider experience and ridership levels, thus benefiting not only the riders, but also the transit agency and the community as a whole. Finally, the positive shift in perceptions of safety from 2009 to 2012 highlights the indirect benefits of mobile real-time applications. Based on this collection of supporting evidence and prior research, investment in real-time information provision can be a valuable endeavor for agencies to undertake even in an environment of limited resources.

4.3 Impacts of Data Accuracy on Riders

Apart from offering a comparison between the two surveys, the main goal of the study was to gain a perspective on the level of accuracy that riders expect from real-time information systems in order to identify the effects of a decrease in prediction data quality. With the understanding that there are external factors in the transit system that prevent completely accurate modeling of arrival times (at least until the bus actually pulls up at the stop), the study looked at what margin of error (or "error tolerance") riders were willing to accept in their real-time prediction information and how those errors impacted their transit experience.

4.3.1 Error Expectations and Experiences

Error Tolerance

Before assessing the impacts of poor data quality and errors in real-time predictions, it is important to understand just how riders interpret predictions and their interpretation of what constitutes an error. To answer that question, the participants were asked: "If a bus arrives earlier or later than when OneBusAway said it would arrive, how many minutes before or after the OneBusAway prediction would you consider it an 'error'?" Respondents were given six ranges with which to answer, from "Less than 1 minute" up to "Greater than 10 minutes". As shown in Figure 8, the range with the largest percentage of respondents was "4 to 5 minutes" with a slight skew towards lower ranges.

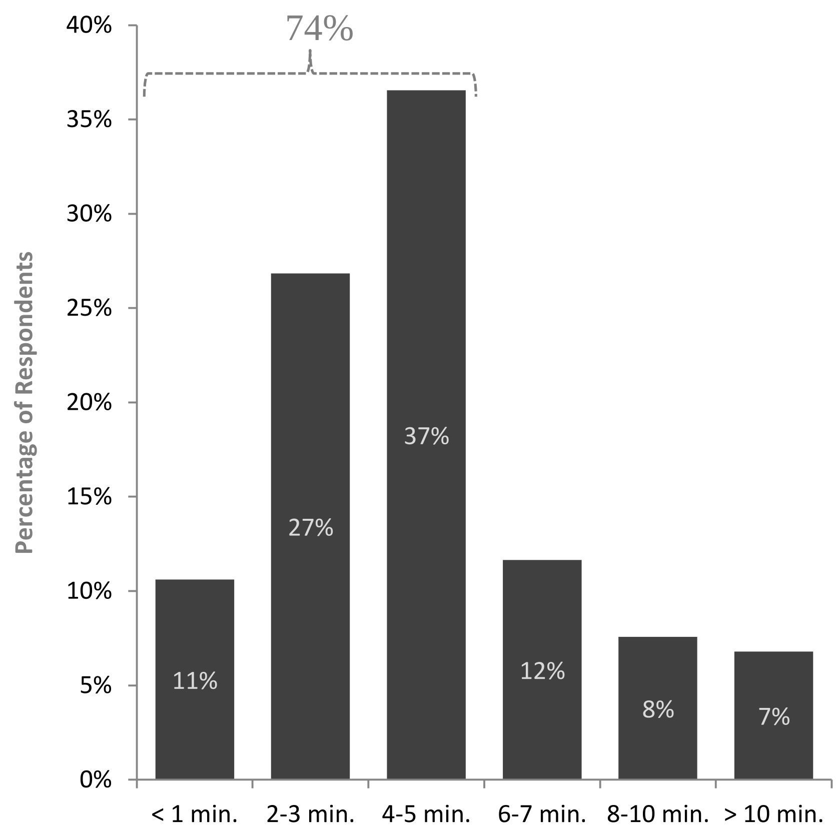


Figure 8: Range of error tolerance

In aggregate, 74% of riders had an error tolerance of 5 minutes or less when assessing real-time information. While the survey did not ask users whether there was a difference in error expectation for "early" or "late" predictions, a number of free-form responses provided insight into the different value placed on an early bus versus a later bus:

> "I'd consider a bus arriving 1 or 2 minutes earlier than predicted an error. But arriving 5 or later an error (missing a bus is a bigger deal than waiting a couple minutes)"

> "It's a complex issue dependent on many conditions. However, I usually don't consider less than 5 minutes difference an error. While it's hugely annoying if the bus is early and you miss it, I understand that sometimes it hits all the right lights with few passengers, which makes it early. After 5 min, though, I start to notice the wait time. By 10 minutes after, I definitely consider it an error."

With a general notion that “earlier is better”, agencies should attempt to strike a balance between ensuring riders arrive in-time against providing riders with too large of a cushion. As shown, if a bus arrives six minutes or later than predicted, a large majority of the riding populace will view the information as incorrect and will begin to distrust the predictions.

While the median of error tolerance from the survey was four to six minutes, different age and other population segmentations displayed varying expectations of real-time prediction accuracy. When compared to the age of the respondent, the error tolerance was significantly related (*Kruskal-Wallis* $X^2 = 21.1076$, $p < .001$). For example, 16% of those respondents who were 45 years and above deemed a prediction an error if it was off by less than a minute as compared to only 9% of the age group 45 years and under.

An additional segmentation of the population was based on ridership frequency and the difference in the respective error tolerances. The relationship between ridership frequency and accuracy expectations was also found to be significant (*Kruskal-Wallis* $X^2 = 63.0871$, $p < .001$). Indeed, as Figure 9 shows, of the “frequent riders” who take more than 16 bus trips per week, a larger percentage (34%) perceive an error if the difference between prediction and actual arrival is more than six minutes compared to “Irregular” riders, in which only 7% of that population have the same tolerance for errors.

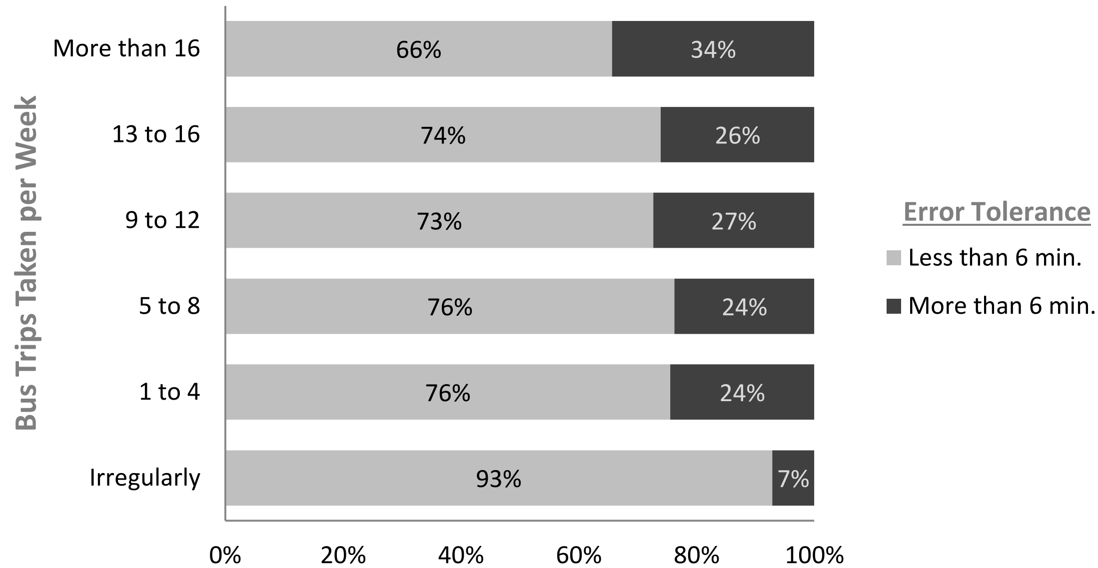


Figure 9: Error tolerance in comparison to ridership frequency

In terms of causality, one possible explanation is that people with a greater tolerance for errors in the predicted arrival times are more likely to take transit, while those with a lower tolerance for prediction variability are less likely to utilize transit. There may also be causality in the other direction as well: as transit users' ridership increases, they become more familiar with the OneBusAway application and its potential limitations based upon real-world constraints, and thus can better interpret the predictions and plan accordingly.

