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Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders

Kari Edison Watkins [a,*], Brian Ferris [b], Alan Borning [b], G. Scott Rutherford [c], David Layton [d]

[a] Department of Civil and Environmental Engineering, Georgia Institute of Technology, 790 Atlantic Dr, Atlanta, GA 30332-0355, United States
[b] Department of Computer Science and Engineering, University of Washington, Box 352350, Seattle, WA 98195-2350, United States
[c] Department of Civil and Environmental Engineering, University of Washington, Box 352700, Seattle, WA 98195-2700, United States
[d] Evans School of Public Affairs, University of Washington, Box 353055, Seattle, WA 98195-3055, United States

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ABSTRACT

In order to attract more choice riders, transit service must not only have a high level of service in terms of frequency and travel time but also must be reliable. Although transit agencies continuously work to improve on-time performance, such efforts often come at a substantial cost. One inexpensive way to combat the perception of unreliability from the user perspective is real-time transit information. The OneBusAway transit traveler information system provides real-time next bus countdown information for riders of King County Metro via website, telephone, text-messaging, and smart phone applications. Although previous studies have looked at traveler response to real-time information, few have addressed real-time information via devices other than public display signs. For this study, researchers observed riders arriving at Seattle-area bus stops to measure their wait time while asking a series of questions, including how long they perceived that they had waited.

The study found that for riders without real-time information, perceived wait time is greater than measured wait time. However, riders using real-time information do not perceive their wait time to be longer than their measured wait time. This is substantiated by the typical wait times that riders report. Real-time information users say that their average wait time is 7.5 min versus 9.9 min for those using traditional arrival information, a difference of about 30%. A model to predict the perceived wait time of bus riders was developed, with significant variables that include the measured wait time, an indicator variable for real-time information, an indicator variable for PM peak period, the bus frequency in buses per hour, and a self-reported typical aggravation level. The addition of real-time information decreases the perceived wait time by 0.7 min (about 13%).

A critical finding of the study is that mobile real-time information reduces not only the perceived wait time, but also the actual wait time experienced by customers. Real-time information users in the study wait almost 2 min less than those arriving using traditional schedule information. Mobile real-time information has the ability to improve the experience of transit riders by making the information available to them before they reach the stop.

1. Introduction

It is imperative to improve potential riders' satisfaction with public transportation, because of its societal benefits. Transit provides mobility to those who cannot or prefer not to drive, including access to jobs, education and medical services

* Corresponding author. Tel.: +1 206 250 4415; fax: +1 404 894 2278.

E-mail addresses: kariewatkins@gmail.com (K.E. Watkins), bdferris@cs.washington.edu (B. Ferris), borning@cs.washington.edu (A. Borning), scottrut@u.washington.edu (G.S. Rutherford), dflayton@u.washington.edu (D. Layton).

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(American Public Transit Association, 2008). Transit reduces congestion, gasoline consumption and the nation's carbon footprint (Davis and Hale, 2007; Schrank and Lomax, 2009). However, from a customer perspective, a mobility choice is only a choice if it is fast, comfortable and reliable. Increasing the competitiveness of non-auto modes is one key to reducing environmental impact (Poudenx, 2008). Transit agencies continuously work to improve transit travel time and on-time performance, but such efforts often come at a substantial cost. One inexpensive way to combat unreliability from the user perspective is real-time transit information. Real-time information can help riders to feel more in control of their trip, including their time spent waiting and their perception of safety. Recent advances in mobile device technology are enhancing opportunities for more productive use of travel time (Lyons and Urry, 2005). Now, the introduction of these more powerful personal mobile devices is also changing the wait time portion of the transit trip as well.

The OneBusAway (OBA) transit traveler information system has existed as a service for transit riders since the summer of 2008 at http://onebusaway.org. The current primary use of OneBusAway is to provide real-time next bus countdown information for riders of King County Metro (KCM) in greater Seattle (Ferris et al., 2009). OneBusAway does this by using the underlying data feed from KCM's Automatic Vehicle Location (AVL) system and the prediction algorithms developed by Dr. Daniel Dailey and others from the Electrical Engineering department at the University of Washington (Maclean and Dailey, 2002). OneBusAway provides a more user-friendly interface to KCM's AVL data by providing multiple means to access the data, including a website, a standard telephone number by which arrival information is read by the computer, an SMS interface for text-messaging, a website optimized for internet-enabled mobile devices, an iPhone application, and an Android application. The OneBusAway interface that has received the most attention to date has been the location-aware native iPhone application (Ferris et al., 2010a), shown in Fig. 1. OneBusAway is being developed as an open-source system to allow other developers to enhance the code in conjunction with the project team, as well as allowing other transit agencies to access the code and use it themselves.

