NATIONAL CENTER FOR TRANSPORTATION SYSTEMS PRODUCTIVITY AND MANAGEMENT

Mobile Technology Usage Amongst the Transit Riding Populace

Contract # DTRT12GUTC12 with USDOT Office of the Assistant Secretary for Research and Technology (OST-R)

Final Report

June 2015

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Summary

Recently, innovative technology has allowed transit agencies to provide real-time information to riders, allowing them to maintain some control over their trips and potentially retaining choice riders and increase ridership. Real-time information removes the uncertainty while waiting for the bus by providing accurate, frequently updated information on when the next bus will arrive at a specific stop.

While there are various means to providing this information to transit riders, including smartphone applications, computer-based websites, and text messaging, agencies do not always have the resources to invest in and develop all of these different technologies. The purpose of this research is to understand the availability of mobile technology amongst transit riders in order to help transit agencies distribute resources that will allow more riders to have access to real-time information. This technology also has the opportunity to provide alerts and other information that can influence an individual's ride.

As society's means to share and gather information evolves, having transit agencies respond to these changes is vital and has been frequently adopted among many agencies. Less than a decade ago, real-time information was not available to the transit riding population but is quickly becoming standard in many cities. This research is influenced by the growing adoption of mobile technology and seeing this change occur in such a short amount of time is exciting. The variability of the technologies providing this data also allows a wider range of riders to obtain this information.

This study was conducted using on-board survey data from Saint Louis Metro transit riders. While working closely with the agency, preliminary findings were summarized in 2013 and presented at the TRB annual meeting in 2014. These results showed that the use of computer-based websites and interactive voice response would best provide real-time information to riders without access to smartphone applications. It was also found that certain demographic groups were less likely to have access to smartphone applications, specifically riders over 40 years old. This information helped influence the development and integration of real time arrival information into the agency's online trip planner.

A second publication provided an update based on an additional survey conducted in summer 2013 and projected smartphone usage over time to advise St. Louis Metro about future directions. Hopefully the resulting publication will inform transportation researchers about the benefits of shift share analysis and transit agencies about potential smartphone adoption into the future.

Chapter 1
Introduction and Resulting Publications

By helping travelers move from single-occupancy vehicles to transit systems, communities can improve the efficiency of the system, improve the safety of the system, and reduce the environmental impact of transportation. However, from a customer perspective, a mobility choice is only a choice if it is fast, comfortable and reliable. One difficulty with unreliability for many transit riders is the unknown wait time they will face. Riders stand at a corner scanning the horizon for the approaching bus, wondering when it will come; or if it will come. Another day they time their arrival exactly to the scheduled minute to see that the early-running bus just passed their stop and they have another 30 minutes (or longer) to wait. By knowing when the bus is actually coming, the entire picture changes. The inherent unreliability is less of an issue if the rider knows in advance when the bus is coming, even if it is a few minutes late. If transit agencies hope to retain choice riders and increase ridership, they need to allow riders to maintain some control over their trips by providing them with real-time information.

The results of an initial survey of mobile real-time next bus arrival system users in Seattle indicated that they 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 real-time information (Ferris, Watkins, et al. 2009). An additional study of the implications of mobile real-time information for perceived and actual wait times 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. In addition, mobile real-time information users in the study waited almost 2 minutes less than those arriving using traditional schedule information (Watkins, Ferris, et al. 2011).

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. Providing the information in a mobile format can have substantial cost savings over fixed signage, especially when considering an entire bus network. Over the past few years, transit agencies have seen the impacts of early adopters of mobile real-time information programs and have begun adopting such programs primarily by opening up their data to developers. The usage of this data has primarily been to create high-tech smart phone applications. With a prevalent usage of smart phones in the population, this would give substantial access to the information. However, if the typical rider does not have a smart phone to access the data, they are left in the dark in terms of improved information.

The current and near-term future prevalence of mobile technology among the existing and potential transit-riding populace is widely unknown. Many current mobile transit information systems provide applications for real-time information via internet-enabled “smart” phones, devices which cost more than $200 to purchase in addition to monthly data plans. In addition to these applications, the data could be 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. However, in many other locations, the information is available via smartphones only. Furthermore, 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.

RESULTING PUBLICATIONS

This project resulted in one MS thesis and two journal publications, one of which has already been published and the other currently in review.

MS Thesis:

Windmiller, S. (2013). *Alternatives to smartphone applications for real-time information and technology usage among transit riders.* Atlanta: Georgia Institute of Technology. http://hdl.handle.net/1853/50369

Journal Publications:

Windmiller, S., Hennessy, T., & Watkins, K. (2014). Accessibility of Communication Technology and the Rider Experience: A Case Study of St. Louis Metro. *Transportation Research Record* #2415, pp. 118-126.

> Real-time information (RTI) informing transit riders about transit schedules, next bus or train arrivals, and service alerts is becoming increasingly available, particularly through internet-enabled smartphone applications. Alternative technologies such as interactive voice response (IVR) and mobile-based websites can also provide this information. Currently, the extent of communication technology usage among transit riders is largely unknown.
>
> Paired with an investigation of cellular phone usage among transit riders and the general American population, an analysis of St. Louis Metro's Onboard Survey data was conducted to examine riders' communication technology usage, as well as to determine how this usage may impact the rider experience and ridership-generating potential. Additional analyses also identified specific demographic groups that would benefit from supplemental technology methods more conducive to their particular information accessibility.
>
> Results found that communication technology usage has risen substantially in recent years, and that Metro riders who use smartphones or text-messaging reported significantly higher levels of satisfaction with service factors such as the ability to make transfer connections and personal security at transit centers. Specific demographic groups (e.g., riders over 40 years of age) were less likely to own smartphones, and it was concluded that computer-based websites and IVR are the best supplementary alternatives for those groups.
>
> The current study emphasizes the growing need for RTI applications in the transit industry and suggests that the development of enhanced communication methodologies can positively impact the rider experience. Furthermore, differences in individual technology accessibility call for RTI application development that mirrors the unique characteristics of its ridership.

Misra, A., Windmiller, S., Watkins, K. (2015). In Search of Equitable Technology for Providing Information to Transit Riders: A Case Study of St. Louis Metro, submitted to *Journal of Intelligent Transportation Systems*.

> For transit agencies, mobile devices can provide an easy and innovative means to provide real-time information, communicate service changes, obtain customer feedback, and pay fares. However, the extent of communication technology usage amongst transit riders, specifically their access to smartphone applications and alternative technologies, is largely unknown. Without this information, transit agencies may not equitably serve their riders.
>
> This study identifies the differences in individual technology accessibility (smartphone, cell phone, text-messaging, and personal computer) and prioritizes investment in technology using longitudinal survey data for St. Louis Metro as a case study based on various demographic factors of transit riders. Metro was then compared with national data on cell phone and smartphone ownership from other similar size transit agencies and the general American population. These analyses identified specific demographic groups, such as riders over 44 years of age, which would benefit from supplemental technology methods.
>
> The final component of the study sought to understand the validity of the results in a five year time horizon, given the dynamic nature of the interaction between population and technology adoption. A shift share analysis was used to forecast technology ownership among different age groups of transit riders based on national technology adoption trends and change in transit ridership of different age groups. Results indicate that a fairly high percentage of riders may have access to smartphone technologies in the future. However, there will still be need for at least another alternative technology independent of smartphone use for delivering and receiving information from transit riders.

ACKNOWLEDGEMENTS

This research was jointly funded and conducted by St. Louis Metro Transit and the National Center for Transportation Systems Productivity and Management at Georgia Institute of Technology. The funding was used to support Sarah Windmiller for the duration of her MS degree at Georgia Tech. Sarah won the 2013 American Public Transport Foundation Parsons Brinckerhoff-Jim Lammie Scholarship as a result of her work and is now employed at Cambridge Systematics in Atlanta, GA. St. Louis Metro Transit's sponsorship included a summer internship for Sarah, as well as data for the entire project. The PI would like to thank Todd Hennessey, Isaac Moses, and Bernadette Marion at Metro for their interest, time, and energy on the study. The PI would also like to thank PhD student Aditi Misra for her mentorship of Sarah throughout her MS program.

Chapter 2
Initial Study of St. Louis Metro Riders Technology Usage

INTRODUCTION

The emergence of mobile communication devices within the past decade not only provided connections between people but enhanced the distribution and collection of information. With the introduction of smartphones, even more innovative means to collect, store, and disseminate data are possible. Information such as news and weather reports can be instantly accessed with interfaces designed to be fast, reliable, and user-friendly. However, the relatively high cost of smartphones and accompanying data plans may serve as an ownership obstacle for some individuals.

Currently, many transit agencies are utilizing this technology by providing applications and General Transit Feed Specification (GTFS) data for real-time information (RTI) that incorporate maps, schedules, and general information. Since this technology is not available to all riders, supplementary measures such as text-messaging (SMS) or interactive voice response (IVR) can be developed to capture a larger portion of transit riders. However, limited information exists about current mobile device users, so it is unknown if these supplementary measures are capturing riders without access to smartphone applications.

This report investigates the accessibility of mobile devices and other supplementary RTI technologies to transit riders, including smartphone applications, SMS, IVR, mobile-optimized websites, and computer-based websites. Additionally, this report provides information regarding cell phone ownership in the United States and how this ownership compares to transit riders. Finally, an in-depth analysis of Bi-State Development Agency's (d.b.a. Metro) riders' usage of mobile devices and related technologies, as well as its impact on rider experience and the potential to generate ridership, is discussed. Specific Metro demographic groups less likely to own a smartphone and the best alternative RTI technologies for these riders are also identified.

BACKGROUND

Several studies have demonstrated how RTI technology improves riders' perceptions of a system and enhances their transit experience *(Ferris et al, 2011)*. The presence of RTI on a system has resulted in higher overall satisfaction with the service due to reduced perceived wait times, increased sense of safety and security, a better utilization of time, and reduced anxiety, uncertainty, and stress *(Ferris et al, 2011; Dziekan and Kottenhoff, 2007)*. The combination of these effects has also been found to increase ridership. A Chicago case study concluded when taking various control variables into account, bus routes with CTA's Bus Tracker, the agency's RTI technology, caused a slight increase in ridership when compared to routes without this technology *(Tang and Thakuriah, 2012)*.

While the effects of RTI have been overwhelmingly positive, there has been a lack of research regarding the availability of this technology to users, whether from mobile devices or computers. This has resulted in assumptions concerning what demographic groups do not have access to these devices and RTI as a whole. By better understanding the 'missing' demographic groups and what technologies they can access, a more informed decision regarding the best supplementary technology to smartphone applications can be formed.

Establishing smartphone applications as the primary tool of RTI, and the reason why supplementary tools to this technology are being investigated, is due to a variety of reasons. First, smartphone ownership is on the rise. As of March 2013, approximately 56% of Americans own a smartphone, an increase of 81% since 2010 *(Smith 2013)*. If this trend continues, a vast majority of Americans will own smartphones and have access to applications. This reasoning is in conjunction with the growing availability of GTFS from transit agencies, sometimes provided for free *(MTA 2013; CTA 2013; LA Metro 2013).* As GTFS becomes more precise and widely available, software developers will be able to create more RTI applications from this information.

METHODOLOGY

In the summer of 2012, Metro conducted a system-wide onboard rider survey designed to measure satisfaction with specific service factors, travel behavior, loyalty and turnover intentions, trip-planning and information gathering preferences, and general demographics.