Errors Experienced

An understanding of the differences in expectations for accuracy amongst various transit user populations provided context to the amount and type of errors experienced, how they were reported and the overall effect on ridership and satisfaction. From the survey responses, 3,866 (or 77%) of participants had experienced an error in the real-time system within the previous six months. As a follow-up, the participants were also asked to list the types of errors they had experienced. The percentages were somewhat evenly distributed, with 72% stating that a “bus had arrived later than predicted”, 58% stating that a “bus had arrived earlier than predicted”, 70% stating that “OneBusAway predicted a bus, but it never arrived” and 28% stating that a “bus arrived while OneBusAway did not show it arriving”. While the question clearly asked riders specifically about errors with OneBusAway, it is possible that some respondents interpreted a late arrival which was predicted correctly as a prediction error. Due to the nature of the survey, it is difficult to ascertain riders’ exact perceptions of the real-time system. This concept is discussed in further detail in a later section.

Satisfaction Shift

An important goal to examine is the relationship between prediction errors experienced and overall transit satisfaction. As Figure 10 displays, by segmenting the population against those riders who had or had not experienced an error, the shift in the distribution of their stated change in overall satisfaction was significant ($X^2 = 33.9135$, $p = 7.762\text{e-}07$).

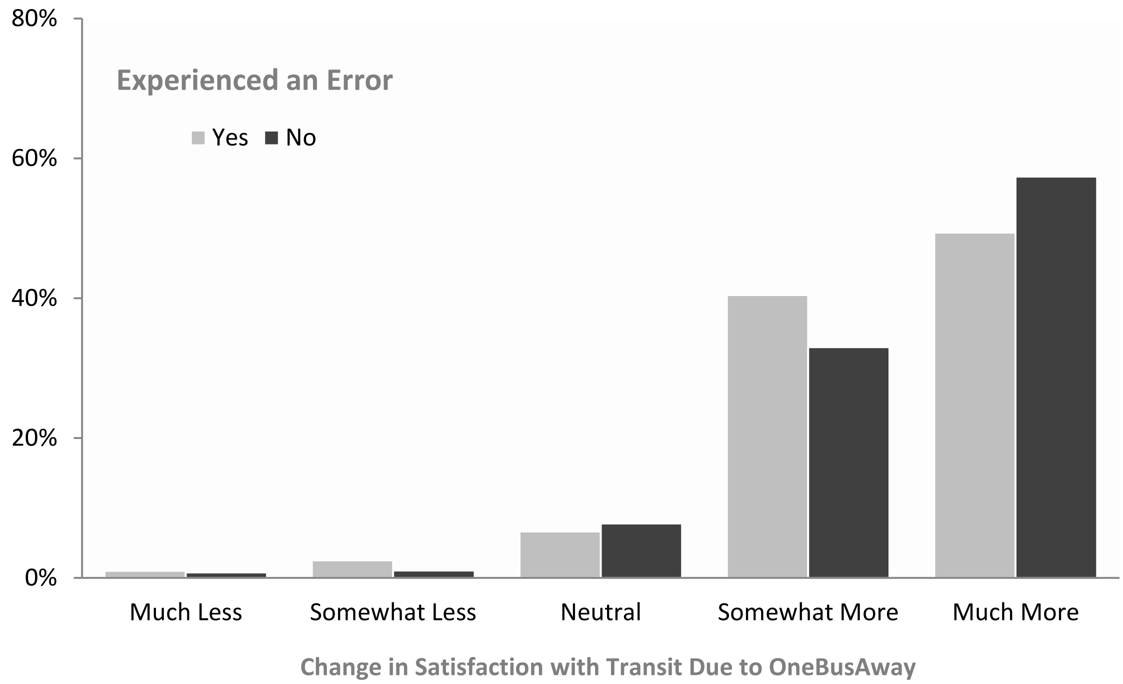


Figure 10: Error effects on satisfaction with transit

A closer look at the chart reveals that riders were still very satisfied with transit due to their usage of OneBusAway; however the presence of errors within the system had a tempering effect on the positive benefits of real-time information. A reasoned assumption therefore can predict that persistent errors within the system will continue to negatively impact overall satisfaction with transit. This drastic impact can reach the point of affecting ridership levels, as prior research has shown the connection between these two concepts of satisfaction and changes in ridership.

Ridership Change

The set of respondents who had experienced an error were asked whether "there had been an effect on the number of bus trips they take due to the errors they experienced". While 89% stated that there had been "No Change" to the number of trips taken, a combined 9% of respondents stated that they took the bus "substantially less often" or "slightly less often"; a significant shift in ridership (X^2 = 316.2177, $p < .001$). What drove these reported changes in ridership can be attributed back to the changes in satisfaction and an overall distrust of the reliability of the system. It should be noted that the iPhone survey alert (which drew by far the majority of respondents to the survey) was only seen by current users of OneBusAway and not former users who may have stopped using the application due to data errors. It would be useful to know how many users there were (if any) of the latter kind – if a significant number, including them would obviously show a larger decrease in ridership due to the errors experienced.

Anecdotally, in free-form responses some users stated that they no longer could trust the predictions and at times simply walked instead of waiting on an unreliable prediction. A few notable statements:

> "I used to use it a lot to catch a bus to the light rail station. Since onebusaway has been unpredictable, [I] just walk to the station instead of depending on onebusaway."
>
> "It's frustrating when I trust onebusaway & end up wasting 30 min [be]cause it was way off."
>
> "It's great knowing when buses are coming. But - the recent drop in reliability has been very frustratin[g] and I am less likely to trust the predictions."

This issue of trust, frustration and the feeling of having no control was referenced often by riders, almost to the point of reverting to an era before real-time information was made available. However, an avenue for riders to potentially improve their situation was available, in the form of error reporting.

Reporting Errors

In the OneBusAway real-time system, a number of methods exist for users to report issues they experience with the information. While they can send email or post notices on the OneBusAway Facebook page or Twitter stream, the only standardized method to submit an error report is via the iPhone "Error Reporting" function. In the survey, the users who had experienced an error were asked if they had reported the issue at the time of occurrence. Only 715 respondents (19%) stated that they had reported an error they experienced.

Out of the 715 respondents, over 89% stated that they had reported their error via the iPhone error reporting function, while only 5% had reported via an email to the transit agency and 7% had reported via an email to OneBusAway. These results are almost certainly influenced by the previously noted survey bias towards iPhone users. In addition, as Figure 11 shows, there was a large discrepancy in the percentage that reported errors based on their classification as "iPhone" or "non-iPhone" user.

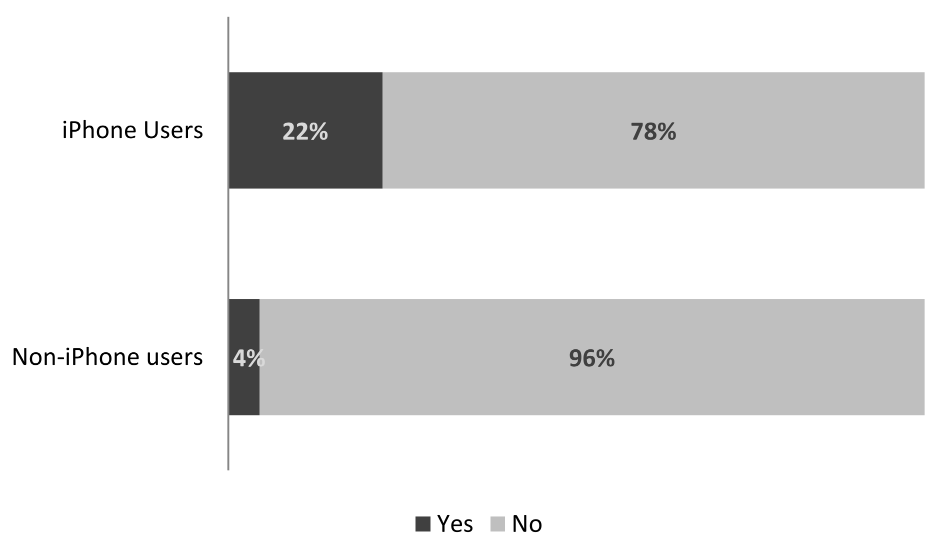


Figure 11 Percent Who Reported Error vs. Platform Used

This significant difference highlights the barriers faced by non-iPhone users in reporting issues. At the same time, with only 22% of iPhone users stating they had reported an issue, a more in-depth look at the reason for the low percentage is essential for understanding the relationship between experiencing errors and reporting them.