The underlying goal of OneBusAway is to reduce the burden of using public transportation and thereby increase rider satisfaction and increase transit ridership. The results of an online survey of OneBusAway users show preliminary indications of

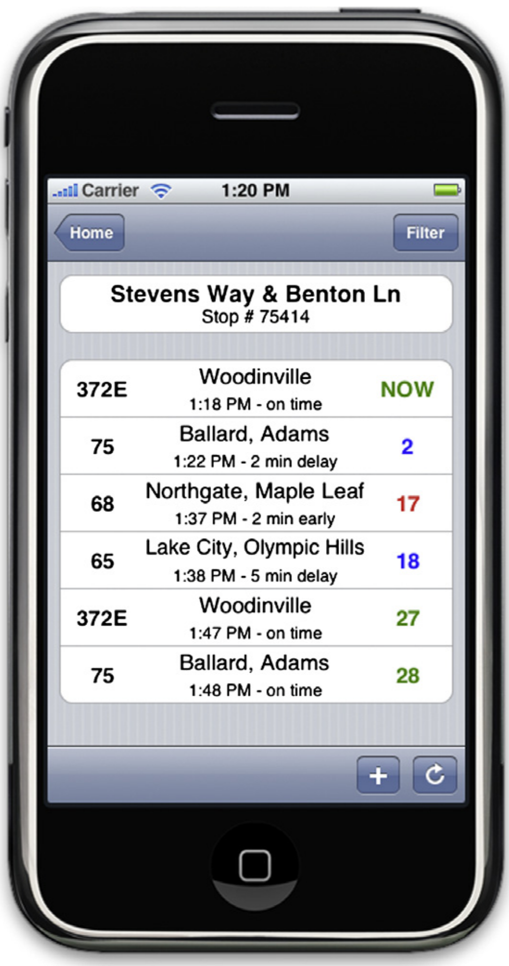

Fig. 1. Example arrival screen for a bus stop from the OneBusAway iPhone application.

success with these goals (Ferris et al., 2010b). The results of this survey indicate that OneBusAway users have an increased satisfaction with public transportation, as well as a perception of a decreased waiting time, increased number of transit trips per week, increased feelings of safety, and an increased distance walked compared with before they used OneBusAway. This survey does have two limitations in that it is self-report data and no control group of non-OneBusAway users was considered.

Several studies have looked at traveler response to real-time information; however few have addressed real-time information via devices other than public display signs. Public display signs are expensive, both for the initial purchase and the ongoing maintenance, thereby limiting the number of stops at which real-time information could be available (Schweiger, 2003). For this reason, it is becoming increasingly popular to provide real-time arrival information via website and handheld devices. Information via mobile devices and the internet has the added benefit of intercepting a rider before they are waiting at the station or stop, allowing them to maximize their time and wait for a shorter period of time. Although many at-stop real-time arrival information displays have been tested, little work has been done with the perceived and actual wait time using phone-based real-time information, including internet-enabled (''smart'') phones.

2. Literature review

There are two principal reasons that OneBusAway is interested in providing better transit traveler information: to increase satisfaction among current riders; and to increase ridership, especially among new or infrequent transit users and for nonpeak hour trips, two key markets for many agencies. Although higher transit ridership is explained mostly by regional geography, economy, population, and transportation system characteristics (Taylor et al., 2009), it has been shown that real-time transit traveler information can result in a mode-shift to public transportation (Multisystems, 2003). This stems from the riders' ability to feel more in control of their trip, including their time spent waiting and their perception of safety. Reducing wait time is important for transit riders, because it occurs at the critical preprocess phase of service delivery, in which delays carry more weight with customers (Dube et al., 1991).