Employing a stratified random sampling strategy, proportional strata were developed based on the average daily passenger boardings by route. Additionally, the bus sampling strategy incorporated secondary attention to the day type, as well as the relative boardings occurring in Missouri and Illinois. Sampling schedules covered most of a route's hours/days of operation, while ensuring the peak service periods were adequately sampled when ridership proportions were highest. The total valid and usable surveys returned were 1,611 (bus) and 1,921 (rail) for response rates of 61.4% and 65.8%, respectively. Margins of error at the 95% confidence level were 2.4% (bus) and 2.2% (rail).

Peer research was also conducted to help conclude whether Metro's technology ownership trends were common among other transit riders. The largest agencies in terms of unlinked passenger trips were selected to be part of this analysis *(Dickens et al, 2012)*. Survey results describing an agency's riders in regards to cell phone and smartphone technology were obtained online *(BART 2009; Infogroup 2012)* or via phone or email (*Boberg, J., O'Malley, T., Pepper, J., and Shank, V., unpublished data*). A total of six agencies had surveys with this information and are listed below:

- BART – San Francisco Bay Area Rapid Transit District
- CTA – Chicago Transit Authority
- King County Metro – King County Department of Transportation
- LAC MTA – Los Angeles County Metropolitan Transportation Authority
- NJ TRANSIT – New Jersey Transit Corporation
- TriMet – Tri-County Metropolitan Transportation District of Oregon

Technology trends among Americans as a whole were also analyzed to establish a baseline of technology use to compare to transit riders.

NATIONAL & AMERICAN TRANSIT AGENCY TRENDS

The Pew Research Center's Internet & American Life Project has collected information regarding the percentage of Americans with cell phones since 2004, describing the growing adoption of this new technology *(Rainie 2013).* With the emergence of smartphones in recent years, these reports have expanded to include statistics regarding smartphone ownership among Americans *(Smith 2013).* Reports regarding the availability of cell phone-related technologies, such as SMS, were also written *(Duggan and Rainie 2012*). This information creates the basis of the mobile technology ownership trend among Americans, which can then be compared to transit riders.

Recently, various transit agencies have collected information regarding their riders' usage of these devices. Surveys asking whether a rider has a mobile device or uses SMS provide insight into the adoption of these technologies, allowing conclusions to be drawn with respect to how accessible various RTI technologies are to transit riders.

Cell Phone Ownership

Cell phones have become commonplace with 91% of Americans owning a mobile device as of May, 2013. This ownership has been steadily increasing since 2004 when 65% of Americans owned a cell phone (Figure 1) *(Rainie 2013).*

This increase in cell phone ownership has also been seen among different transit agencies. It is important to note that these surveys were conducted in different years and questions may have varied slightly; therefore, the results cannot always be directly comparable. However, most transit agencies had similar, if not a greater, percentage of riders with cell phones when compared to the national trend.

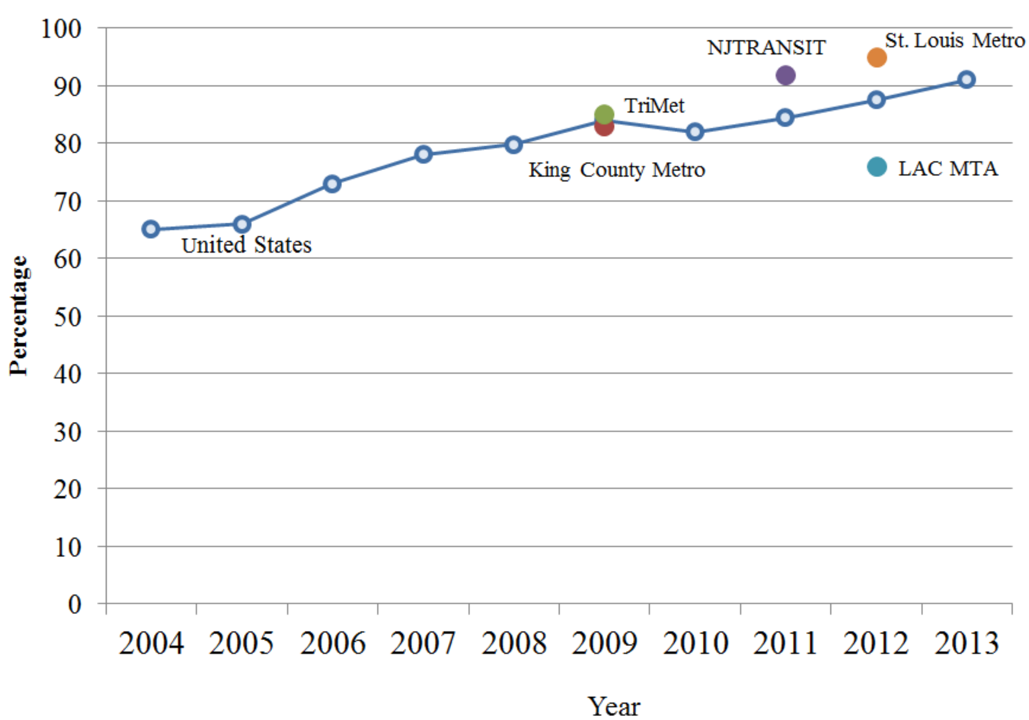


FIGURE 1 Cell Phone Ownership for United States and Transit Riders

Smartphone Ownership

As cell phones have evolved, smartphones have become the most prevalent mobile device type. Similar to cell phone ownership, there has been a steady increase of smartphone ownership within recent years. Specifically, in 2010, 31% of Americans owned a smartphone; just three years later, 56% of Americans own a smartphone. As more Americans own cell phones, the chances of the device being a smartphone are increasing as well (Figure 2) *(Smith 2013).*

This trend is also true among transit riders. With the exception of one agency, transit riders' smartphone ownership was actually higher than the national average, and for most surveys conducted in 2011 or later, the majority of transit riders own a smartphone. This suggests that more transit riders will have the ability to access smartphone applications providing RTI in the following years. Again, it is important to note that surveys among transit agencies are not necessarily directly comparable, but are provided for general trends and comparison to general population data.

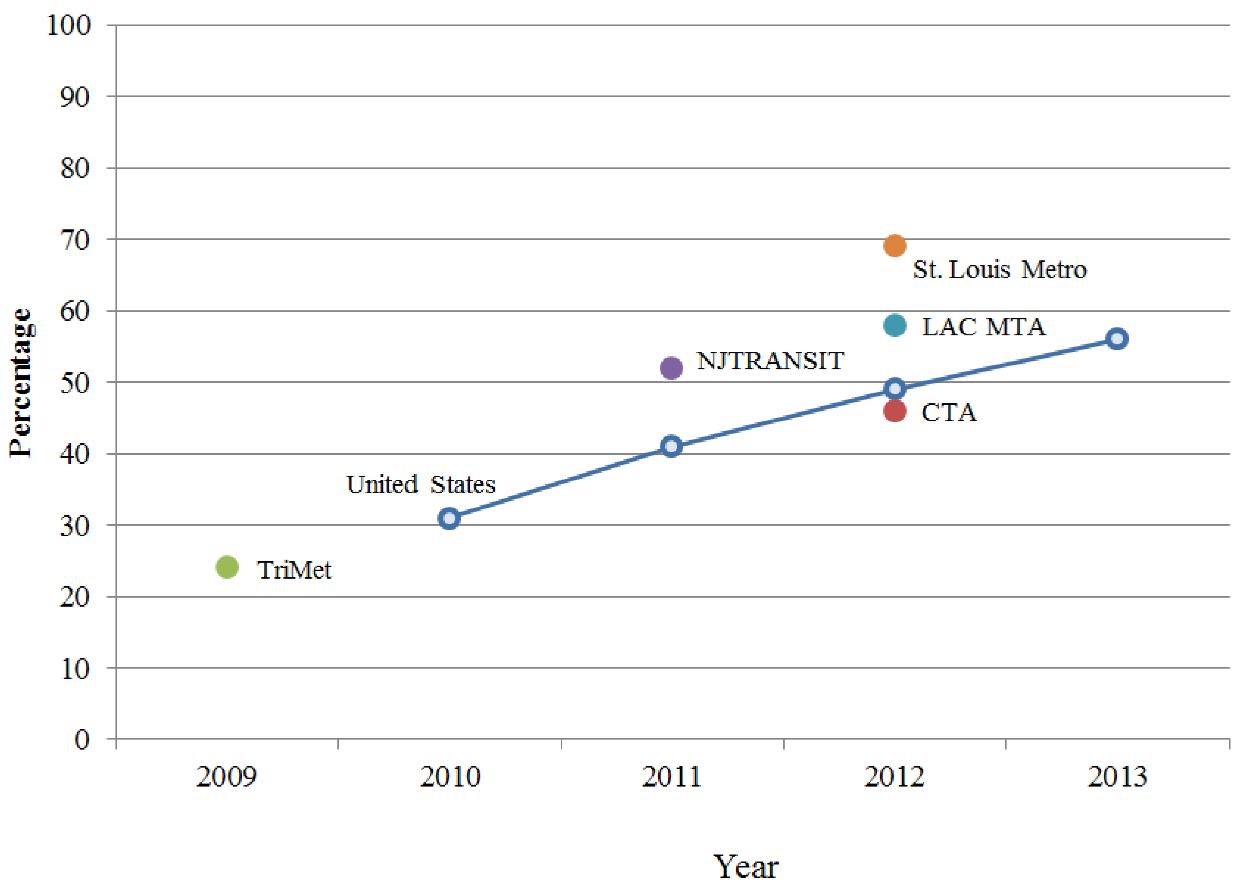


FIGURE 2 Smartphone Ownership for United States and Transit Riders

Availability of Alternative Technologies

Despite the increase in smartphone ownership, not all transit riders have mobile devices that are able to access RTI information due to constraints on the device, lack of certain data or internet plans, or preferences of the user.

Therefore, certain technologies and access are needed to supplement smartphone applications. Particularly, users with internet on cellular devices are able to access mobile-optimized websites, users with text messaging are able to send and receive SMS, users with any cellular or stationary phone can access IVR services, and those with computer internet access can access websites.

Having access to a computer with internet was available to 77% of American adults in 2010 *(US Census Bureau 2011).*In 2012, 93% of CTA riders had internet access through a computer while in 2012, 81% of Metro riders had this access. In 2012, of those with mobile devices, 80% used text messaging, resulting in approximately 68% of all Americans, regardless of cell phone ownership, with access to this alternative. Of Metro riders with cell phones, 88% had text messaging in 2012 while 70% of CTA riders had SMS in 2012. Also, of Americans with cell phones, 56% are able to access the internet on that device (approximately 48% of all Americans). In 2012, this same technology was accessible to 76% of LAC MTA and 72% of Metro riders *(Duggan & Rainie, 2012;* Boberg, J., O'Malley, T., unpublished data).

While there is a high percentage of cell phone ownership, allowing IVR access, providing a RTI website would also be accessible by a large percentage of Americans and transit riders. However, while this is the most accessible alternative to smartphone applications, it is unknown if this technology is the best alternative. While these trends do provide a basis of comparison, the next section investigates this by taking an in-depth look into Metro riders.