Error Resolution

One factor that may contribute to a low error reporting rate is the current lack of feedback to users regarding the issues they reported. Essentially, did the OneBusAway team or the transit agency fix something as a result, or did the report just get filed with no action? To help explore this, the survey asked respondents whether the issue they reported had been resolved. While 31% stated that the error had been resolved, 44% stated that it had not and 24% stated "Other" with a free-form response. Comparing the ridership change due to errors against whether riders had experienced a resolution to the reported issue produced a significant relationship ($X^2 = 9.6533$, $p < .05$). As Figure 12 notes for example, 14% of respondents who stated that their errors had not been resolved now reported that they rode "slightly" or "substantially less" due to the errors. It is a significant difference to the 7% of respondents who reported they rode slightly or substantially less but stated that their errors were resolved.

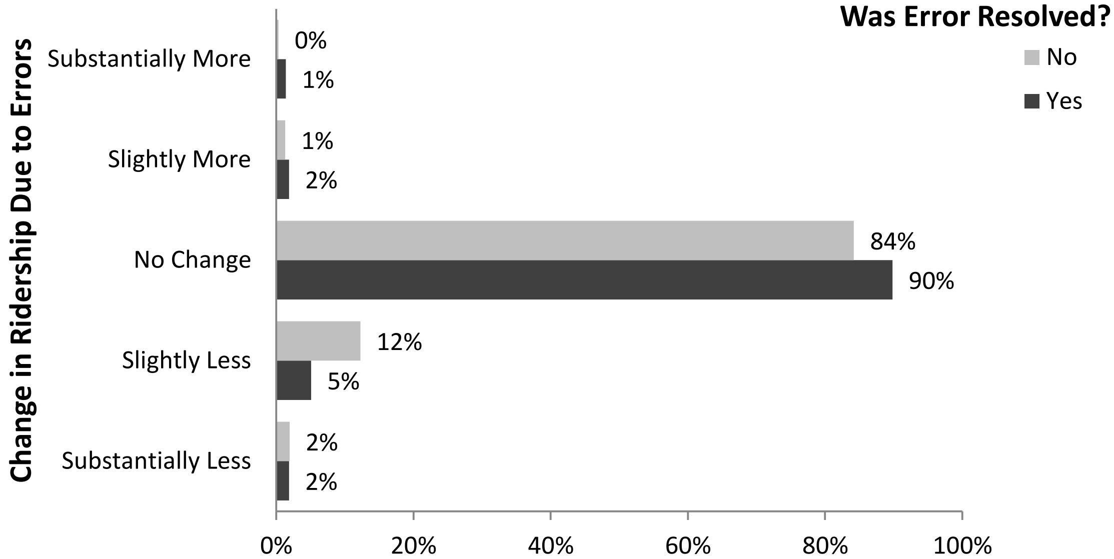


Figure 12: Change in ridership due to errors vs. error resolution

This result provides insight into the potential for actionable error resolution to temper the negative impacts realized by poor real-time information quality. In addressing the underlying sources of inaccurate predictions, agencies can not only improve the overall quality of their real-time systems, but they can prevent any potential reductions in ridership due to the initial errors experienced.

<u>Source of Blame</u>

Finally, the survey asked respondents to state with whom “do you typically attribute as the source of the error?” While 23% of the respondents blamed the transit agency, roughly 18% blamed OneBusAway and 21% attributed “Conditions beyond control” to the errors they experienced. Of note is that almost a third stated that “they did not know”. This question, as well as a related general comment question, provided some notable quotes from users that highlighted this murky issue of blame:

> “I think it is a great application. I understand that some factors affecting are in controllable [sic] so I don't get too frustrated when I experience those rare errors.”

> “I don't blame OneBusAway at all for the errors and I'm actually impressed the tracking works so well considering the data you're dealing with.”

> “I guess I typically blame OneBusAway but upon further thought I suppose it could be a problem with the transit agency signals or communication between the two.”

> “[It] really depends on the error. I'm more hopeful things will be fixed than interested in assigning blame.”

> “Don't care, as long as it gets fixed.”

No single entity in the real-time information process was held responsible by a majority of riders. Generally (as well illustrated by the final quote above for example), riders simply wanted the issue to be resolved, regardless of the source of the error.

4.3.2 Discussion of Data Accuracy Impacts

While largely beneficial to all aspects of the community, the provision of real-time information does expose a transit agency to a new level of expectation from their riders. By understanding the margin of error that riders expect with arrival predictions, developers and transit agencies can work together to provide a level of accuracy that is attainable from a cost and feasibility perspective. The average margin of error of 4-6 minutes expected by riders provides an initial minimum benchmark for agencies to set with their real-time prediction accuracy as they continually modify the underlying predictive algorithms. In addition, care should be taken to ensure that proper buffers are in place to minimize the amount of time that a vehicle would arrive earlier than predicted, due to the narrow margin of error expressed by riders. While the results highlight the lower margin of error that infrequent riders expect, in general, people with lower tolerances for travel-time variability (or tolerances for errors) may actually ride transit less. In developing and managing real-time information systems, agencies can attempt to improve the accuracy and thus increase ridership from that infrequent population by properly accounting for trends in traffic, boardings and other aspects that may impact real-time predictions. While many of these factors may be uncontrollable or costly to account for, agencies should thus strive for real-time accuracy that is tailored to their respective populations.

Overall, the percentage of respondents who had experienced a real-time prediction error was over 77%, a level of unreliability that is of major concern from all perspectives. The negative effects the errors had on ridership and overall satisfaction with transit were significant and should convey to agencies the importance of providing accurate real-time information. While these errors undermine the overall positive effects of the provision of mobile real-time applications, agencies should weigh the costs of lost ridership and satisfaction against the additional investment needed to provide more reliable predictions. In this emerging environment of open-data, developers should also be concerned with the data provision as the study highlighted the shared blame attributed to agencies and application developers alike. Errors caused by application coding issues may be incorrectly blamed on the agency; conversely riders may mistakenly blame developers for errors originating from poor agency data. By working in coordination, agencies and developers can highlight and identify causes of prediction errors in order improve the overall functionality of the system. This cooperative relationship can be enhanced with a robust communication link from the transit users to the developers and agencies. The issue-reporting feature available with the iPhone was shown to be a valuable component of the real-time information system as it had a noticeable effect on tempering the negative impacts of initial data quality issues. Yet, there was a large number of users who did not use the error-reporting function or who did not have access to it. This discrepancy in the propensity to report errors also highlighted the equity issues that should be accounted for in the design of any real-time information system. To the fullest extent possible, all transit users should have equal opportunity to receive information, report the errors they experience with that information and to have their reports acted on, regardless of their incomes, locations, or the platforms they utilize for real-time information. A lower income user with only a text-based phone should not have less of a voice in the real-time information feedback system. Leveraging input from the entire range of transit users will allow agencies and developers to properly identify and resolve errors present in the real-time predictions.

4.4 Opportunities for Continued Research

The study was the first to highlight potential issues with real-time data accuracy and additional research should explore this concept. A key missing participant in the study was the set of former transit users, or those users who ceased to utilize the OneBusAway application. Additional research should be conducted that specifically reaches out to former riders who have discontinued use of the application or even of the transit system as a result of inaccurate data in order to better understand the impacts of real-time data accuracy. They are the riders who were among those most affected by the issues and thus are vital to developing a more accurate understanding of the relationship between errors and rider satisfaction.

Related to the impacts of errors is additional analysis on user expectations of real-time accuracy. The OneBusAway interface will show that a vehicle is arriving “now” when it is within 2 minutes in order to provide transit users with a better guarantee of arriving at the stop in time to catch the bus. With that said, this 2 minute buffer was not directly conveyed to the user and was also not asked about specifically in the survey. To remove this localized effect, a study of transit riders within other agencies may provide a more robust estimate of the accuracy users expect.

Finally, the notion of agency-rider communication, the methods of that communication and the role riders can play in enhancing the transit system is an evolving concept. While research has provided evaluations of past emerging technologies *(41, 42)*, the linkage between these mobile-based communication channels and their role in improving real-time information has not been directly assessed. In the following chapter, the role of the riding community in improving real-time information accuracy and overall agency-rider communication is discussed while a proposed solution is described within the context of the situation experienced within the Seattle transit system.