Several studies have looked at traveler response to real-time information. However, the use of AVL only began in the last decade and the provision of actual real-time information to riders is an even more recent development. Before many transit agencies even had real-time bus tracking capabilities, Reed conducted a conjoint analysis of the response to real-time information using ratings of hypothetical situations. He found that real-time information was expected to reduce the burden of the wait as the degree of certainty increased (Reed, 1995).

As of 2003, when the Transit Cooperative Research Program (TCRP) synthesis document on Real-time Bus Arrival Information Systems was written, only three US and five international agencies had measured the rider reaction to real-time arrival information. According to the synthesis, London Transport's Countdown program, which used at-stop real-time arrival signage, found that the perceived wait time dropped from 11.9 to 8.6 min. In addition, passengers felt less stress and felt reliability had improved since implementation (although it had actually decreased) (Schweiger, 2003). Transit Watch, a program implemented with real-time information via video monitors in Seattle, was found to be useful, but not to increase overall satisfaction with transit. One major finding was that customers wanted the information via internet websites and at malls or office buildings close to transit (Mehndiratta et al., 2000). A study of Portland's Transit Tracker, another at-stop real-time arrival system, did not find a change in the perceived wait time, nor did it find a change in overall satisfaction with transit (Science Applications International Corporation, 2003).

In order to determine the possible benefit of real-time information, Mishalani, et al. looked at the difference between perceived and actual waiting times at a bus stop. The study was conducted at campus bus service stops on the Ohio State University campus in Columbus by lurking at bus stops and observing the arrival time, then asking riders how long they had been waiting when the bus approached. There was a statistically significant difference in the perceived versus actual waiting time. However, this difference was small and no actual real-time arrival information was tested (Mishalani et al., 2006).

Katrin Dziekan has also done significant work with rider reactions to real-time arrival information via at-stop displays. In one paper, she summarizes that real-time arrival displays increase feelings of security, reduce uncertainty, increase ease-of-use, adjust travel behavior and improve customer satisfaction. Most importantly to this investigation, permanent real-time arrival signage at transit stations showed that the ability to determine when the next vehicle is coming brings travelers' perception of wait time in line with the true time spent waiting (Dziekan and Kottenhoff, 2007).

Dziekan also conducted a before and after study of the perception of wait time after the installation of real-time arrival information signage on a tramline in The Hague, Netherlands. The study was conducted via survey mailed to the same respondents before the installation, 3 months after the installation and again 16 months after the installation. The perceived wait time decreased from 6.22 to 5.00 to 4.81 min, a difference of 20% over 3 months and 23% over 16 months (Dziekan and Vermeulen, 2006).

In a before and after study of the ShuttleTrac system on University of Maryland College Park campus, seven models were estimated using panel data to determine behavioral and psychological response (Zhang et al., 2008). The real-time information for ShuttleTrac is provided via terminals at selected stops, a large display at an activity center, telephone and website. The results indicated that real-time information increased rider's feelings of security after dark and boosted their overall level of satisfaction, however it was not found to significantly increase trip frequency, nor was it found to reduce waiting anxiety or the perception of on-time performance.

3. Methodology

To begin to overcome the limitations of the earlier self-report survey, this study more thoroughly looks at rider perceptions of wait time versus actual wait time. The earlier self-report survey showed that 91% of OneBusAway users indicate that they spend less time waiting for the bus than they did before using OneBusAway (Ferris et al., 2010b). The study reported in this paper will quantify how varying forms of real-time transit information, including OneBusAway via the basic voice interface, via the custom iPhone application, via the website and via text-messaging changes the actual and perceived time waiting for transit riders.

For the purposes of this study, eight researchers worked in pairs at fourteen bus stops in the vicinity of the University of Washington in February 2010. Both members of the survey pair attempted to remain inconspicuous, with the first surveyor (the recorder) standing in a location away from the stop for easy observation and the second surveyor (the questioner) attempting to appear as a typical bus rider waiting at the stop. Using a spreadsheet, the recorder noted the arrival times, gender and age group (college-age or older) of all riders who approached the bus stop. In addition, they recorded any distinguishing characteristics (purple hat, leather jacket, beard, etc.) to help them identify this rider throughout the survey. The questioner chose respondents randomly for a series of questions about waiting. Upon the beginning of the questioning, the recorder noted the time and survey ID from the back of the survey form. After the survey was complete and the rider boarded a bus, the recorder noted the bus number the respondent had boarded for verification of that answer on the survey form.