METRO RIDER MOBILE AND INTERNET TECHNOLOGY UTILIZATION

In 2007, Metro Transit began asking customers about their use of cellular and internet technology to better understand these tools' penetration of use among riders, as well as to gather baseline information on the emerging general trend of cellular phone and internet use. In 2012, cellular and internet-related questions were redesigned to account for design and utility advancements in cellular technology and internet-based transit applications since the previous onboard survey conducted in 2008. As reported below, significant preference shifts away from traditional methods (e.g., telephone call line, printed schedules) of information gathering and trip planning toward internet and mobile-based methods have been observed among its riders.

Internet Access

Metro riders were asked whether they had internet access from a *computer at home*, *work*, *school*, or *other place*. Results from the previous 2008 onboard survey suggested that access to the internet was on the rise, and this suggestion was strongly confirmed by the 2012 survey. The rate of internet access since 2008 grew substantially for both transit modes with 76% of bus riders and 85% of rail riders reporting they now have access. The growth rate of access by rail riders was 10% and an astounding 25% by bus riders.

Cellular Phone Penetration

Onboard surveys conducted in 2007 and 2008 did not address the use of specific smartphone technology, but rather simply asked whether riders used a cell phone or not. The 2012 onboard survey was revised to ask not only whether a cell phone was used but also what *type* of cell phone was used (e.g., *iPhone, Non-Smartphone, Do Not Own a Phone)*. Results showed strong growth in cell phone usage by both bus and Rail Riders. While higher rates of cell phone usage were historically observed among Rail Riders, the 2012 survey challenged that trend with a significant uptick in reported cellular usage among bus riders (92% of respondents) toward that of Rail Riders (95% of respondents).

With respect to the specific phone types in use, some proportional usage similarities existed between bus and Rail Riders (e.g., Blackberry, Android-based); however, Rail Riders were more likely to be carrying an iPhone. Identifying specific smartphone preferences among riders facilitates the development of the most effective RTI applications for particular market segments.

Finally, riders were asked whether they had internet access on their phones (that they use), as well as whether their phones had a text messaging ability (that they use). Nearly 75% of Bus and Rail Riders stated they access the internet via their phones. Eighty-eight percent (88%) of all respondents reported they use their phones' text-messaging ability, representing dramatic proportional usage growth rate increases of 52% since 2008 for Bus Riders and an increase of 83% for Rail Riders.

System-wide, the exceptionally high proportion of cellular phone penetration (95%), robust 70% smartphone penetration, and dramatic increases in mobile texting and internet access activity point toward a growing potential for transit experience-enhancing service improvements such as mobile RTI applications (e.g., OneBusAway) and revenue service enhancements (e.g., smartphone-integrated fare collection).

Impact on Rider Experience and Satisfaction

Expanded service and improved intra- and intermodal connectivity on the Metro transit system have contributed to increased transfers rates in recent years, especially for bus riders. Using a one-way analysis of variance (ANOVA) paired with a Tukey post hoc multiple comparison, the 2012 survey revealed that bus riders who transferred more during a trip reported significantly less satisfaction with the bus system's *on-time performance* ($F = 3.821$, $p < .05$) and the *ability to make transfer connections* ($F = 7.614$, $p < .01$). The survey also found that bus riders who used smartphones were significantly more satisfied with their *ability to make transfer connections* ($F = 5.839$, $p < .05$) than those riders who do not use a cell phone at all.

Finally, bus riders who stated they use their phones' text-messaging ability reported significantly higher levels of satisfaction with Metro's *communication of service changes or disruptions* ($F = 6.753$, $p < .01$). Texting-capable riders also reported significantly higher levels of satisfaction with *personal security at transit centers and train stations* ($F = 22.830$, $p < .001$), as well as *overall satisfaction* ($F = 4.441$, $p < .05$) with bus service.

These results strongly suggest that having immediate access to service-related information (e.g., via texts, website, social media, email) provides an enhanced benefit to smartphone and texting-capable users over those riders who must rely solely on printed material that may be outdated or even unavailable. Furthermore, this research suggests that having access to smartphones or texting capability may serve to boost positive perceptions of personal safety and security, thus contributing to a better overall transit experience, increasing the likelihood that a rider will continue riding, and increasing the likelihood that the rider will recommend the transit service to others.

In addition to examining technology users' satisfaction with specific service elements, it is important to note how these results relate to the key drivers of *overall satisfaction* and perceptions of the *value of service for fare paid*. Using exploratory factor analysis and multiple regression, models were developed that identified key service dimensions impacting riders' *overall satisfaction* and perceptions of *value of service for fare paid*.

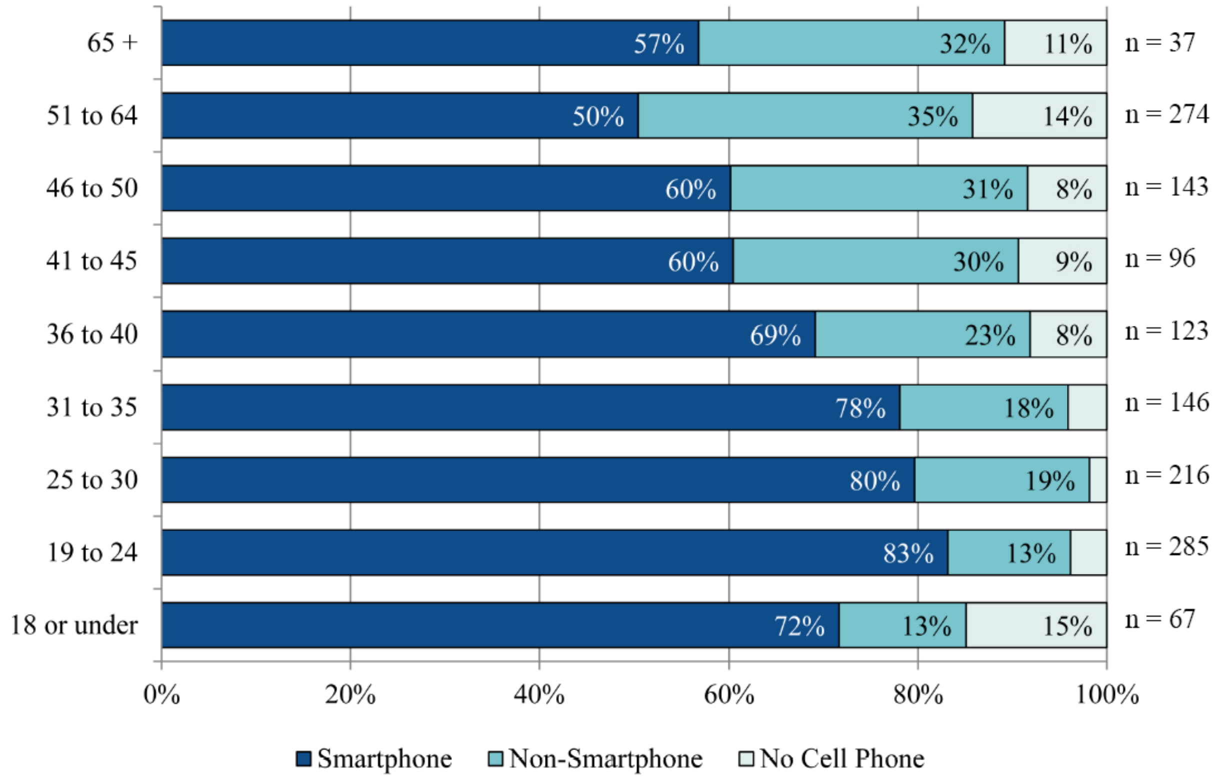
With respect to *overall satisfaction* on the bus system, a top factor was labeled "Travel Efficiency" and accounts for riders' perceptions of the *ability to make transfer connections*, *on-time performance*, and the *ability to travel when and where desired*. While not as predictive of *overall satisfaction*, a factor labeled "Communication" was the strongest predictor of Rail Riders' perceptions of the train service's *value of train service for fare paid*. Consisting of four service performance areas, this primary factor includes *helpfulness of Metro website information*, *helpfulness of Transit Information Call Line*, *ease of reading printed train schedules*, and *communication of service changes or disruptions*.

Given the impact these primary factors have on *overall satisfaction* and *value of service for fare paid*, the results described above indicate that real-time mobile and internet application development has the potential to strongly influence the rider experience. Supporting this notion, previous research found that riders were significantly more satisfied using transit after trying a RTI application, as well as feeling significantly safer while using transit *(Ferris et al, 2011).* It is important to note, however, that while the availability of RTI has the potential to positively impact a rider's transit experience, inaccurate information can also negatively impact that rider's overall satisfaction *(Gooze et al, 2013).*

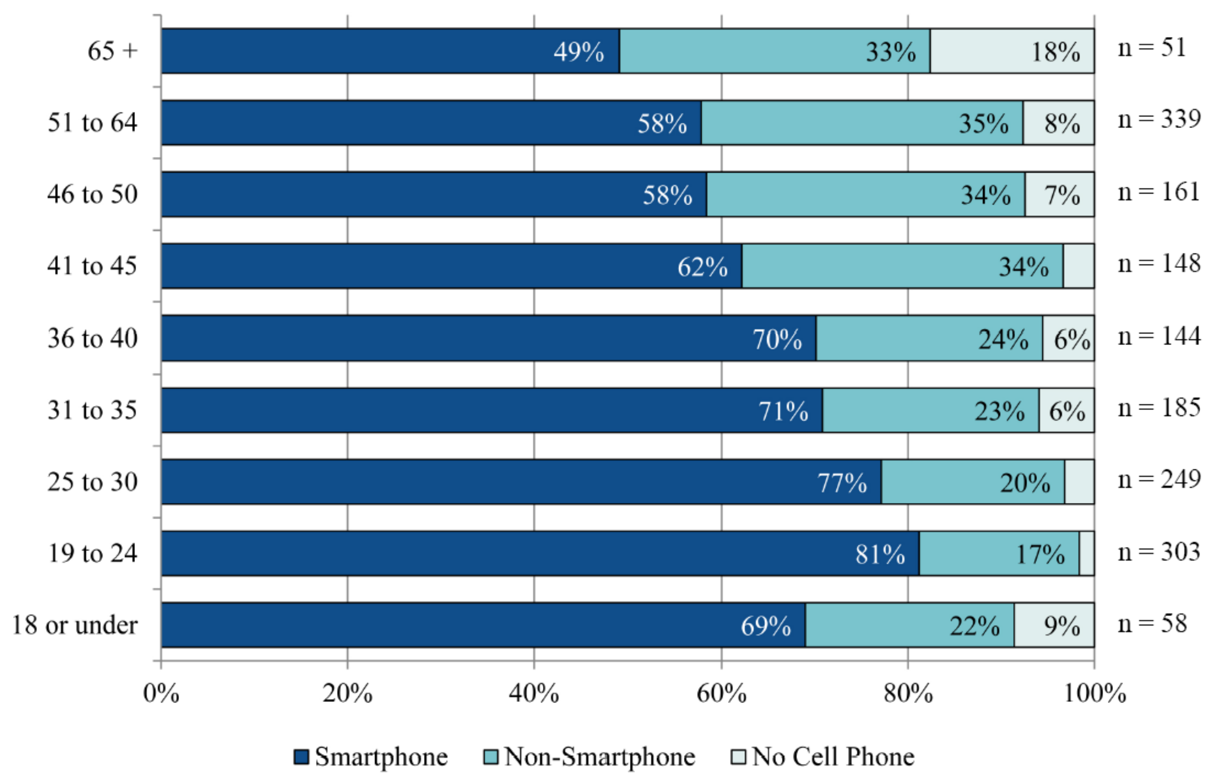
Identify Non-Smartphone Users

As more riders own mobile devices, understanding who does not have potential access to RTI applications and what is the best supplementary technology can maximize the benefit from accessing this information.