CHAPTER 5

PROPOSED SOLUTION

As noted in the research results, if left unchecked, significant data accuracy issues within the real-time information system can have a significant effect on customer satisfaction and overall ridership. As more and more agencies continue to expand their real-time information provisions, a solution to the data accuracy element within this environment of open data is required as a means to efficiently leverage the potential of a fully functioning system. In this chapter, a brief synopsis of other transit agencies' real-time information systems is presented as a means of providing background and context to potential solutions, while research on the notion of crowdsourcing is summarized. From this base of information, the proposal and development of a Transit Ambassador program is described as a potential solution to data accuracy issues existing within real-time information systems. Finally, the process and results of a pilot program implemented in Seattle from this research are described and evaluated.

5.1 Background of Agency Experiences

As a means of developing a working solution to the data accuracy issues, it was useful to evaluate other agencies' responses to real-time information accuracy. Nine transit agencies were evaluated through online research, email correspondence and at times, phone interviews with relevant personnel *(43–51)*. This included the following systems:

- Chicago Transit Authority (CTA)
- LA Metro (Los Angeles)
- San Francisco Municipal Transportation Authority (MUNI)
- Washington Metro Area Transit Authority (WMATA)

- Massachusetts Bay Transportation Authority (MBTA)
- TriMet (Portland)
- Bay Area Rapid Transit (BART)
- Metropolitan Transportation Authority (MTA – New York City)
- Southeastern Pennsylvania Transportation Authority (SEPTA)

For each agency's real-time system, three core elements were evaluated as a means of providing a comparison to the situation in Seattle. This included assessing what real-time services were provided by the agency directly, the level of developer coordination exhibited by each agency as well as the process, if any, for error reporting and accuracy monitoring of their real-time system. Full details of the responses are located in Appendix A and a summary is provided below.

Agency Provided Services

In many cases, agencies provided real-time information via their websites, both desktop and mobile-optimized. In addition, many agencies provided SMS tracking capability and at times, automated voice response services. If agencies contracted with the NextBus company for their real-time information, often they provided a link directly to their relevant NextBus page as opposed to displaying the information directly on their own page. In some cases, such as LA Metro and MUNI, agencies provided their own native mobile applications for iPhone and Android platforms. However, agencies in general felt that their responsibility was to provide a baseline of information via website support while offering open real-time information for developers to build native mobile-applications.

Developer Coordination

The level of coordination between agencies and developers varied from agency to agency, however the underlying theme of single-point contact was consistent. All agencies charged a dedicated person with communication related to questions developers had with the provided data, however the actual position of that person at the agency ranged from webmaster to IT personnel to public communications associates. Most agencies offered full documentation related to the real-time information feed and in many cases, a developer's forum had been established for a dedicated communication channel between agencies and developers. This forum also allowed for developer to developer communication as a means of providing immediate assistance due to the collaborative nature of the developer community, thereby freeing up the dedicated agency personnel to resolve other more-pressing issues.

Error Monitoring and Response

A consistent theme from the agency contacts was the fact that no agency had a structured error response system in place. In many cases, the information flow took on the following form: a rider would email a developer with a persistent experienced error, the developer would contact the agency coordinator via the developer's support group and the agency would respond with a potential fix. In general, the agency contacts stated that they received a number of requests during the initial deployment of their real-time systems, but after a few months, often there were very few errors reported or monitored. That is not to say that no errors existed within the system. For example, a study of reliability impacts with the MUNI system revealed the riders had experienced an error with the real-time predictions within the last one to six months *(52)*. Related to errors experienced yet unreported, from all of the interviews and research, none of the mobile applications with the agencies had a specified crowdsourcing function to allow riders to immediately report an issue with the real-time predictions.

5.2 Synopsis of Crowdsourcing

The notion of crowdsourcing and the perceived benefits of a properly designed system must be understood before embarking on the design of a Transit Ambassador program. A Wired article in 2006 first coined the term "crowdsourcing" *(53)*, and since that time, the concept of systematically obtaining information from a collection of the public has been researched extensively over the past four to five years. At its core, crowdsourcing "operationalizes crowd wisdom, and it is a mechanism for leveraging the collective intelligence of online users toward productive ends" *(54)*. Dr. Brabham also stated that crowdsourcing could provide for localized knowledge, acquired through experiences and appropriate context. Dr. Michael Goodchild, in discussing crowdsourcing processes within geographic mapping utilized the term "citizen science", as the information generated is not to the level of a professional, yet it is a step above the quality of an average citizen *(55)*.

In a real-time transit information environment, this "super user" status can equate to a rider's understanding of the daily variations in their particular routes along with the intricate knowledge of their local stops and stations. However, the benefits of a crowdsourcing system may be overrun by problems with the quality of information being provided and the validation required to ensure appropriate levels of accuracy *(54)*. Regarding the importance of information quality, Dr. Christian Heipke assessed that "quality issues have been a primary point of debate since crowdsourcing results started to appear" *(56)*. Yet the benefit of public input in a crowd-sourced process can outweigh the potential issues arising from invalid or inaccurate reports stemming from the public. SeeClickFix is a seminal example of leveraging the hyper-local expertise of concerned citizens by employing them to report any problems they witness related to public structures such as streets, sidewalks, lighting or public spaces. The system utilizes mobile application technology and coordination between citizens and the underlying public agency in order to quickly and efficiently resolve reported issues *(57)*. Additionally, citizens have the ability to vote for other citizens' reports as a means of validation and priority assessment. Feedback mechanisms exist for the public entity to respond to the report and to provide an account of the action taken. For example, in Dallas, citizens reported on signal-timing issues and the flow of traffic was quickly improved by a concerted effort of the traffic department in response to these requests *(58)*. If properly managed, a crowdsourcing process can efficiently improve the functionality of a system and the overall level of information quality.

5.3 Transit Ambassador Program

5.3.1 Underlying Elements

At its core, a Transit Ambassador program would provide the foundation for an agency to efficiently address errors stemming from the real-time information system. The basis of the program centers on an error-reporting functionality of the mobile real-time applications. Quality control is crowd-sourced by the thousands of riders moving throughout the transit system on a daily basis. These eyes on the street provide the capability to compare the predicted information against the actual arrivals, with coverage that can span the entire system. However, while this crowd-sourcing element could very easily exist at a number of agencies, the system would only be beneficial if leveraged in an efficient manner. The true benefits of a Transit Ambassador program stem from the support of a set of dedicated riders, or Ambassadors in addressing the crowd-sourced information and providing functional coordination with agency personnel.

5.3.2 Objectives of the Program

In developing a Transit Ambassador program, the identification of substantive goals and objectives provides the basis for the structure of the program. The background research on other agencies and crowdsourcing systems highlighted three key objectives that any Transit Ambassador program should aim to achieve: problem resolution, community involvement and agency-rider communication.

Problem Resolution

A Transit Ambassador program can fill the gaps in this crowd-sourced error reporting structure in order to efficiently solve issues generated within the real-time system. A Transit Ambassador would provide the necessary layer of expertise and communication in which to evaluate the crowd-sourced information produced by the riders of the transit system. Equipped with an expanded amount of agency-specific information, these volunteers can triage and relay the error reports to the responsible entity or respond directly to the riders. In this sense, agency resources and the developers' time is no longer wasted on inspecting every issue reported, regardless of its validity. Without the time-requirement to validate and organize error reports, agencies and developers can focus only on the major issues identified and therefore provide more expedient resolution to the underlying issues.

Community Involvement

The crowdsourcing and ambassador elements share a common ideal: the engagement of the community to improve their transit system. When people are engaged in a process and given the opportunity to directly impact their surroundings, they often respond in a positive manner *(54)*. In addition, the very act of involving users of a system can have a significant impact in reducing the negative impact typically associated with other factors not directly addressed. Given the resources and information typically restricted within the transit agency, ideally Transit Ambassadors transition from critics to champions of the agency and are able to positively address concerns brought up by the riding community; and in instances when they are still critical of the agency, they become better informed and more fair in their critique.

Agency-Rider Communication

Many Transit Ambassadors will be able to respond to and/or resolve issues immediately rather than requiring official agency response. They can act as agency-rider liaisons as they coordinate information flow, thus enhancing communication response within the transit network and improving agency-rider relations. A typical message relayed from a Transit Ambassador may have a greater impact and may be perceived with more validity than a message direct from an official agency source. While the content may be the same, the differing source of information provides for an enhanced trust within the communication channels from agencies to riders, a benefit that may lead to increased rider satisfaction overall with the transit system.