The questioner surveyed as many riders as possible at the stop, aiming to begin surveying a rider after an average of approximately 5 min wait time and attempting to avoid influencing the answers of the next person by speaking in a quiet voice, alternating ends of the stop to choose respondents and waiting between respondents. The first two questions inquired about the respondent's willingness to participate and whether or not they had been surveyed previously. In all, 856 riders were approached for the survey. 804 were willing to participate, equating to a response rate of 94%. It is of note that many of those not willing to participate indicated that they saw their bus approaching and therefore did not have enough time. Of those who were willing and able to begin the survey, 13 had previously been approached by the survey team at another stop or on another day; another 20 respondents had a missing arrival time due to the recorders inability to catch all arrivals at busy stops; 54 were missing a critical piece of information due to the rider boarding a bus before the survey was complete; and 62 were transferring at the time of the survey. Therefore, in all there were 655 usable surveys in the analysis.

The first question asked of all respondents was "As precisely as possible, how long have you been waiting for the bus?" If a respondent answered in a 5-min increment, they were asked if they could be more precise and answer in a 1-min increment. The second question asked of all respondents was "On a scale of 1–10, 1 being relaxed and 10 being aggravated, how do you feel about waiting for the bus?" If asked for clarification, they were told that the question referred to their general impression about waiting and not just this specific instance. At the end of the survey, all respondents were asked "As precisely as possible, how long do typically wait for this bus?" Again, they were asked to attempt to answer in a 1-min increment. In the middle of the survey, respondents were asked what they use to find out when the next bus is arriving, what type of device they use to access this information, the bus route, their destination, and how frequently they take this particular bus.

Of those surveyed, the breakdown of next bus arrival information was as follows:

- 88 were OneBusAway users.
    - o 55 of those primarily used the smart phone application.
    - o 10 primarily used their cell phone.
    - o 8 primarily used text-message.
    - o 12 primarily used the website.
    - 544 arrived without real-time information (used schedules, trip planners, maps, etc.), which are referred to below as "Traditional Methods".
    - 23 used other programs for real-time information, including KCM Tracker (http://trackerloc.kingcounty.gov/), BusView (http://busview.org), MyBus (http://www.mybus.org/)

The data collected in the survey allows for the testing of three hypotheses:

1. Bus riders perceive that they are waiting longer for a bus than they actually are waiting.
2. Real-time bus arrival information will reduce the perceived wait time of a bus rider to bring it in line with the measured wait time.
3. Real-time bus arrival information will reduce the aggravation level experienced by a bus rider.

In addition, for 156 surveys, the recorder noted the actual arrival times of the buses. This aspect of the survey was added later as it became apparent that we would not be able to do this automatically using KCM data. By comparing this to the arrival times and the bus boarded, a 4th hypothesis can be tested:

4. Real-time bus arrival information will reduce the <u>actual</u> wait time of a bus rider.

Each of these hypotheses can be tested using difference of means tests. In the case of the first hypothesis (#1), a series of Paired Differences of Means *T*-tests can be used to find the difference between the mean measured wait time and the mean perceived wait time:

$$H_0 : \mu_{\text{Perceived wait}} - \mu_{\text{Measured wait}} = 0$$

The other three hypotheses (#2–#4) can all be tested using an Independent Difference of Means *T*-test by taking the difference between the mean wait time or aggravation level for those riders with traditional information (schedules, trip planners) versus those with real-time information:

$$H_0 : \mu_{\text{Real-time}} - \mu_{\text{Traditional}} = 0$$

In the case of the wait times specifically (#2), this hypothesis can be expanded to:

$$H_0 : (\mu_{\text{Real-time measured}} - \mu_{\text{Real-time perceived}}) - (\mu_{\text{Traditional measured}} - \mu_{\text{Traditional perceived}}) = 0$$

In addition to these hypotheses, a regression model for the prediction of perceived wait time can be developed based on the actual wait time, the use of real-time information, and other factors about the rider or the bus. Based on the data available from the collection effort, several variables can be tested for inclusion in the prediction model, including:

- real-time information categorical variables (OneBusAway user, other real-time user, traditional arrival information),
- rider categorical variables for gender and age (college or older),
- user frequency variables for the frequency that the rider uses that particular bus (4+ times per week, 2–3 times per week, about 1 time per week, about monthly, infrequent, first time),
- rider aggravation level (scale of 1–10, 1 being relaxed and 10 being aggravated),
- distance variable corresponding to the approximate distance the rider was about to travel,
- environmental categorical variables for weather (sunny, rainy, cloudy),
- time of day categorical variables for PM, midday, evening,
- bus route-related variables for bus frequency/headway and percent of late buses.

4. Results

4.1. Effect of real-time on perceived wait time

For riders who arrived at the bus stop having used traditional methods, such as a schedule, map, trip planner or other static data source or simply showed up at the stop, Table 1 shows the hypothesis that their perceived wait time is equal to their measured wait time is rejected. On average, these riders perceive that they are waiting 0.83 min (15%) longer than they are. This is consistent with previous findings in both the transportation literature discussed previously and service industry literature (Jones and Peppiatt, 1996).

However, as shown in Table 2, for riders using real-time information from OneBusAway, the hypothesis that the perceived wait time is equal to the measured wait time cannot be rejected. The 0.32 min difference in perceived and measured wait time is not significant (*p*-value 0.1884).

Similarly, for the users of real-time information from other mobile sources, the hypothesis that their perceived wait time is equal to their measured wait time cannot be rejected. As shown in Table 3, the 0.30 min difference in perceived and

Table 1
Perceived versus measured wait times (in min) of bus riders using traditional arrival information.

Variable	Mean	Std. dev.	95% CI
Perceived wait	6.19	3.51	5.90–6.49
Measured wait	5.36	2.97	5.11–5.61
Difference	0.83	2.85	0.59–1.07
No. observations = 544 t = 6.8169, Pr($T > t$) = 0.0000			

Table 2
Perceived versus measured wait times (in min) of bus riders using OneBusAway real-time arrival information.

Variable	Mean	Std. dev.	95% CI
Perceived wait	4.98	2.76	4.39–5.56
Measured wait	4.66	2.43	4.14–5.17
Difference	0.32	2.25	−0.16 to 0.80
No. observations = 88 t = 1.3256, Pr($T > t$) = 0.1884			

Table 3
perceived versus measured wait times (in min) of bus riders using other real-time arrival information.

Variable	Mean	Std. dev.	95% CI
Perceived wait	4.96	3.15	3.59–6.32
Measured wait	4.65	2.17	3.72–5.59
Difference	0.30	2.10	−0.60 to 1.21
No. observations = 23 t = 0.6956, Pr($T > t$) = 0.4940			

measured wait time is not significant (p-value 0.4940). The sources of information for these other real-time users include King County Metro's own Tracker, the predecessor to OneBusAway called MyBus, and other smart phone or website-based programs developed by independent developers.

After combing the two groups of real-time information users, the hypothesis that real-time information is reducing the perceived wait time to bring it in line with the actual wait time can be tested with an Independent Difference of Means T-test.

The results, shown in Table 4, indicate that the hypothesis that the two ways of obtaining information about arriving differ from each other cannot be rejected.

4.2. Regression model for the prediction of perceived wait time

In order to expand upon these results, a regression model for the prediction of perceived wait time based on the measured wait time, presence of mobile real-time information, and other bus and rider factors was developed. Possible variables included an indicator variable for gender, an indicator variable for college-age, a categorical variable for frequency of rider use as well as indicator variables for the categories of rider frequency, a discrete variable for the rider aggravation level, a continuous variable of the approximate distance the rider was about to travel, environmental categorical variables for weather, time of day categorical variables, a discrete variable for bus frequency/headway, and a continuous variable for the percent of late buses on the route.

After testing these variables for their significance, the final model was determined to be:

$$\mathrm{PW} = \beta_0 + \beta_1\mathrm{MW} + \beta_2\mathrm{RT} + \beta_3\mathrm{PM} + \beta_4\mathrm{BF} + \beta_5\mathrm{FL}$$

where PW is the perceived wait time, MW the measured wait time, RT the categorical variable for Real-time Information, (RT = 1 if real-time is available, RT = 0 if traditional arrival), PM the categorical variable for PM peak period, BF the bus route frequency in buses per hour, and FL is the typical frustration level as experienced on a scale of 1–10.