Riders were categorized through cross tabulations comparing the distribution of smartphone, non-smartphone and no cell phone ownership between different demographic groups. The demographic groups investigated included age, race, employment, income, and gender. Figure 3 displays one cross tabulation of cell phone ownership and age--the most noticeable relationship.



(a) Bus Riders



(b) Rail Riders

FIGURE 3 Cell Phone Ownership Based on Age for Bus *(a)* and Rail *(b)* Riders

As the age of Bus and Rail Riders increases, the portion of riders with smartphones decreases. Of the five different demographics analyzed, this was the most predominate relationship.

When race and cell phone ownership were compared, among Bus and Rail Riders, White / Caucasians had the lowest smartphone ownership at 59% and 61% respectively. This compared to 74% of Black / African American Bus and 71% of Black / African American Rail Riders with smartphones.

Considering employment status, riders employed full-time, part-time, and student riders were the most likely to have a smartphone. Among Bus Riders, 72%, 71%, and 72% respectively had this device while 69%, 72%, and 72% of Rail Riders had smartphones. This resulted in unemployed, retired, or homemaker riders as the least likely to own a smartphone with smartphone ownership percentages ranging from 54% to 57% of Bus and 51% to 63% for Rail Riders.

It was also found that smartphone ownership differed, but not drastically, among income levels. For Bus Riders, 67% of riders with a household income below $20,000 had a smartphone while 71% riders earning over $100,000 had these devices. This difference was more noticeable among Rail Riders with 66% earning less than $20,000 with a smartphone, compared to 77% of riders with incomes greater than $100,000.

Finally, it was concluded that smartphone ownership did not differ between males and females. Approximately 71% of female and 67% of male Bus Riders had a smartphone while among Rail Riders, 69% of females and 68% of males had these devices.

These percentages allowed specific demographic groups to be identified as the most likely to not have smartphones. In order to provide statistical support for these groups, the data were reorganized separating riders' responses into those who do and do not have a smartphone. Additionally, these responses were further recoded to be within a demographic category most likely to own and not own a smartphone.

For this statistical test, the null hypothesis is the distribution of smartphone and non-smartphone owners is similar for all demographic categories. Table 1 displays the frequency distribution as well as the results of the chi-square goodness of fit test.

	Bus Riders			Rail Riders		
	Owns a Smartphone		Chi square goodness of fit test	Owns a Smartphone		Chi square goodness of fit test
	Y	N		Y	N	
Age			$x^2 = 83.251$, 1 d.f.			$x^2 = 55.046$, 1 d.f.
40 and Under	656	181	$p < 0.0001$	710	229	$p < 0.0001$
Over 40	303	247		407	292	
Employment			$x^2 = 28.408$, 1 d.f.			$x^2 = 26.777$, 1 d.f.
Full-Time, Part-Time, Student, or Full-Time & Student	767	292	$p < 0.0001$	954	395	$p < 0.0001$
Unemployed, Homemaker, Retired	139	114		108	98	
Income			$x^2 = 4.297$, 1 d.f.			$x^2 = 1.770$, 1 d.f.
Under \$20,000	383	192	$p < 0.05$	308	157	$p > 0.05$
Over \$20,000	444	170		612	263	
Race			$x^2 = 14.771$, 1 d.f.			$x^2 = 25.325$, 1 d.f.
White / Caucasian	157	108	$p < 0.001$	359	232	$p < 0.0001$
Other	785	311		752	279	

TABLE 1 Smartphone v Non-Smartphone Ownership Distribution and Chi square Test

Nearly every chi-square test conducted was found to be statistically significant at the 1% level, rejecting the null hypothesis. Interestingly, while the distribution of income and smartphone ownership among bus riders was significant, it is only significant at the 5% level. Only rail data when considering income was found to not be statistically significant with $p = 0.183$. This suggests that, when compared to other demographic characteristics, income is not the most dominate indicator of smartphone ownership.

The chi-square tests investigating the age cut-off were found to have the highest x^2 as well as the lowest *p*-value when compared to other demographic groups. This indicates a strong statistical relationship and concludes that smartphone ownership between riders above and below 40 years old differs. The strength of this disproportion between smartphone and non-smartphone owners is the greatest among these age groups than any other demographic categories.

The two different employment statuses and race categories identified above were also statistically significant. The unequal employment distribution could be due to a variety of factors, including the price of smartphone data plans which may be perceived as unnecessary costs by non-employed riders. In addition, students are generally below 40 years old and due to the statistically significant age relationship, it is logical that students also have access to smartphones.

These tests result in a finalized list identifying the demographic groups that are most likely to *not* own a smartphone:

- Above 40 years old
- Retired, unemployed, homemaker
- Earns less than $20,000 (Bus only), or
- White / Caucasians

After identifying these groups, further research was conducted to better understand the access these groups have to alternative technologies that provide RTI.

Access to Alternative Technologies

While smartphone applications are the new and upcoming means to provide RTI, there are other alternatives to retrieve this information such as:

- Interactive Voice Response (IVR)
- Mobile-Optimized Website
- Computer-Based Website
- Text Messaging (SMS)

IVR is accessible from any phone line, mobile or otherwise. Users call a specified number and speak information describing their stop, what line they want, and where they want to travel. Mobile-optimized websites are optimized for the size of mobile devices, as opposed to computer-based websites. Text Messaging, or Short Message Service (SMS), can be used if riders text their stop ID to a specific number to receive RTI.

The technology required to benefit from RTI through these different means is not readily available to all users, however. The following section describes the ability to utilize these alternative technologies among Metro riders without access to smartphone applications.

All Non-Smartphone Users

The access to these alternative technologies depends on the capabilities of a mobile device (i.e. internet access, SMS). Table 2 displays the availability of different technologies between all Metro riders and those without smartphones.

Alternative Technology Access		Bus Riders: All Riders	Bus Riders: Riders without Smartphones	Rail Riders: All Riders	Rail Riders: Riders without Smartphones
IVR	Yes	93%	75%	95%	83%
	No	7%	25%	5%	17%
Mobile-Optimized Website	Yes	66%	32%	68%	26%
	No	34%	68%	32%	74%
SMS	Yes	81%	60%	83%	63%
	No	19%	40%	17%	37%
Computer-Based Website	Yes	76%	66%	85%	79%
	No	24%	34%	15%	21%

TABLE 2 Metro Rider's Access to Alternative Technologies

When smartphone users are removed, the accessibility to these technologies decreases. Most notably, the percentage of riders who own a cell phone with internet access decreases by over 50%, suggesting that the majority of riders with internet on their cell phone own a smartphone. This further implies that mobile-optimized websites, which require a mobile device with internet access, would not be an optimal alternative.

However, there is a high percentage of riders without smartphones who still own a cell phone, including 75% of Bus and 83% of Rail Riders. The majority of these riders can use IVR features and this number could be higher when landlines are considered.

Another option, using SMS, is available to 60% of Bus and 63% of Rail Riders. While this access is more prevalent than mobile-optimized websites, it does require the rider to know the ID for a specific stop or station, which may require improvements to bus stop signage for some agencies.

The final technology alternative is a computer-based website, which is not dependent on cell phone ownership or usage. Internet access, and therefore access to these websites, is available to the majority of riders. This is the second highest available technology to riders without smartphones, behind IVR.

Specific Demographic Groups Most Likely to Not Have Smartphones

As previously discussed, there are certain demographic groups most likely to not own smartphones, and therefore, not have the ability to download and access mobile applications. Table 3 provides insight regarding the availability of these technologies to these certain demographic groups, compared to all riders without smartphones.

Alternative Technology Access		Bus Riders: All Riders Without Smartphones	Above 40 years old	Retired, unemployed, or a homemaker	White / Caucasian	Earns less than $20,000
IVR	Yes	75%	74%	72%	80%	74%
	No	25%	26%	28%	20%	26%
Mobile-Optimized Website	Yes	32%	25%	31%	25%	32%
	No	68%	75%	69%	75%	68%
SMS	Yes	60%	59%	58%	63%	60%
	No	40%	41%	42%	37%	40%
Computer-Based Website	Yes	66%	60%	55%	69%	65%
	No	34%	40%	45%	31%	35%

Alternative Technology Access		Rail Riders: All Riders Without Smartphones	Above 40 years old	Retired, unemployed, or a homemaker	White / Caucasian	Earns less than $20,000*
IVR	Yes	83%	82%	73%	86%	-
	No	17%	18%	27%	14%	-
Mobile-Optimized Website	Yes	26%	19%	26%	16%	-
	No	74%	81%	74%	84%	-
SMS	Yes	63%	59%	51%	64%	-
	No	37%	41%	49%	36%	-
Computer-Based Website	Yes	79%	80%	61%	88%	-
	No	21%	20%	39%	12%	-

TABLE 3 Non-Smartphone Users' Access to Alternative Technologies for Bus and Rail Riders (*Not Significant)

One outstanding observation is the relatively different proportion of alternative technology access between Bus and Rail Riders. This variation suggests that when selecting an alternative, the most effective choice may not be the same for all transit modes.

Providing an IVR service to riders above 40 years old would capture most Bus and Rail Riders. A computer-based website would also be available to a large portion (80%) of Rail Riders.

When considering retired, unemployed, or homemaker riders, the most available alternative is also IVR. However, it is interesting that this demographic group deviates the most between all non-smartphone Rail Riders. For example, while 83% of Rail Riders without smartphones do have a cell phone, only 73% of the unemployed/retired/homemaker group has a cell phone.

Out of all the demographic groups investigated in this section, White / Caucasian Bus and Rail Riders have the highest percentage of cell phone ownership; however, having internet access is even more common among these Rail Riders (88%).

Finally, for Bus riders earning less than $20,000 a year, having a cell phone, and thus IVR, is the most prevalent at 74%. However, the availability of the other alternatives does not greatly differ between low income riders and all Bus Riders without smartphones.

DISCUSSION

One of the great benefits of RTI is the range of technologies providing this type of data. Utilizing the different types of communication on cell phones as well as computers allows a greater portion of the transit riding population to access this information, but as mobile technology becomes increasingly oriented around smartphone applications, understanding the different alternative technologies ensures this information can be available to as many riders as possible. In the previous sections, the availability of these non-smartphone technologies has been discussed, forming a basis of which technology is the best alternative.

Alternative to Smartphone Applications

The results from the previous analysis illustrated that IVR captures the most transit riders without smartphones. Specifically, 75% of Bus and 83% of Rail Riders without smartphones do have access to a mobile device, which allows them to access IVR information.

However, selecting the 'next best' alternative to smartphone applications is not that straightforward. There are many factors to consider when determining this solution, such as the goals and resources of an agency and the unknown optimal balance between information and availability of a technology.

In addition, the optimal balance between the amount of information a specific technology provides and an individual's preference for that technology is unknown. For example, while IVR is the most available alternative technology, it requires the user to know specific stop information, and depending on the service, is limited to receiving information about one stop at a time. Mobile-optimized websites, the least available alternative, provide information very similar to smartphone applications and can include route maps and service alerts. In other words, not all technologies are created equal. This optimal balance is not currently known and can also be subjective. One user may prefer the information provided through SMS while another rider may prefer his/her personal computer to receive RTI. Some studies confirm that not all RTI technologies are equal. A study of riders in Calgary, Canada stated that browsing a website was the most preferred method for planning a trip and that preferences could change depending if the customer is planning a trip or en-route *(Rahman et al, 2013)*.