5.4 Implementation Case Study: Seattle

These elements and objectives provided the basis for a Transit Ambassador pilot program implemented in response to the errors identified in the study from June of 2012. In this section, the background to the situation is summarized and the implementation process is described below as a means of providing context for agencies to base future implementations of a Transit Ambassador program in coordination with their real-time information system deployments.

Background to the Situation

As previously described from the study, 77% of riders were experiencing errors with the predictions in the Seattle-area. This included buses arriving earlier or later than predicted, not arriving at all or deviating from what the OneBusAway (OBA) real-time application was displaying. The main transit agency, King County Metro (KCM), had processes in place to monitor some core levels of accuracy with the GPS and real-time systems, however they were limited to what the automated system could assess. While the agency could easily assess if a GPS unit was displaying completely inaccurate data such as a route jumping back and forth in space, they had no ability to compare real-time predictions to what riders were actually experiencing. While riders could submit issues directly via the error-reporting feature within the OBA iPhone application, the feature was not available on Android platforms until late in the process, thus other platform users could only email the agency or developer as a means of reporting a problem.

Despite the lack of cross-platform functionality, the iPhone error-reporting system provided a robust amount of information, allowing users to relay their stop location, their route and the type of error experienced. Figure 13 provides the screenshot of the user interface for the reporting feature.

Figure 13: iPhone error-reporting tool

The ease of this feature allowed for a large number of reports to be sent, even if there was a low percentage of riders who reported errors they experienced. In fact, on a weekly basis, there were on average, 500 issues being reported by iPhone users. The error reports were directly sent to the central OneBusAway server and were provided in a public fashion via an RSS feed.

While the process displayed a beneficial amount of detail, there were some major drawbacks. The system had no confirmation element in order to properly assess whether an error reported was valid. As such, there was a large stream of newly generated errors that had to be evaluated, regardless of their validity or their importance. Oftentimes there were duplicates of errors reported by the same rider, or a rider would report that a bus had arrived late, even if the real-time prediction information had stated that fact correctly. In other instances, the information reported by the rider was not sufficient to properly address; thus follow-up was required to determine the true issue reported. Additionally, there was no system in place to organize issues by the entity that was responsible, whether it be the OBA administrator or the transit agency. For example, if the source of an error was faulty location data generated by the GPS equipment, the transit agency should have been notified in order to resolve the issue. However, if the error stemmed from data transfer issues within the OBA system, the issue should have been resolved via the OBA administrator. Finally, there was no process to differentiate or prioritize these error-types. With upwards of 500 errors being reported on a weekly basis, the time required to evaluate these reports was overwhelming and any attempt to leverage them in order to resolve underlying problems with the real-time system would require a coordinated effort from a collection of individuals. From this environment, the core structure of a Transit Ambassador pilot program was developed. In the following section, the implementation process is described with a concluding discussion of lessons learned throughout the deployment.

5.4.1 Program Development

In order to effectively assist the transit agency in dealing with these reports and the underlying issues with their real-time information, the development of the Transit Ambassador program required two key components. First the type and underlying source of each error had to be categorized as a means of developing the proper response and action to resolve each error-type. The second component involved the role of the Transit Ambassadors in the process and the method in which these actions would be undertaken at the agency and OneBusAway administrator level in order to respond to the needs of the riding community.

Error-type Identification Process

Before establishing a work-flow process in which to manage the incoming error-reports, the types of errors submitted had to be identified. This involved evaluating the errors in order to establish a pattern based upon a given set of characteristics exhibited within the error. The OneBusAway system came equipped with an error-assessment web interface, originally for use by the administrator that allowed the incoming errors to be viewed with a large set of meta-data related to the vehicle’s prior positions, the user’s location, and information specifying the status of the real-time system. Figure 14 provides a snapshot of the interface, in which this data was clearly displayed for error-type definition.

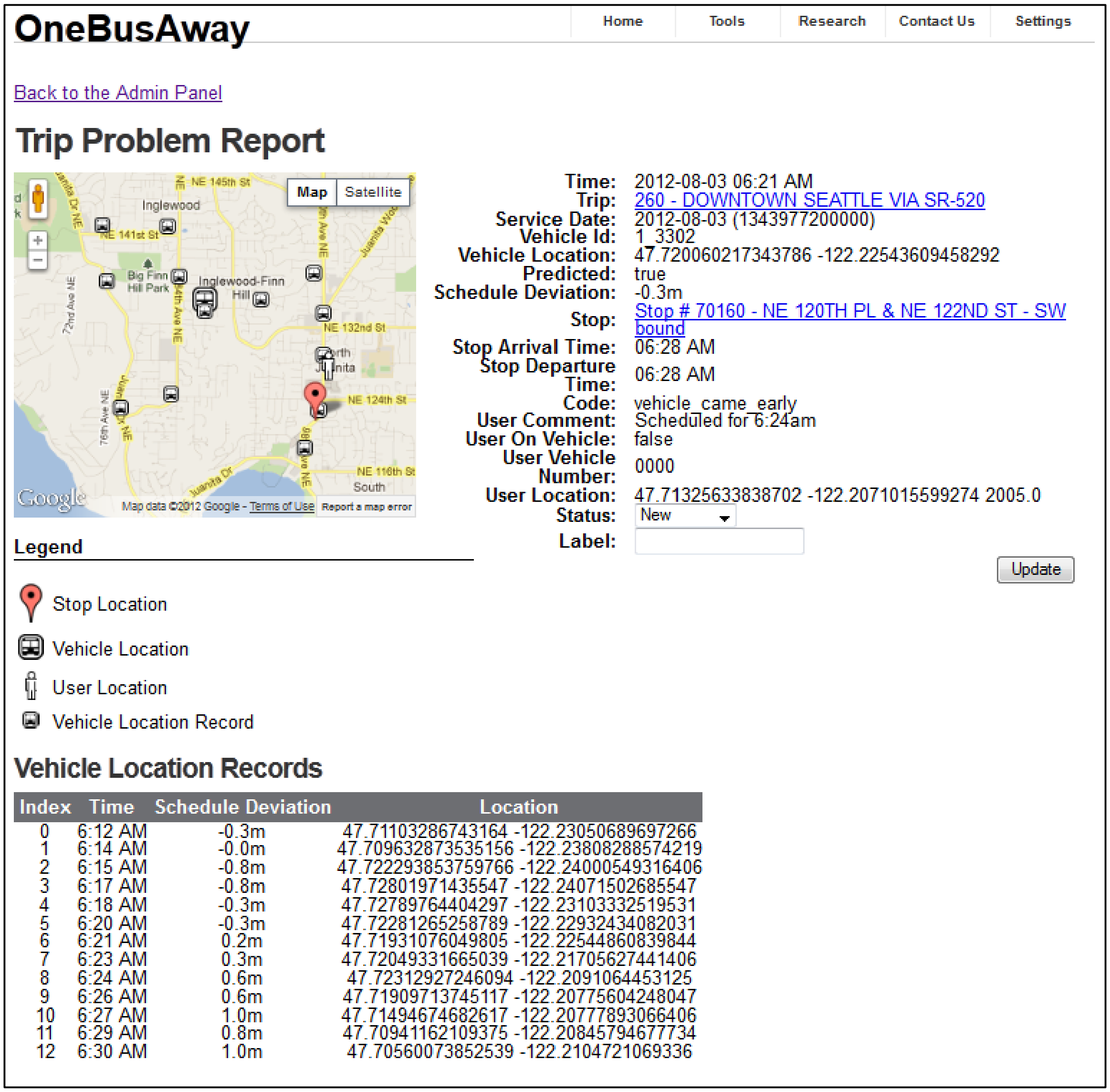


Figure 14: Error Report Assessment Interface

Careful analysis of a sample of errors along with discussions between the OBA administrator and the transit agency IT department provided the basis for a list of expected types of errors within the real-time system. Table 2 provides a simplified description of each error present within the system along with the necessary response of the Ambassador.