As shown in Table 5, all variables are significant and the overall R^2 was 0.43. The Breusch–Pagan test for heteroskedasticity indicated that the regression model is heteroskedastic (chi^2 = 97.33, p-value = 0.0000), therefore robust standard errors have been used. On average, riders perceived that they are waiting 1.9 min plus 0.72 min for every minute they actually wait with an additional 0.59 min if they are waiting in the PM peak and 0.19 min for every integer increase in the level of aggravation. For every additional bus per hour, the perceived wait decreases by 0.14. The addition of real-time information decreases the perceived wait time by 0.73 min.

Table 4
Difference of means test for perceived wait time (in min) comparing traditional arrivals versus real-time arrivals.

Group	Observations	Mean	Std. dev.	95% CI
Real-time	111	0.32	2.21	−0.10 to 0.73
Traditional	544	0.83	2.85	0.59 to 1.07
Difference		−0.52		−1.00 to −0.04
t = −2.1305, Pr($T > t$) = 0.0344				

Table 5
Estimation results for perceived wait time (PW) model.

Variable	Coefficient	Robust standard error	t-Statistic (p-value)
Intercept	1.9	0.40	4.82 (0.000)
Measured wait (MW)	0.72	0.049	14.63 (0.000)
Real-time info (RT)	−0.73	0.24	−3.08 (0.002)
PM peak period	0.59	0.22	2.73 (0.006)
Buses per hour (BF)	−0.14	0.064	−2.24 (0.025)
Aggravation level (AL)	0.19	0.054	3.53 (0.000)
No. observations = 646 R^2 = 0.43, F(2652) = 56.10 (P = 0.0000)			

Accepting our model as a linear approximation in the vicinity of wait times actually experienced, the model suggests several conclusions. The insignificance of the percentage of late buses and significance of real-time information shows that riders do not care as much about buses being late as they do about knowing that buses are late. Personal rider variables such as gender, college-age, the distance they expected to travel or the frequency with which they used the bus did not impact the perception of wait time. However, the aggravation level, which could be considered a personal measure of many other factors from their trip (Is someone waiting? Are they late for a meeting? What is their personality type?) was significant – frustrated users perceive that they wait longer. The insignificance of environmental variables may be unique to Seattle and the weather patterns experienced here. Many riders are accustomed to waiting in rainy weather in February, so the presence of rain does not impact their stated perception of wait.

One interesting point is the balance between providing additional service (increasing buses per hour) and providing real-time information. It is not until the route reaches a level of 6 buses per hour (10 min headway) that the bus per hour coefficient (-0.84) is greater than the coefficient for the provision of real-time information. By using cost estimates for providing real-time predictions and for adding frequency on routes, a transit agency could use these estimates to determine which is more cost effective.

In summary, real-time information significantly reduced perceived wait time. Rider characteristics do not significantly impact the perception of wait time except for the typical aggravation level waiting for the bus. Real-time could be a very cost-effective means for reducing perceived wait time.

4.3. Effect of real-time information on perceptions of typical wait time

In addition to their perceived wait time for the one particular instance in which they were waiting, riders were also asked about their typical wait time if they took the bus more than once per month. The difference between real-time information users (OneBusAway or other real-time programs) versus those using traditional arrival information (schedules, trip planners, etc.) can again be tested using an Independent Difference of Means *T*-test.

As shown in Table 6, real-time information users say that their average wait time is 7.54 min versus 9.86 min for those using traditional bus arrival information, a difference of 31%. The *t*-test is significant with a *p*-value of 0.000. Clearly, real-time information makes a significant difference in the typical bus wait time, indicating that riders use the information to arrive closer to the actual arrival of the bus.