Considering this information, computer-based websites may be the best alternative to smartphone applications. While this alternative had the second-highest availability among Metro's non-smartphone users and the specific demographic groups identified, it provides more information than IVR, including maps and RTI for multiple routes and stops.

Implications for Ridership Retention and Generation
In the case of Metro transit, Bus and Rail riders are dramatically shifting their information-gathering and trip-managing preferences toward the convenience, accessibility, and immediacy that internet and mobile-based information provides. Results from the current survey support existing RTI research by strongly suggesting that the development of enhanced communication methodologies can positively impact the rider experience. The need for developing and maintaining accurate RTI resources is becoming an increasingly critical necessity for transit agencies.

As discussed earlier, a significant driver of Bus Riders' *overall satisfaction* is the service dimension, "Travel Efficiency," which consists of a rider's perceptions of *on-time performance*, *ability to make transfer connections*, and the *ability to travel when and where desired*. With Bus Riders reporting increased transfer rates, the need for RTI is becoming increasingly important for making immediate, informed decisions related to scheduling, connectivity, and travel access. Additionally, traveling via bus can be a more uncertain experience than rail, especially for new riders or those individuals who are unfamiliar with a particular area. RTI would likely serve to moderate any negative service-related effects associated with transferring and connectivity, as well as those associated with the unfamiliarity with public transit travel.

With respect to rail riders, aspects of Metro's ability to communicate had the strongest influence on their perceived *value of train service for fare paid*. Perceptions of how well Metro communicates via its website, RSS rider alerts, call center, and printed materials have a significant impact on their satisfaction with Metro service. As with the aspects of "Travel Efficiency," RTI can serve to improve the perceived transit experience of riders by impacting these key service areas that drive their satisfaction.

For any transit property, growing ridership ranks among the highest of all performance objectives. A strong, positive correlation exists between Metro riders' *overall satisfaction* and their *willingness to recommend bus and rail transit service to others*. The simple assumption exists that if Metro makes more of its existing riders happy, the more new potential riders it may have. Given the research supporting the impact of RTI on the rider experience, developing internet and mobile-based applications provides one very effective approach for ridership retention and creation.

FUTURE RESEARCH
Future research defining the preferences of using the different RTI technologies among transit riders will better conclude what is the best alternative technology to smartphone applications. This will create a basis of how riders select their preferred technology based on what is available to them, what information can be obtained through that technology, and what they actually use.

Also, due to the constantly evolving world of mobile devices, applications, and the internet, the availability and preferences of various technologies could change over time. Just as smartphones have evolved from cellular phones over the past decade, the emergence of a new mobile technology could occur, resulting in yet another new alternative to smartphone applications. Agencies need to be mindful of these changes and understand the riding population’s access and preferences regarding these technologies.

CONCLUSION

This paper investigated how accessible mobile devices and other supplementary RTI technologies are to transit riders, as well as whether these technologies improve the transit rider experience. The ownership of smartphones and other mobile devices have been steadily increasing in recent years among Metro riders, other transit agencies' riders, and the nation. The majority of Metro Bus Riders own smartphones, and it was found that these riders reported significantly higher levels of satisfaction with the ability to make transfer connections. Additionally, Bus Riders who stated they use their phones' text-messaging ability reported significantly higher levels of satisfaction with Metro's communication of service changes or disruptions and with personal security at transit centers and train stations.

However, it was found that there are certain demographic groups less likely to own a smartphone, particularly riders over 40 years old. The other RTI technologies available to riders include SMS, IVR, mobile-based websites and computer-based websites. After considering the availability of these technologies among non-smartphone owners and the information each provides, it was concluded that computer-based websites and IVR are the best supplementary technology to smartphone applications. IVR can be supplemental, as the population with access to phones, both cellular and otherwise, is the largest among transit riders, especially those at-risk categories of riders without access to a smartphone. In all, smartphone applications and other technologies providing RTI are becoming increasingly available and popular among transit riders. By understanding who and how many riders have access to this information, this resource can be better developed and targeted to provide RTI to more riders.

Chapter 3
Follow-up Study of St. Louis Metro Riders Technology Usage Change over Time

INTRODUCTION

The growing adoption of mobile devices within the past decade has not only enhanced communication but has allowed information to be instantly accessible. More specifically, smartphones provide an easy and innovative means to access information through the use of mobile applications and mobile-optimized websites designed to be fast, reliable, and user-friendly. To utilize the growing adoption and innovation of these devices, many transit agencies are developing smartphone applications and/or opening up their data to developers to provide riders with real-time information (RTI), communicate service changes, obtain customer feedback, and even pay fares. As the utilization of smartphones in the transit industry increases, it is important to understand the proliferation of such devices among transit riders as well as supplementary means of communication such as text-messaging (SMS) or interactive voice response (IVR).

It is critical to enable the provision of RTI, service changes, feedback, and fare payments through smartphone applications and/or supplementary measures, because the use of mobile devices in such situations allows agencies to improve riders' perceptions of the system and enhance their transit experience. Trip planning information via smartphone can have a substantial impact on riders (Gan 2015). Several studies have demonstrated that the presence of RTI on a system has resulted in a higher overall satisfaction with the service, less actual and perceived wait time, faster journey times, perception of safety, and even increased ridership (Dziekan & Kottenhoff, 2007; Ferris, et al., 2011; Watkins et al, 2011; Tang & Thakuriah, 2012; Fonzone & Schmocker, 2014). Smartphones have been used successfully to survey transit riders en route (Zhao, et al. 2015; Dunlop et al, 2015) and provide agencies with feedback from riders (Watkins et al, 2015). Even fare payment by smartphone has been adopted in multiple cities (Barry, 2014; Brakewood, et al 2014)

To date, there has been a lack of research regarding the availability of mobile and internet technology to different types of transit riders, leading to equity concerns regarding the ability to obtain and provide information. The price of owning these devices and the accompanying data plans may serve as an ownership obstacle for some individuals. In addition, the added features of these devices may not be suitable or preferred by all users. Understanding these obstacles is particularly important for transit agencies who, by adopting technologies, are risking investing in a particular technology that may not sufficiently supply information and provide services to as many riders as possible and may leave certain population groups without equal access.

Due to the constant evolution of technology, the availability of and preferences for various technologies will change over time. Agencies need to be mindful of these changes and understand the riding population's access and preferences regarding these technologies. Towards understanding the reach of mobile technologies among transit users, this study investigates the changing ownership of mobile devices, such as cell phones and smartphones, using the Bi-State Development Agency (d.b.a. Saint Louis

Metro) as a case study. The accessibility of other supplementary technology platforms including SMS, IVR, mobile-optimized, and computer-based websites is also studied, in addition to identifying specific rider demographic groups less likely to own a smartphone. The study is then further extended to forecast the future smartphone and cellphone ownership among the riders within a time horizon of five years to allow future decisions about applications. It is expected that this study will contribute to better understanding of varying demographic groups' access to smartphones and alternative technologies to help transit agencies make a more informed decision about technology applications.

ST. LOUIS METRO RIDER SURVEY

In the summer of 2012 and 2013, Saint Louis Metro conducted a system-wide, onboard rider survey designed to measure satisfaction with specific service factors, travel behavior, loyalty and turnover intentions, trip-planning and information gathering preferences, and general demographics. Data specific to the technology usage and demographics of the riding population were the primary concern of this study and were extracted from the survey.

Employing a stratified random sampling strategy, proportional strata were developed based on the average daily passenger boardings by route, day type, and state. The total valid and usable surveys returned in 2013 were 3,063 for bus and 2,865 for rail, with a response rate of 90% and 88%, respectively. Results from the 2013 survey are presented here, with references to the 2012 survey when 2013 results notably differ or display a supporting trend in technology adoption. A full report describing the 2012 survey results can be found in Windmiller, Hennessy, & Watkins, 2014.

METRO RIDER MOBILE AND INTERNET TECHNOLOGY UTILIZATION

Specific to this study, Metro asked questions pertaining to their communication technology usage, such as their smartphone ownership or ability to send and receive text messages, as well as demographic characteristics. Smartphones were defined as an iPhone, Blackberry, Android-based, or Windows 7-based cell phone types. If a respondent selected any of these as their cell phone, they were considered to have a smartphone. Furthermore, if the respondent answered he / she had a smartphone *and* answered 'Yes' to "If you use a cell phone, does it have internet access *that you use*?", then that respondent was considered to have access to smartphone applications.

The data obtained from these surveys were organized and analyzed through a variety of different statistical methods. General descriptive statistics reported the overall ownership of smartphones and cellphones. Chi-square tests of independence were conducted to test whether smartphone ownership is statistically different between these different demographic attributes. Finally, binary logistic regression models were constructed and the results corroborated the findings of the other statistical tests. Note that the descriptive statistics are based on respondents who indicate they have a smartphone. Further analysis revealed that some riders had a smartphone, but did not use it actively for accessing the internet and "apps". Therefore, the later statistical tests include respondents who had access to a smartphone *and* mobile internet as access to internet is necessary to access smartphone applications to obtain information from and provide information to the agency.

Statistical Analysis

As the ownership of mobile devices increases, understanding who does not have potential access to smartphones helps establish what is the best supplementary technology. For this analysis, cross tabulations comparing the distribution of smartphone, non-smartphone and no cell phone ownership between different demographic groups were created. The demographic groups considered include age, race, employment, income, and gender, and are shown in Table 4 and Table 5. The figures in parenthesis represent percentage change in ownership in that category from 2012 to 2013.