Table 2: Error types for OneBusAway Seattle

Error Type	Probable Causes	Action by OBA Ambassador	Responsible Entity
Duplicate	1. Same user submitted twice for some reason 2. Different users submitted same issue	Archive error as Duplicate	No action required
MyBus	1. MyBus prediction error 2. Actual schedule deviation on bus	Archive error as MyBus	No action required
ScheduleOnly	1. GPS data issue 2. OBA prediction issue	Archive error as Schedule	No action required
BadGPS	1. Possible GPS feed issue from bus 2. Data conversion from KCM to OBA	Label error as GPS and provide sublabel	Transit Agency and possibly GPS provider
AdditionalDelay-GPS	1. Traffic caused last-minute delay 2. Re-route of bus possible	Archive error as Delay	OBA Ambassador or transit agency
GTFS	1. Incorrect GTFS file from the transit agency 2. Temporary re-route due to construction	Label error as GTFS and notify OBA admin	OBA admin or transit agency
Unknown	1. User frustration with a late bus 2. Driver behavior, bus cleanliness, etc.	Label error as Unknown and take additional action	OBA Ambassador or transit agency

As shown, a number of error-types included those which had no potential resolution or required no immediate action. This included errors erroneously submitted multiple times from the same rider, issues related to the legacy vehicle location system (MyBus) along with errors reported by riders in which the vehicle was only displaying schedule information at that time. Issues related to the underlying General Transit Feed Specification (GTFS) were identified by aspects such as an incorrectly placed stop in the application or route that was missing from the real-time application. Finally, the general "Unknown" error type was identified as a means of grouping errors unrelated to real-time issues, such as driver behavior or general on-time performance. The core error-types that required action by the OBA developer or agency personnel were related specifically to GPS-related issues and prediction errors and the sub-labels of that error-type are listed in Table 3.

Table 3: GPS sub-label types for OneBusAway Seattle

BadGPS Sub-label	Identifying Characteristic
NoChange	No change in Schedule Deviation values throughout entire trip
TripStart	GPS broadcasted location while the bus was at a layover and showed delay for the next trip, only to reset to "on-time" when the trip started
WrongTrip	The trip was incorrectly assigned and showed the bus in a completely different area or on both directions of a route for the same trip
Erratic	The GPS was showing correct then had erratic behavior such as jumping backwards in space

For example, regarding the error-type “NoChange”, at times a vehicle would display a consistent schedule deviation of zero minutes for the entire trip, a known issue with the functionality of the GPS equipment as a trip is never able to adhere perfectly to a schedule for its entire length. Other GPS-related issues included problems with the real-time broadcasts while a vehicle was at a layover position, labeled “TripStart”. In this instance, the vehicle would interpret its schedule adherence as delayed while stopped at a scheduled layover. Riders waiting for the vehicle down the line would see an increasing delay on their OneBusAway prediction, however when the vehicle actually began its trip, the predictions would switch to showing the vehicle on-time, thus causing confusion and frustration for the users. Finally, any major deviations in the direction or speed of the vehicle would identify the error as “Erratic”, in which case, some underlying issue was causing the GPS to vary widely in its accuracy.

This error identification process provided a true understanding of the types of errors users were experiencing and the sources of those issues. The next step therefore required the development of a system to properly manage these errors and divert them to the appropriate personnel for resolution.

Error Management System

From a high-level perspective, the management of the errors required the coordination between the agency, the OneBusAway administrator and the riding community. However, due to the constrained resources of each organization, there was no single contact to coordinate between these entities. This role would fall to a collection of volunteers, or OneBusAway Transit Ambassadors.

Transit Ambassadors would be viewed as "super users" of the system, with an underlying devotion to improving the transit experience not just for themselves, but the entire riding public. The overarching role was to provide a level of expertise that could accurately evaluate the incoming errors and thus efficiently triage and divert any relevant issues to the appropriate organization. Figure 15 provides a visual summary of the flow of information established within the program and the role of the Ambassadors in coordination of the process.

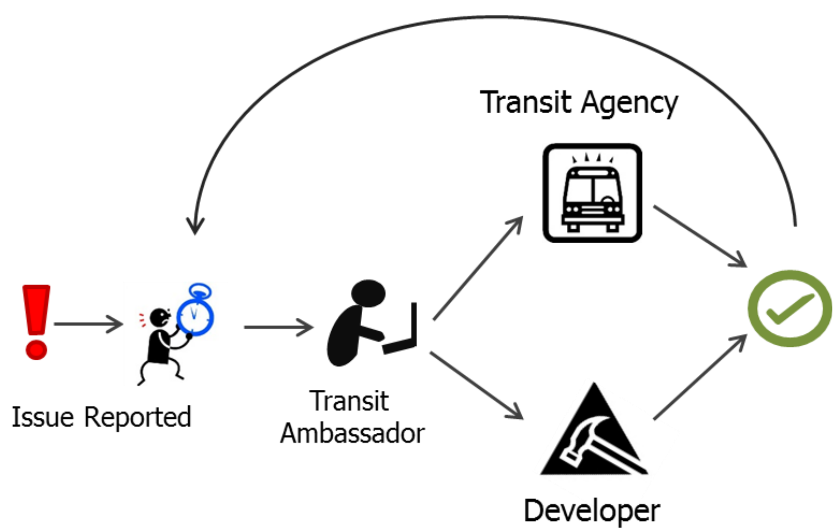


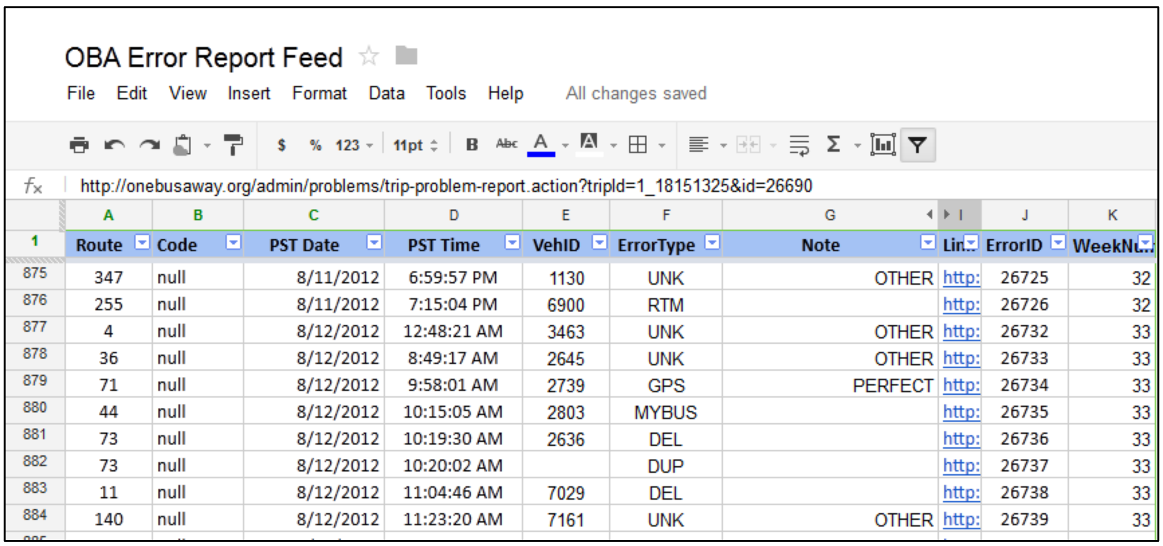
Figure 15: Information Flow of the Transit Ambassador Program

Ambassador Recruitment and Training

An initial group of three Transit Ambassadors were recruited via online blog postings and email outreach. The call for volunteers asked for those people in the riding community who could devote between one and two hours a week to assisting the transit agency in resolving the core issues of the real-time system. The requirements of any potential ambassador included a solid understanding of the transit network and basic computational and analytical skills. In addition, an aim in the recruitment of volunteers included ensuring broad geographic coverage with the set of Ambassadors as a means of guaranteeing solid expertise of the entire transit system. Upon the evaluation and selection of the three initial Ambassadors, a meeting between the Ambassadors, the OBA developer and agency personnel was held as a means of providing the Ambassadors with information on the underlying structure of the real-time system and the processes currently in place for error monitoring at an agency-level. This offered Ambassadors the chance to understand how they could best assist the agency in improving its real-time information. Components of the meeting included establishing a communication structure in which to relay a summary of the error reports to the agency and identifying issues that the Ambassadors should look for when evaluating the error reports.

Ambassador Tools

With this understanding of agency operations and the overall structure of the real-time information system, Ambassadors could be utilized to efficiently process the large stream of incoming error reports. A set of tools provided the means to organize and coordinate the work of multiple Ambassadors. This included a Transit Ambassador website with a collection of resources such as the GTFS-dataset, agency alert information and agency feedback links. The website also housed the Error Decision Matrix, a shared document that categorized each error-type and provided the Ambassadors with the underlying characteristics to identify each error and the proper response required. In addition an Ambassador forum was established to simplify discussion between the ambassadors, similar to the developer outreach groups established at other agencies. Finally, the main resource developed for the program was the Error Report Feed, a shared online document for identifying and organizing all of the error reports submitted by riders. Figure 16 provides a snapshot of the information located on the Error Report Feed.