After the survey was complete, if respondents answered that they use OneBusAway to access real-time arrival information, they were asked to comment about their use of OneBusAway. Their comments were specifically directed toward how OneBusAway has changed their trip making patterns, wait time or frustration with waiting. Of those asked about OneBusAway, 25 respondents commented specifically about its effect on their wait time, with 16 (64%) stating that OneBusAway has reduced their wait time and 9 (36%) stating that their wait time has not changed. No one indicated that their wait time was longer as a result of OneBusAway. Some of the comments received include:

> "I absolutely do use it to do other things or go back to my desk. It has changed my morning routine – I wait no time at all in the morning."

> "OneBusAway is valuable, especially when coming in the morning. In the afternoon, I have two buses to choose from and it tells me which one to try to catch. It has probably changed my wait time."

4.4. Effect of real-time information on aggravation level

In addition to questions about perceived wait time, riders were asked how they felt about waiting for the bus. This aggravation level was measured on a scale of 1–10, with 1 being relaxed and 10 being aggravated. The model for the prediction of perceived wait time includes the aggravation level as a significant variable, indicating that riders who are less aggravated predict their wait time more accurately while those who are more aggravated tend to perceive their wait times as being longer, other things being equal. It is also worth investigating if real-time information is leading these riders to be less aggravated. Conceivably, if a rider knows when the bus is coming, they will be more relaxed as they wait for the bus.

However, as shown in Table 7, this is not the case. There was no significant difference between the real-time information users self-reported aggravation level and the self-reported aggravation level of those without real-time information.

Table 6
Difference of means test for typical perceived wait time (in min) comparing traditional arrivals versus real-time arrivals.

Group	Observations	Mean	Std. dev.	95% CI
Real-time	103	7.54	3.56	6.85–8.24
Traditional	497	9.86	5.19	9.40–10.32
Difference		2.32		1.49–3.15

$t = 5.5022$, $\Pr(T > t) = 0.0000$

Table 7
Difference of means test for aggravation level (scale 1–10) comparing traditional arrivals versus real-time arrivals.

Group	Observations	Mean	Std. dev.	95% CI
Real-time	110	3.35	1.96	2.98–3.72
Traditional	540	3.29	2.17	3.11–3.48
Difference		−0.05		−0.46 to 0.36
$t = -0.2442$, $\Pr(T > t) = 0.8074$				

Table 8
Difference of means test for actual wait time (in min) comparing traditional arrivals versus real-time arrivals.

Group	Observations	Mean	Std. dev.	95% CI
Real-time	26	9.23	4.05	7.59–10.87
Traditional	130	11.21	5.08	10.33–12.09
Difference		1.98		0.14–3.82
$t = 2.1695$, $\Pr(T > t) = 0.0357$				

Of those who indicated they use OneBusAway, their comments were also directed toward their aggravation level since using OneBusAway. Of the 25 who commented about their aggravation, 19 (76%) indicated that they are less frustrated and 5 (20%) indicated that they are equally frustrated as before using OneBusAway. One person responded that they are more frustrated when OneBusAway shows that the bus was late and less frustrated when it shows the bus is on time. Other comments received include:

> "Before OneBusAway, my average aggravation would have been a 9. I definitely use the bus more often. I can plan around the bus with OneBusAway."

> "OneBusAway improves the fluidity of moving. I have less anger and I manage my time better as a result. I am more relaxed on the bus."

4.5. Effect of real-time information on actual wait time

In Tables 1 and 2, the mean measured wait of riders using traditional arrival information was reported as 5.36 min and the mean measured wait of riders using real-time information was reported as 4.66 min. The difference between these mean measured waits could indicate that real-time information users not only perceive their wait to be shorter, but their actual wait time is shorter as well. However there is one caveat to this claim. Although the surveyors attempted to be random in their selection of riders to respond to the survey, they may have inadvertently influenced the measurement of actual wait time because the surveyors knew this was a study for OneBusAway. In particular, iPhone users are obvious to spot at the stop and their desire to make sure they got enough OneBusAway users may have lead them to ask about wait time sooner than for other riders. Therefore, in order to supplement this information, for some of the survey periods, the arrival time of the buses was recorded to see the entire wait time of the survey respondents. In all, 156 respondents were surveyed when the exact bus arrivals were being recorded.