Age	Smartphone	Non-Smartphone	No Cell Phone	Sample Size
18 or under	83% (+11%)	10% (-3%)	7% (-8%)	191
19 to 24	86% (+3%)	9% (-4%)	5% (+1%)	548
25 to 30	86% (+6%)	12% (-7%)	2% (+0%)	411
31 to 35	76% (-2%)	16% (-2%)	8% (+4%)	250
36 to 40	78% (+9%)	18% (-5%)	5% (-3%)	242
41 to 45	70% (+10%)	21% (-9%)	9% (0%)	232
46 to 50	66% (+6%)	23% (-8%)	11% (+3%)	247
51 to 64	51% (+1%)	33% (-2%)	17% (+3%)	448
65 +	39% (-18%)	38% (+6%)	23% (+12%)	98

Race	Smartphone	Non-Smartphone	No Cell Phone	Sample Size
Black/African American	76% (+5%)	16% (-5%)	8% (+0%)	1970
White/Caucasian	62% (+3%)	27% (-5%)	11% (+3%)	471
Asian/Asian American	73% (-4%)	27% (+8%)	0% (-4%)	49
Latino/Hispanic American	74% (-15%)	17% (+6%)	9% (+9%)	35
Other	78% (+8%)	12% (-14%)	10% (+5%)	91

Employment	Smartphone	Non-Smartphone	No Cell Phone	Sample Size
Employed Full-Time	77% (+4%)	17% (-4%)	6% (-1%)	1221
Employed Part-Time	77% (+6%)	15% (-8%)	8% (+3%)	459
Student	80% (+9%)	15% (-6%)	5% (-3%)	260
Employed Full-Time and Student	89% (+15%)	5% (-14%)	5% (-2%)	55
Employed Part-Time and Student	83% (+5%)	16% (-2%)	1% (-3%)	98
Unemployed	57% (+4%)	29% (-6%)	14% (+2%)	270
Retired	48% (-9%)	29% (0%)	24% (+10%)	153
Homemaker	44% (-13%)	34% (+5%)	22% (+8%)	41

Income	Smartphone	Non-Smartphone	No Cell Phone	Sample Size
Under $20,000	71% (+4%)	19% (-6%)	11% (+2%)	1322
$20,000 to $39,999	74% (+3%)	20% (-3%)	7% (+2%)	672
$40,000 to $59,999	81% (+8%)	13% (-6%)	7% (-1%)	289
$60,000 to $79,999	74% (+3%)	19% (-2%)	6% (-3%)	124
$80,000 to $99,999	73% (-12%)	17% (+2%)	10% (+10%)	30
$100,000 +	76% (+5%)	20% (-5%)	5% (+1%)	41

Gender	Smartphone	Non-Smartphone	No Cell Phone	Sample Size
Male	74% (+7%)	18% (-7%)	8% (+0%)	1203
Female	72% (+1%)	19% (-3%)	9% (+2%)	1430

TABLE 4 Cell Phone Type and Demographics - Bus

Age	Smartphone	Non-Smartphone	No Cell Phone	Sample Size
18 or under	83% (+14%)	13% (-9%)	4% (-5%)	119
19 to 24	84% (+3%)	12% (-5%)	4% (+2%)	512
25 to 30	81% (+4%)	14% (-6%)	5% (+2%)	389
31 to 35	80% (+9%)	15% (-8%)	5% (-1%)	269
36 to 40	76% (+6%)	18% (-6%)	5% (-1%)	238
41 to 45	69% (+7%)	20% (-14%)	10% (+7%)	206
46 to 50	66% (+8%)	27% (-7%)	7% (0%)	269
51 to 64	60% (+2%)	33% (-2%)	6% (-2%)	511
65 +	44% (-5%)	35% (+2%)	21% (+3%)	103

Race	Smartphone	Non-Smartphone	No Cell Phone	Sample Size
Black/African American	77% (+3%)	16% (-5%)	6% (+1%)	1401
White/Caucasian	67% (+6%)	27% (-7%)	6% (+0%)	967
Asian/Asian American	75% (+11%)	20% (-12%)	5% (+0%)	65
Latino/Hispanic American	74% (+1%)	23% (-4%)	3% (+3%)	39
Other	74% (+4%)	18% (-5%)	7% (+0%)	94

Employment	Smartphone	Non-Smartphone	No Cell Phone	Sample Size
Employed Full-Time	76% (+7%)	19% (-8%)	5% (+1%)	1504
Employed Part-Time	69% (-3%)	25% (+3%)	5% (+0%)	362
Student	73% (+4%)	22% (-4%)	6% (+1%)	234
Employed Full-Time and Student	82% (-3%)	14% (-1%)	4% (+4%)	57
Employed Part-Time and Student	82% (-1%)	14% (+1%)	4% (+0%)	57
Unemployed	66% (+15%)	24% (-14%)	10% (-1%)	173
Retired	52% (+0%)	32% (-3%)	16% (+3%)	101
Homemaker	59% (-4%)	23% (+7%)	18% (-3%)	22

Income	Smartphone	Non-Smartphone	No Cell Phone	Sample Size
Under \$20,000	71% (+5%)	20% (-7%)	9% (+2%)	722
\$20,000 to \$39,999	73% (+1%)	21% (-2%)	6% (+1%)	538
\$40,000 to \$59,999	71% (+6%)	24% (-8%)	5% (+3%)	343
\$60,000 to \$79,999	77% (+11%)	19% (-11%)	4% (0%)	235
\$80,000 to \$99,999	77% (+5%)	20% (-8%)	3% (+3%)	156
\$100,000 +	82% (+5%)	16% (-6%)	2% (+0%)	180

Gender	Smartphone	Non-Smartphone	No Cell Phone	Sample Size
Male	73% (+5%)	20% (-6%)	7% (+1%)	1274
Female	74% (+5%)	21% (-5%)	5% (+0%)	1331

TABLE 5 Cell Phone Type and Demographics - Rail

Descriptive Statistics

Age was found to have an inverse relationship with smartphone ownership with riders over the age of 65 having the lowest percentage of smartphone ownership, and a decrease of 18% compared to 2012. In contrast, approximately 83% of bus and rail riders under the age of 18 have a smartphone in 2013, up 1% to 14%. White / Caucasians bus and rail riders had the lowest smartphone ownership at 62% and 67% respectively as compared to 76% and 77% of Black / African American bus and rail riders with smartphones. Unemployed, retired, or homemaker riders had the lowest smartphone ownership percentages ranging from 44% to 57% for bus riders and 52% to 66% for rail riders. In addition to having a lower percentage of smartphone ownership, these riders have a high percentage of not owning any cell phone. These statistics are similar to what was seen in 2012. Income and gender did not show in any recognizable pattern in smartphone ownership across categories.

Chi-Square Test of Independence

A chi-square test was conducted separately for bus and rail riders where the null hypothesis is that the distribution of riders with and without access to smartphone applications is similar for all demographic categories. Each demographic category was used in these tests and separated into two different groups. One group represented the riders within a certain demographic category that are most likely to own a smartphone with access to mobile applications. The second group represented riders most likely to *not* have access to this technology. The cross tabulations in the previous section were utilized to establish thresholds between the two groups for each category.

The information provided in Table 6 displays the frequency distribution as well as the results of the chi-square test of independence among riders in 2013. Nearly all chi-square tests conducted were found to be statistically significant at the 1% level, rejecting the null hypothesis. Gender and race differences for both bus and rail riders were found to be not significant for rail riders. The chi-square test for the age demographic had the highest χ^2 when compared to other demographic groups.

	MetroBus Riders			MetroLink Riders		
	Owns a Smartphone with Internet Access		Chi square goodness of fit test	Owns a Smartphone with Internet Access		Chi square goodness of fit test
	Y	N		Y	N	
Age			$X^2 = 298.941$, 1 d.f.			$X^2 = 202.205$, 1 d.f.
40 and Under	69%	31%	$p < 0.0001$	72%	28%	$p < 0.0001$
Over 40	37%	63%		44%	56%	
Employment			$X^2 = 126.566$, 1 d.f.			$X^2 = 49.915$, 1 d.f.
			$p < 0.0001$			$p < 0.0001$
Full-Time, Part-Time, Student, or Full-Time & Student	63%	37%		63%	37%	
Unemployed, Homemaker, Retired	35%	65%		43%	57%	
Income			$X^2 = 43.346$, 1 d.f.			$X^2 = 11.430$, 1 d.f.
Under $20,000	50%	50%	$p < 0.0001$	56%	44%	$p < 0.001$
Over $20,000	62%	38%		64%	36%	
Race			$X^2 = 15.942$, 1 d.f.			$X^2 = 3.322$, 1 d.f.
White / Caucasian	48%	52%	$p < 0.0001$	58%	42%	$p > 0.05$
Other	58%	42%		62%	38%	
Gender			$X^2 = 0.7121$, 1 d.f.			$X^2 = 2.171$, 1 d.f.
Male	53%	47%	$p > 0.05$	59%	41%	$p > 0.05$
Female	53%	47%		62%	38%	

TABLE 6 Chi-Square Test of Independence

Binary Logistic Regression

To have a better understanding of how rider demographics contribute to access to smartphone applications, binary logistic regression models were constructed with demographic attributes as explanatory variables. The data used in these regressions were recoded to a binary variable to represent access to smartphone *and* mobile internet. On the survey, a respondent needed to specify smartphone ownership *and* access to the internet through a mobile device to be considered as an individual with access to smartphone applications.

The 27 different variables shown in the descriptive statistics were organized in a binary fashion– if an individual was within a demographic group it was indicated as '1' and if an individual did not belong to that group it was represented by '0'. Models were then constructed to understand if these demographic characteristics contribute to the probability of an individual *not* having access to smartphone applications i.e., the explained variable in the models is 'not having access to smartphone application'. A positive coefficient then represents a demographic attribute associated with those more likely to *not* have access to smartphone applications to identify possible demographic characteristics that are more likely to need an alternative technology. A negative coefficient signals a demographic attribute that is more likely to have access to smartphone applications. The final binary logistic regression results for both bus and rail riders are shown in Table 7.

Variable Name	Coefficient		S.E.		% of Total Sample		P-Value	
	Bus	Rail	Bus	Rail	Bus	Rail	Bus	Rail
Intercept	1.461	-1.208	0.099	0.107	-	-	**< 0.0001**	**< 0.0001**
Black / African American	-0.327	-0.291	0.088	0.085	69%	51%	**< 0.0001**	**< 0.0001**
40 Years Old and Below	-1.262	-1.204	0.082	0.084	56%	55%	**< 0.0001**	**< 0.0001**
Employed and/or Student	-0.925	-0.803	0.094	0.105	72%	81%	**< 0.0001**	**< 0.0001**
Income Over $80,000	-0.503	-0.896	0.262	0.139	3%	12%	0.0551	**< 0.0001**

Fit Statistics	Bus	Rail
Rho-Squared	0.212	0.173
AIC	3847.6	3689.4
Final Log Likelihood	-1830.622	-1752.686
Total Sample Size	3032	2865

*Positive coefficient = No Smartphone Application Access

TABLE 7 Binary Logistic Regression - Bus and Rail

In the final logistic regression model for bus riders in 2013, nearly every demographic variable included is statistically significant at the 1% level. Race category of Black / African Americans is statistically significant in predicting a rider's smartphone application accessibility and riders in this category are more likely to have access to this technology. Riders who are younger than 40 years are also more likely to have access to smartphone applications. Riders who are employed and/or are a student are more likely to have access to smartphone applications. Income is the only demographic attribute that is not statistically significant.

The final binary logistic regression model among rail riders in 2013 resulted in all demographic attributes significant at the 1% level. Black / Africans Americans are still more likely to have access to smartphone applications when compared to other ethnic groups; however, the remaining demographic variables have stronger coefficients, suggestion that transit rider's other demographic attributes have a stronger influence over access to smartphone applications. The demographic attribute representing riders who are 40 years of age and under again has the largest-magnitude coefficient. Income, with a threshold at $80,000 was also found to be statistical significant, with riders earning more than $80,000 more likely to have access to this technology.

For both the rail and bus model, the low rho-squared values of 0.212 for bus and 0.173 for the rail imply that a rider's demographic characteristics alone are not sufficient to predict smartphone application access and that other unobserved factors contribute much more to smartphone ownership decisions. However, certain demographic attributes were found to be consistently statistically significant in these models, including race and employment status. Gender was removed from the models, as it was never a statistically significant factor. Age was the most influential attribute in accessing smartphone applications among bus as well as rail riders with the largest-magnitude coefficient in both models.

Access to Alternative Technologies

For the groups that were shown to be most likely *not* to have access to smartphone applications, those above 40 years old, *non*-Black / African American, unemployed (including homemakers and retirees), and those with income lower than $80,000, supplementary technologies that utilize cell phone features and computers should be explored, including:

- Interactive Voice Response (IVR),
- Mobile-Optimized Website,
- Computer-Based Website, and
- Text Messaging (SMS).