OBA Error Report Feed

File Edit View Insert Format Data Tools Help All changes saved

http://onebusaway.org/admin/problems/trip-problem-report.action?tripId=1_18151325&id=26690

	Route	Code	PST Date	PST Time	VehID	ErrorType	Note	Lin…	ErrorID	WeekN…
875	347	null	8/11/2012	6:59:57 PM	1130	UNK	OTHER	http:	26725	32
876	255	null	8/11/2012	7:15:04 PM	6900	RTM		http:	26726	32
877	4	null	8/12/2012	12:48:21 AM	3463	UNK	OTHER	http:	26732	33
878	36	null	8/12/2012	8:49:17 AM	2645	UNK	OTHER	http:	26733	33
879	71	null	8/12/2012	9:58:01 AM	2739	GPS	PERFECT	http:	26734	33
880	44	null	8/12/2012	10:15:05 AM	2803	MYBUS		http:	26735	33
881	73	null	8/12/2012	10:19:30 AM	2636	DEL		http:	26736	33
882	73	null	8/12/2012	10:20:02 AM		DUP		http:	26737	33
883	11	null	8/12/2012	11:04:46 AM	7029	DEL		http:	26738	33
884	140	null	8/12/2012	11:23:20 AM	7161	UNK	OTHER	http:	26739	33

Figure 16: Sample of the Error Report Feed

This feed automatically pulled all of the errors reported out of the OneBusAway database on a daily basis and allowed the Ambassadors to sort, filter and process each issue identified utilizing the Error Type Matrix described previously. At the end of each week, the errors would be aggregated and forwarded to the appropriate entity, either the transit agency IT department or the OneBusAway administrator. This included reporting a summary of vehicles and their related GPS issues along with a route-level analysis to determine if particular routes were exhibiting reoccurring issues with their predictions.

Through this action, the summary of errors by vehicle and route provided the transit agency and the OneBusAway administrator with valuable supporting information to help target their actions to improve the real-time information system.

5.5 Discussion of Process

The pilot implementation of the Transit Ambassador program provided the framework for what could be possible with a full deployment; however a number of issues were also identified throughout the process. In this section, the pilot program is evaluated against the initial objectives described in the previous section as a means of providing guidance to any future implementation of an Ambassador program.

Problem Resolution

It was difficult to assess the impact that the pilot program had on improving the underlying issues affecting the real-time information system. The summary reports provided by the Ambassadors to the agency IT personnel were deemed useful, however they often only provided confirmation of issues the agency had already discovered. The agency often knew that a particular vehicle had GPS-equipment issues, but often the agency staff did not have an available solution, or the solution required resources outside of their control. A common theme was "we know it's a problem, but it's extremely complicated to resolve". The complication stemmed from a number of factors, including the fact that any resolution often required coordination between the agency and the GPS-equipment provider. In other cases, the agency would reach out to the set of Ambassadors to personally assess an identified issue, such as whether real-time audio updates were occurring on buses, however this was often as a means of simply validating that an error existed rather than identifying any new issues. Finally, even with the large amount of filtering applied by the Ambassadors to remove erroneous or invalid error reports, the amount of information and the number of problems that were forwarded to the agency and the OBA developer was somewhat overwhelming for their limited time and resources. For example, the program correctly identified the large number of vehicles and routes that were incorrectly displaying real-time information while on layover, however the agency had no means to quickly resolve the issue or to fully assess the information provided by the Ambassadors. In this sense, the Ambassadors could only convey to the riders the reality of the situation as a means of tempering any frustration the riders might have been feeling with the real-time information.

Community Involvement

This objective was accomplished simply by the large amount of interest generated with the program. A large number of dedicated riders sought to become involved and to provide any available assistance. The level of passion exhibited by the Ambassadors and others interested in the program was a welcome relief to see after months of negative experiences and frustration with the real-time system. This extremely important aspect revealed the unrealized benefits of rider engagement. Previous critics of the agency who simply wanted the ability to fix their situation now were given some form of control to assist in improving the transit system. While the pilot program only reached a level of three Ambassadors, the underlying structure could have utilized upwards of a dozen effectively, with each Ambassador acting as representative of their respective geographic area in the network. An additional effect with the program was the substantial increase in the amount of errors reported, possibly as a result of more riders feeling a sense of engagement with the transit agency.

That said, the percentage of riders reporting errors was still somewhat low, which brings to light a larger question regarding crowdsourcing that could not be fully addressed in the timeframe of this pilot program. In an instance such as a real-time transit system, not every rider that experiences an error necessarily needs it reported. Recall that a key aspect of the Transit Ambassador program was merely to organize an already large volume of reports sent in from riders. In theory, if a vehicle is experiencing issues with its real-time predictions, just one rider that particular trip needs to report the error to fulfill the needs of the error-reporting system. In that sense, the reporting percentage may not be the metric of evaluation to ensure proper coverage of the system. While the 2012 study of OneBusAway users revealed that 19% of users who experienced an error had reported it, only 5% of those riders who were non-iPhone users reported their error due to the limited ability to report with only email and social media outlets. Additionally, while the Android platform now has error-reporting capability, any rider with no smartphone is still limited in their representation within this crowdsourcing environment. Therefore, a more rational goal for community engagement should ensure *equal opportunity* to report even if a level of 100% reporting is not needed, nor ideal. While the scope of the pilot program did not allow for further development, such as SMS reporting or automated IVR response, a necessary element for effective community involvement is to provide a feedback mechanism for all types of users, regardless of age, income or geographic location.

Agency-Rider Communication

While not perfected, this aspect was realized to some degree with the Ambassador pilot program. Providing a behind-the-scenes look to the Ambassadors allowed them to relay that information to the rider community and to provide some context to the errors that everyone was experiencing. For example, a typical public relations response by the agency would have been interpreted far differently as compared to the Ambassadors relaying this information out in the community, which provided an enhanced level of trust. While some underlying real-time issues could not be resolved by the agency, the Ambassadors provided a means to explain to riders why an issue could not be fixed and how they could best adjust to the situation.

The success of the outreach exhibited by the Ambassadors and their role in representing not just the agency but the riders themselves gave validity to the potential that a fully deployed Ambassador program has within any real-time information system. With the proper adjustments to the available agency support and an expansion of the amount of Ambassadors, a Transit Ambassador program can effectively accomplish the core objectives and serve as not only a means for improving the real-time information product but serve as a mechanism for an agency to fully engage its riding community in a method that improves the overall functionality and quality of the transit service provided.

CHAPTER 6

CONCLUSION

The rapid expansion of real-time information availability has enabled transit agencies to improve the overall quality of their service. In addition, the advances in mobile location-aware applications have provided agencies with a cost-effective means to deploy this information to a larger ridership base. Benefits of the expansion have included quantifiable reductions in perceived and actual wait-times as riders seize back control over their travel choices and patterns. Due to this sense of control, research has shown the correlation between real-time information provision and an increase in the perception of safety along with an improvement in satisfaction with the transit agency. All of these elements have allowed agencies to not only maintain ridership, but to increase it through the use of real-time information deployments. However, these implementations are not without their faults, and the presence of inaccurate predictions reveals a number of issues. The tolerance for errors and the expectations that varying rider groups have for the real-time system creates a difficult situation for agencies to address. While frequent riders are often more tolerant of variations with the data due to their understanding of the factors involved, those infrequent and choice riders often require higher levels of accuracy to realize any increase in transit usage. If left unchecked, these errors can lead to an overall decrease in satisfaction with transit, and possible abandonment of the system entirely. The research presented a valid case for further study to offer a more robust analysis of the impacts of accuracy on transit riders. While only current users of the transit system could be captured for this survey, analysis of former riders frustrated with the real-time errors would provide additional support to the powerful impact that accuracy has on satisfaction and ridership. Solutions exist however, and the ability for a rider to report an experienced error immediately provides a sense of control, which can minimize the initial adverse effects of the inaccurate data. Furthermore, resolving an error or at least acknowledging the underlying issue to a rider can deflect negative perceptions and provide avenues to improve the real-time system overall. A Transit Ambassador program, developed around a crowdsourcing component is a primary example of a solution with benefits beyond the improvement of the real-time system. The pilot program deployed in Seattle effectively engaged the community and enhanced agency-rider communication while providing support towards resolving some of the core issues present. Where it fell short in resolving all of the errors within the real-time information system, the program succeeded in identifying key champions within the rider community who could channel their passions towards a positive response. Research of other agencies concluded that no program of its kind existed, despite the presence of errors within their systems.