The results of these actual wait times are shown in Table 8. Based on the independent difference of means *t*-test, real-time information users wait almost 2 min less than those arriving using traditional information, a result which is significant at a *p*-value of 0.0357. This is perhaps the most important finding of the study. By using mobile real-time information, users are not only perceiving that their wait is shorter, but they are actually arriving at the stop closer to the actual arrival of the bus.

5. Summary and conclusions

The underlying goal of this research is to help transit agencies improve the ridership and satisfaction with public transportation. Giving passengers real-time information about the arrival of the next bus helps minimize waiting time, improves the perception of the wait and alleviates the stress of wondering when the bus is coming. Although bringing the perception of wait time in line with the actual wait time will not improve the reliability of transit, it can improve the perceptions that relate to reliability by giving riders more control.

Many of the hypotheses tested in this study relate to perceptions of wait time. It was found that on average, transit riders perceive that they are waiting 0.83 min longer than they are. However, for riders using real-time information, the hypothesis that the perceived wait time is equal to the actual wait time cannot be rejected. The difference between the perceived and measured wait times for those with real-time information and those without real-time information is significant and large. This is substantiated again by the typical wait times riders report. Real-time information users say that their average wait time is 7.54 min versus 9.86 min for those using traditional arrival information, a difference of 31%.

A model to predict the perceived wait time of bus riders was developed, with significant variables that include the measured wait time, an indicator variable for real-time information, an indicator variable for PM peak period, the bus frequency in buses per hour, and a self-reported typical frustration level. The addition of real-time information decreases the perceived wait time by 0.73 min. The model results show that the percentage of late buses was not as significant as the provision of real-time information, indicating that riders do not care as much about buses being late as they do about knowing that buses are late. Real-time information is also more important than bus frequency, with the coefficient on real-time information exceeding the coefficient for frequency until the route reaches a level of 6 buses per hour (10 min headway).

Although real-time information effects the perceived wait time of riders, real-time information makes no difference in the self-reported aggravation level experienced by riders in this study. However, comments received from OneBusAway users indicate that they feel a reduced level of aggravation as a result of using OneBusAway. It could be that real-time information users are a self-selecting group, which has a naturally higher level of aggravation with waiting for the bus and real-time information brings their aggravation down to the level of a typical rider. This can only be tested with a before and after study of OneBusAway users. Therefore, the next phase of this project will be a longitudinal study of riders before and after they begin using OneBusAway. This future study will recruit non-OneBusAway users and introduce them to real-time information to investigate changes in number of transit trips, wait time, and perceptions such as level of aggravation with waiting for the bus.

Finally, a critical finding of this study is that mobile real-time information reduces the actual wait time experienced by customers. Real-time information users wait almost 2 min less than those arriving using traditional information. Although previous studies about perceived wait time have been done using real-time information signage, the advantage of mobile real-time information is that it can change the actual wait time of riders. OneBusAway users routinely comment about their ability to grab a cup of coffee because they know there is a 10-min delay one particular day or that they should literally run to the stop because their bus is on time and they are running late.

With the introduction of more powerful, easier to use and less expensive personal mobile devices, mobile transit information has the ability to become more prevalent for riders. OneBusAway provides applications for real-time information via internet-enabled ‘‘smart'' phones, devices which cost more than $200 to purchase in addition to monthly data plans. However, in addition to these applications, the data is available via text-message, website and a regular phone line, allowing use by a substantial portion of the transit-riding population. By opening up the data via multiple media, the likelihood of riders being able to access real-time information increases. Regardless of these multiple media, a small percentage of riders are still not able to access the real-time data because they cannot afford cell phones. One possible way to overcome this is to implement a free-511 program similar to the free-911 program in which inactive cell phones can still make emergency calls. Such a program could distribute older cell phones and chargers to the transit-dependent population to enable access to real-time information at every stop in a system without the use of expensive real-time arrival signage.

In summary, mobile real-time information via devices such as websites, cell phones, text-messaging and smart phones changes the perceived wait time of transit riders to be insignificantly different from their actual wait time. Additionally, mobile real-time information changes the actual wait time of transit riders by allowing them arrive at the stop when the bus is actually approaching, rather than leaving for the stop according to the schedule data. Not only does mobile real-time information save a transit agency money by avoiding the installation of real-time signage, it actually improves the experience of transit riders by making the information available to them before they reach the stop.

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