IVR is accessible from any phone line, not only cell phones. To retrieve information, users call a specified number and relay information describing certain aspects of their trip including their stop, what line they want, and where they want to travel. Mobile-optimized websites are designed to be viewed on mobile devices, in addition to computer-based websites, and are therefore accessible from any device that has internet access. Text messaging, or Short Message Service (SMS), is used in transit often by texting a unique stop ID to a specific number. Understanding the ability of these alternative technologies amongst the target groups can help agencies such as St. Louis Metro provide riders without access to smartphone applications a means to access and provide information.

Table 8 displays the availability of different technologies between all Metro riders and riders without access to smartphone applications. It should be noted that the availability of these alternatives includes all riders, not just those with cell phones. Therefore, these percentages will not directly reflect the data provided earlier due to including riders that do not own a cell phone in the analysis. Note that the question was phrased to only include those respondents who feel comfortable using the technology, as in "If you use a cell phone, does it have a text messaging ability *that you use*?". Incomplete answers on the surveys were not coded, therefore sample sizes vary across alternative technologies.

2013 Survey

Alternative Technology Access		Bus Riders: All Riders	Bus Riders: Riders without Smartphone Applications	Rail Riders: All Riders	Rail Riders: Riders without Smartphone Applications
IVR	Yes	91% N = 2738	74% N = 921	94% N = 2662	81% N = 847
Mobile-Based Website	Yes	71% N = 2667	24% N = 890	73% N = 2557	22% N = 792
SMS	Yes	82% N = 2599	61% N = 880	86% N = 2506	65% N = 779
Computer-Based Website	Yes	76% N = 2803	61% N = 1042	81% N = 2859	75% N = 922

TABLE 8 Metro Rider's Access to Alternative Technologies - 2013

The highest percentage of riders with access to technology amongst riders without smartphones is those who own a cell phone, enabling access to IVR. This includes 74% of bus and 81% of rail riders who do not have smartphone. This is clearly the best supplementary mobile technology. Mobile-optimized websites are mostly accessible to those with smartphones, as there are relatively few devices with internet access that are not smartphones. The majority of riders are able to access SMS, even amongst groups without smartphones, specifically 61% of bus and 65% of rail riders. However, a drawback of this technology for stop-level information is the requirement to know the ID numbers for a specific stop or station. This may require improvements to bus stop signage for some agencies. Among rail riders, computer-based websites were noticeably more available to riders without smartphones when compared to the availability of text messaging but is just as available among bus riders. This makes computer-based websites, overall, the second most accessible alternative technology.

NATIONAL & AMERICAN TRANSIT AGENCY TRENDS

To investigate whether St. Louis Metro's technology ownership trends are common amongst the transit industry, peer research of the largest transit agencies was conducted. Some other large transit agencies have collected information regarding their riders' usage of smartphone and cell phone devices via survey questions asking whether a rider has a mobile device or other various alternative technologies. The largest agencies in terms of unlinked passenger trips were selected to be part of this analysis (Dickens, Neff, & Grisby, 2012). Recent rider survey results describing customer's cell phone and smartphone technology ownership and/or usage were collected online (Infogroup / ORC, 2009) or via phone or email (Boberg, J., O'Malley, T., Pepper, J., and Shank, V., personal communication, 2012). A total of five agencies had surveys with this information which was then used for a comparison against data from Metro. These agencies included King County Metro, TriMet, NJ Transit, CTA, and LA County Metro.

The transit agency survey results are useful to compare to the general population of all Americans, which is regularly assessed by The Pew Research Center's Internet & American Life Project (Duggan &

Rainie, 2012; Rainie, 2013; Smith, 2013). The technology trends among Americans as a whole form a baseline of technology use to compare to transit riders from the surveys, as shown in Figure 4 and 5. It is of note that the years the transit surveys were conducted differ from agency to agency. These differing survey years allow for a general comparison due to the continuous changing availability of these technologies.

Cell Phone Ownership

Within the past nine years, cell phones have become increasingly prevalent among Americans, as shown in Figure 4. Since measured in 2004, when 65% of Americans owned these devices, the adoption of this technology has been steadily increasing. These devices are now commonplace with 90% of the population owning a cell phone as of January 2014 (Smith & Page 2015). With a recent trend of slightly decreasing cell phone ownership rates, the market appears to have saturated at around 90%.

This trend in cell phone ownership is not only seen among Americans but transit riders as well. Please keep in mind these surveys were conducted in different years and questions may have varied slightly; therefore, the results cannot always be directly comparable. However, the availability of cell phones among transit riders, across nearly all agencies, is similar to the United States trend. In fact, most transit agencies had a greater percentage of riders with cell phones when compared to the national trend.

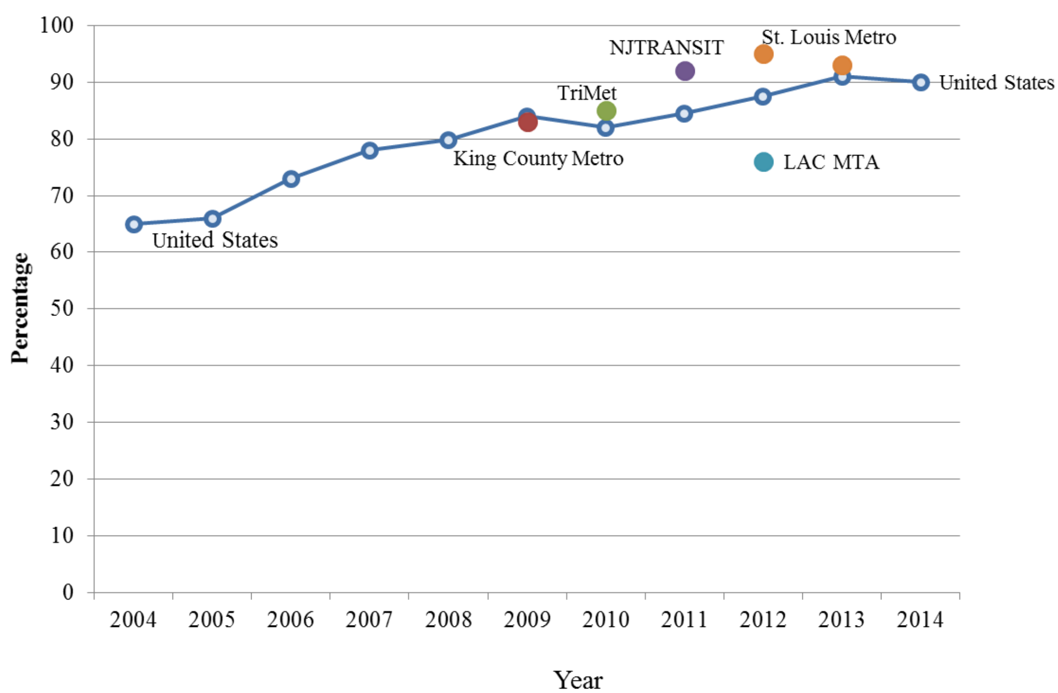


FIGURE 4 Cell Phone Ownership among Americans and Transit Riders

Smartphone Ownership

As cell phones have evolved, smartphones have become the most prevalent mobile device type, as shown in Figure 5. The trend of smartphone ownership among Americans is similar to cell phone ownership and is actually increasing at a higher rate. When first measured in 2011, 35% of Americans owned a smartphone and, in only three years, 64% of the population had these devices. As more Americans own cell phones, the chances of the device being a smartphone are increasing as well (Smith, 2013; Smith & Page, 2015).

This trend is also true among transit riders. With the exception of one agency, transit riders' smartphone ownership was actually higher than the national average, and for all surveys conducted in 2011 or later, the majority of transit riders owned a smartphone. If this trend continues, transit riders' accessibility to smartphone applications will continue to increase substantially over the next several years.

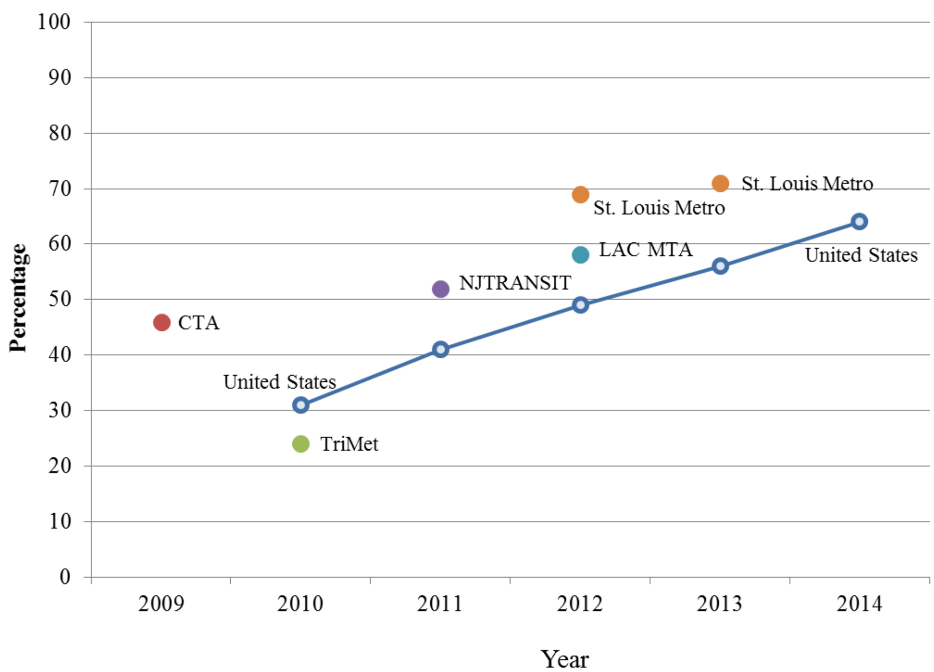


FIGURE 5 Smartphone Ownership among Americans and Transit Riders

FORECASTING THE FUTURE TECHNOLOGY USE AND RIDERSHIP

As demonstrated by the change in smartphone usage from 2012 to 2013, using a single timepoint is not enough to understand the usefulness of technology over time. Therefore, technology adoption was projected over a 5-year period to better prioritize future usage. Two components were identified as particularly important for deciding usefulness of adopting a technology: (i) penetration rate of that technology during the forecast period and (ii) change in ridership and its composition during that period which, in turn, also will decide the availability of any particular technology among the riders. Due to age being the most significant variable in all of the earlier analysis, the technology penetration was forecasted based on transit riders' age. During the analysis period, the ethnic composition of the population of St. Louis was fairly stable with the only notable difference being a 2.8% decrease in Black/African American population from 2010 to 2013 and a corresponding 1.4% increase in White population over the same time period (American Community Survey, 2013). Gender, income and employment distribution remained consistent from 2010 through 2013 (American Community Survey, 2013) and hence were assumed to not have additional influence on smartphone ownership.

Technology Penetration Forecast

The technology penetration rate among age groups was performed using on-board survey data from St. Louis Metro from 2007 to 2013. Technology penetration was analyzed using the 'S' curve method popular in predicting new technology adoption patterns (Blackman 1974, Rogers 2010). The 'S' curve pattern of technology adoption assumes a slow rate of adoption during the initial phases of the introduction of the technology followed by a rapid increase in the adoption rate during the intermediate phase and then a slow rate again as the technology matures (Figure 6).