Transit agencies must understand the passion that many people within the riding community have in improving their transit system and the sense of control that riders strive for in their daily travel activities. The historical approach of agencies to this enthusiasm has often been a top-down, one-directional response, further entrenching the line between themselves and riders. In this new age of technology-based coordination, transit agencies can take a more inclusive route by leveraging the expertise of the entire rider population to break down these historical barriers. Empowering riders with the tools necessary to effect positive change within a transit system is the next step in the long process to achieve an optimal collective form of transportation. From that perspective, a coordinated relationship between the rider and the agency can lead to not only improvements in the real-time information system, but in overall progress in the quality of transit service as a whole. Only then can society address the transportation problems existent today in a constructive and effective manner.

APPENDIX A

DETAILS OF TRANSITY AGENCY RESEARCH

Created on 7 June, 2012

Below is a brief summary of some of the current real-time information systems in place at other transit agencies based upon a collection of email correspondence, phone interviews and web-based research.

Chicago Transit Authority (CTA)

CTA has taken a balanced approach with real-time data; providing support for developers while offering some of the basic underlying real-time information themselves.

- "BusTime" system supplies AVL, developed by Clever Technologies
- *In-house services*
    - Real-time website, mobile-optimized website and short-messaging system (SMS) tracking
    - General customer call center with person-response for tracking
- *Developer coordination*
    - Full listing of third-party applications on website
    - RTI supplied via CTA-sourced XML feed
    - Manager for External Electronic Communications is contact
    - CTA Developers Google Support Group is active for comments/questions
    - 35-page PDF documentation for utilizing the feed
- *Error monitoring*
    - Via email to Communications contact at CTA
    - Very few emails
    - If AVL has anomaly, simply won't push out RTI

LA Metro – Los Angeles, CA

Metro takes a slightly more involved approach compared to CTA and has produced their own in-house mobile application.

- NextBus system supplies AVL

- *In-house services*
  - iPhone/Android application (released Spring 2012)
  - Mobile-optimized website and text-only mobile website
  - Links to NextBus website (NextBus supplies SMS and 511 touch-tone tracking)
- *Developer coordination*
  - Full listing of third-party applications on website
  - RTI supplied via LA Metro-sourced XML, JSON and JSON-P feeds
  - Link to the NextBus XML feed if developer prefers
  - Webmaster is contact
  - Developer website provides blog posts, full documentation and "Developer Challenge"
- *Error monitoring*
  - Error-reporting feature is on in-house application
  - No formal structure between NextBus, developers and LA Metro.
  - If AVL has anomaly, simply won't push out RTI (Boolean field)
  - Developers can post user-reported issues to the NextBus Google Group
  - Very small amount of issues posted over 1 year time-span

San Francisco Municipal Railway (MUNI)

The overall approach of MUNI is to leverage the NextBus resources for real-time information and developer relations.

- NextBus system supplies AVL
- *In-house services*
  - iPhone/Android application (released Spring 2012)
  - No link to NextBus, which supplies website, "511" and SMS RTI
- *Developer coordination*
  - Developer page of SFmuni.com Labs
  - Only links to NextBus API documentation
  - NextBus Google Support Group
  - Data Development Manager is the contact at MUNI for NextBus issues
- *Error monitoring*
  - No formal structure between NextBus, developers and MUNI
  - If AVL has anomaly, simply won't push out RTI (Boolean field)

Washington Metropolitan Area Transit Authority (WMATA) – Washington DC

WMATA provides a fairly reasonable level of real-time information and support, mostly through the NextBus systems.

- NextBus system supplies AVL
- *In-house services*
    - NextBus RTI website is embedded in WMATA real-time page
    - All mobile, phone or SMS-based tracking done by NextBus
- *Developer coordination*
    - No listing of third-party applications on WMATA website
    - Developer Resources page includes a WMATA-based JSON and XML feed information
    - Large API documentation support page along with comment feed that WMATA admin monitors for questions and coding issues
    - NextBus API feed can also be utilized directly, however WMATA does not provide that information
- *Error monitoring*
    - No formal structure between NextBus, developers and WMATA
    - If AVL has anomaly, simply won't push out RTI (Boolean field)
    - Any issues are reported on the NextBus Google Support Group

Massachusetts Bay Transportation Authority (MBTA) - Boston

While MBTA defers all real-time information to developers they do provide a high level of support in order to allow third-parties to supply RTI to riders.

- NextBus system supplies AVL
- *In-house services*
    - No website of RTI nor any phone or SMS information
    - All website, mobile, phone or SMS-based tracking done by NextBus
    - No link on MBTA website to NextBus tracking
- *Developer coordination*
    - "App Center" link on main MBTA page
    - NextBus XML feed and GTFS-realtime feed provided
    - Documentation on both feeds provided on the developer page
    - MBTA specific Google Support page
- *Error monitoring*
    - No formal structure between NextBus, developers and MBTA

- If AVL has anomaly, simply won’t push out RTI (Boolean field)
- Any issues are reported on the MBTA or NextBus Google Support Group

<u>TriMet - Portland</u>

TriMet provides a robust amount of RTI in-house along with full developer support.

- Unspecified system for AVL
- *In-house services*
  - TransitTracker website, mobile website, SMS and automated phone response all provided by TriMet
  - QR codes provided at stops, finalized by September 2012 at all stops
- *Developer coordination*
  - “TriMet App Center” link on TransitTracker page with full third-party applications listing
  - GTFS-realtime feed provided
  - Documentation provided on the developer page, however much is simply linked to the Google GTFS documentation page
  - TriMet specific Google Support page
  - Developer contact is employee within GIS/Location Services department at TriMet
- *Error monitoring*
  - Posting to TriMet Google Support page
  - No formalized process

<u>Bay Area Rapid Transit (BART) – San Francisco</u>

While only supplying RTI for heavy-rail systems, BART provides solid real-time support both directly and indirectly through third-party developers.

- Zonal-based sensor technology tracking system
- *In-house services*
  - Website, mobile website and SMS
  - No in-house mobile application
- *Developer coordination*
  - Direct link to over 65 third-party applications
  - Full documentation on developer page
  - GTFS-realtime feed and older raw-XML feed
  - Developer contact is website manager
  - BART specific Google Support page

- *Error monitoring*
    - Posting on Google Support page
    - Monitored by website manager
    - Online submit form for “Developer Feedback”

<u>Metropolitan Transportation Authority (MTA) – New York</u>

The MTA, in coordination with OBA, OpenPlans and Cambridge Systematics is currently in the rollout phase of full system-wide real-time bus information implementation. There are currently only a select number of routes, but the support structure is in place for full MTA-sourced information along with developer resources.

- Trimble-GPS system with OneBusAway software
- *In-house services*
    - MTA BusTime website, mobile website, text-only website, SMS
    - No in-house mobile application
- *Developer coordination*
    - Direct link to “App Center”
    - Full documentation on developer page
    - JSON and XML feeds supplied via SIRI standard
    - MTA-specific Google Support page
- *Error monitoring*
    - Posting on Google Support page
    - Prompts users to email any errors identified in a standardized format
    - Google Support page for any coding/format issues with the feed

<u>Southeastern Pennsylvania Transportation Authority (SEPTA) - Philadelphia</u>

SEPTA lacks visibility on its website for third-party applications along with a complicated mechanism for users to obtain RTI from the site directly.

- Unknown GPS service-provider at this moment
- *In-house services*
    - TrainView website. SMS is only for train real-time and just schedule info for bus

- Extremely difficult to find real-time information for SEPTA buses
- No in-house mobile application

- *Developer coordination*
  - No links to 3rd-party mobile applications
  - Developer page has no link from the Septa.org page
  - Very minimal documentation
  - JSON/JSON-P feed
  - SEPTA specific Google Support page provides feedback mechanism for developers
- *Error monitoring*
  - Posting on Google Support page
  - Monitored by website manager

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