Smartphones are a new mobile device and the trend in adoption of this technology can be conveniently extrapolated using the 'S-curve' pattern of penetration for new technologies. To validate the use of 'S-curve' for future smartphone adoption rate, the current adoption rate of two existing technologies, the cellphone and the internet, from 2007 through 2013 for the different age groups of St. Louis Metro riders were plotted and it was found that the trend fairly matches the trend predicted by the 'S' curve of technology adoption rate (Figure 7). Therefore, the same technique was used in predicting the smartphone ownership among the riders of Metro.

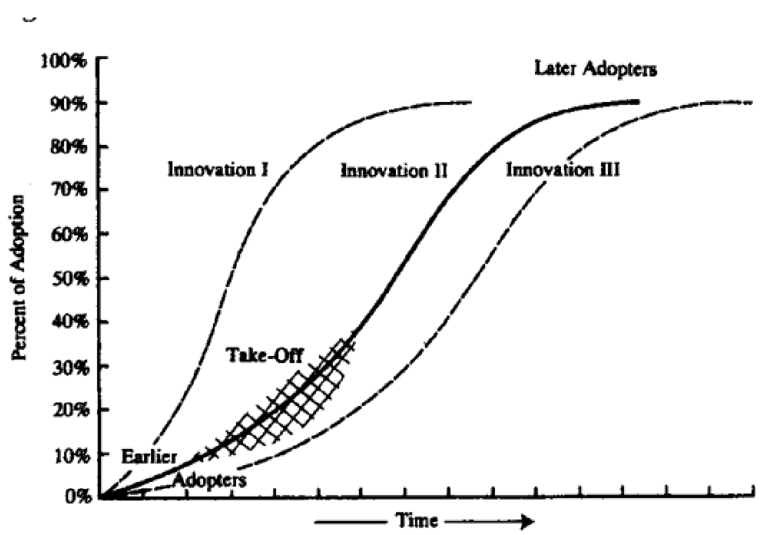


FIGURE 6 Technology Adoption Pattern (S – Curve) (Rogers 2010)

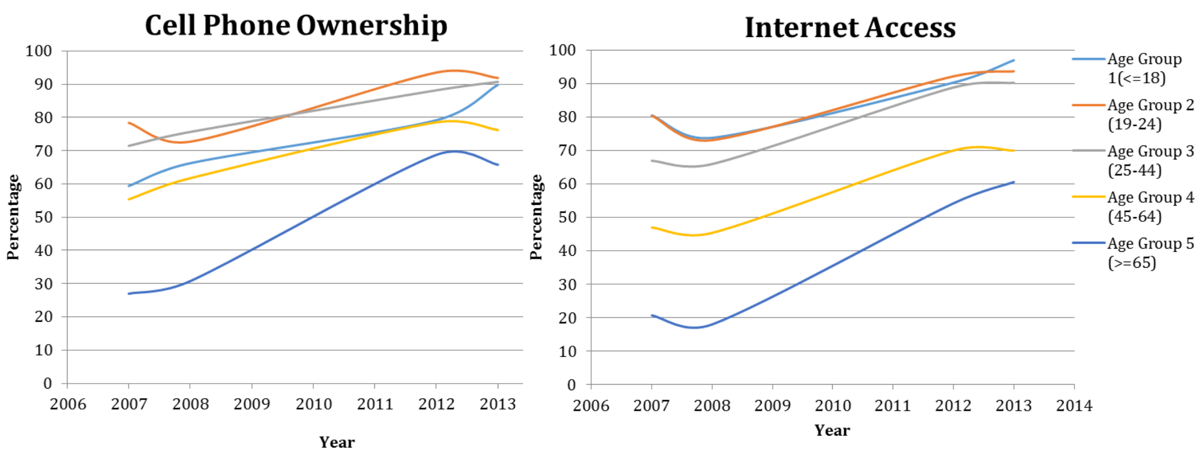


Figure 7 Technology Adoption of St. Louis Metro Riders from 2007 to 2013

As mentioned earlier, the adoption trend given by the S- curve is slow at the initial stages, high at the half-way point and again slow as it approaches the maximum level. The shape of the curve will depend on the rate of adoption and the estimated maximum penetration level and is given by

$$\ln\left({}^{f}/_{F} - f \right) = c_1 + c_2 \times t$$

where:

$$f = current\ penetration\ (percent\ of\ total)$$
$$F = maximum\ penetration\ (percent\ of\ total)$$
$$t = current\ year, where\ in\ initial\ year\ t = 0$$
$$c_1, c_2 = constants$$

(Blackman 1974, Handy et al. 1994). If the adoption level is known for two years, then we can solve for the two constants c_1 and c_2.

For this analysis, a regression model of the form $y(t) = c_1 + c_2 \times t$ was fitted to the dataset where $y(t) = \ln\left({}^{f}/_{F} - f \right)$. The current penetration f was obtained from the St. Louis Metro survey data for cellphone ownership. Ideally, smartphone ownership data should have been used but the onboard survey carried out in 2007 and 2008 did not ask for smartphone ownership and hence there were only two data points (2012 and 2013) which could be used for the regression analysis. Therefore, it was thought logical and more appropriate to use the total cellphone ownership data, which followed S-curve adoption with data available for 2007, 2008, 2012 and 2013. The maximum penetration F was assumed based on the general technology adoption trend nationally. As in the binary logistic model, two age groups were used in the analysis – (i) people below and at the age of 44 and (ii) people above the age of 44. The maximum possible penetration rate was set at 97% for riders in the group with age ≤44 years and at 90% for riders in the group with age >44. The different rates of saturation were adopted based on data on other similar technology usage (for example, cellphone and laptop usage among American adults) which showed different adoption saturation among different age groups.

Figure 8 (a) and 8(b) show the relevant plot of the data while Table 9(a) and 9(b) show the detail of the calculation for the analysis. The rapid adoption part of the S-curve was obtained by fitting a linear regression equation to the available data points. Following the S- curve of technology adoption, the matured adoption phase was then plotted by flattening the linear part of the curves through the final saturation point (97% for age group <=44). The regression equations provided the constants c1 and c2 of the generic technology adoption equation and were used to estimate and forecast the adoption percentage for the years before saturation. It should be noted that the slope of the smartphone adoption curve was higher than that of the cellphone adoption curve in the age group of <=44 years among bus riders. Based on the abovementioned analysis, in the age group <= 44 years, the cellphone adoption will be ~ 96% in 2019 among bus riders and will reach saturation (97%) for rail riders. Smartphone adoption will be about 85% among bus riders and 95% among rail riders in the same <=44 years age group. For the age group >44 years, backcasting the linear part of the curve showed a later uptake in adoption than the younger age group. However, for the purpose of forecasting, the initial adoption year was assumed to be the same for the age groups. The cellphone adoption in this age group was predicted to be ~ 88% among bus riders and 90% among rail riders in 2019. However, in case of smartphone adoption in this age group for bus riders, there were only two data points which showed a lower adoption in 2013 than 2012. Therefore, the slope of rail riders smartphone adoption curve was used to construct the adoption curve. The curve was then extrapolated through the saturation point to obtain the matured adoption part of the curve. It should be noted that any prediction for the smartphone adoption in this age group is, therefore, the maximum possible adoption at that year and may not be the real adoption. Based on the above analysis, smartphone adoption for both rail and bus riders is predicted to be ~ 75% in 2019 in the age group >44 years.

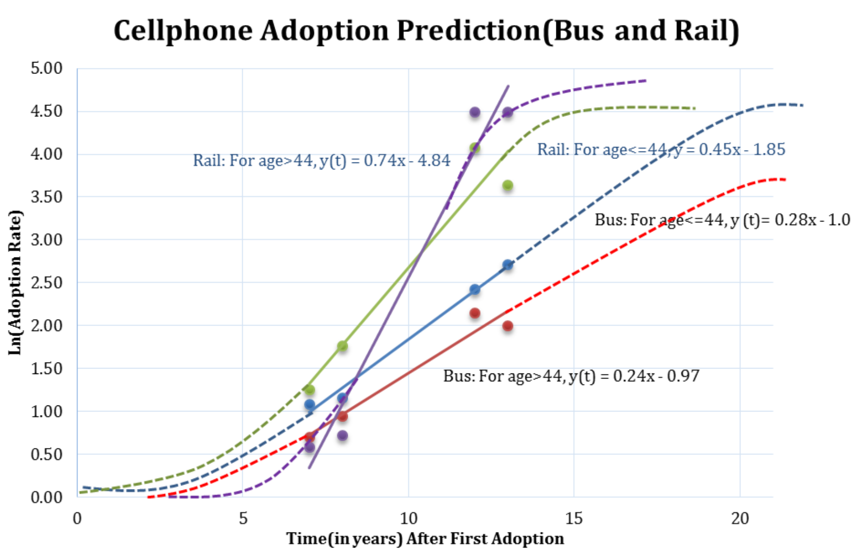


FIGURE 8(a) Cellphone Adoption

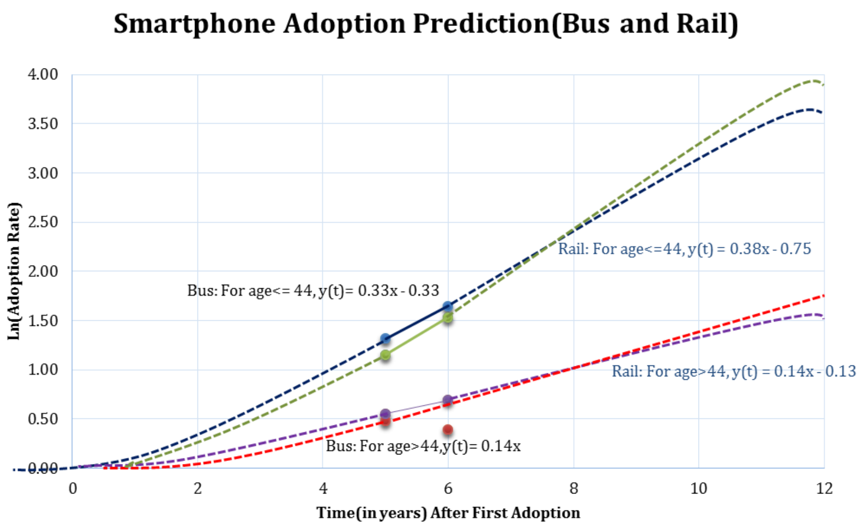


FIGURE 8(b) Smartphone Adoption

Year	Time (in years) from First Adoption	f (Age <=44)	f (Age >44)	F (Age <=44)	F (Age >44)	y(t) for Age<= 44	y(t) for Age> 44	Prediction (Age <=44)	Prediction (Age >44)
2007	7	75.4	57.6	97	90	1.25	0.58		
2008	8	82.76	60.58	97	90	1.76	0.72		
2012	12	95.38	91	97	90	4.08	NA		
2013	13	94.51	92.4	97	90	3.64	NA		
2016	16			97	90	NA	NA	Saturation	Saturation
2019	19			97	90	NA	NA	Saturation	Saturation

TABLE 9(a) (i): Cell Phone Adoption Forecast (Rail)

Year	Time (in years) from First Adoption	f (Age <=44)	f (Age >44)	F (Age <=44)	F (Age >44)	y(t) for Age<= 44	y(t) for Age> 44	Prediction (Age <=44)	Prediction (Age >44)
2007	7	72.47	60.17	97	90	1.08	0.70		
2008	8	73.86	64.85	97	90	1.16	0.95		
2012	12	89.1	80.54	97	90	2.42	2.14		
2013	13	90.97	79.26	97	90	2.71	2.00		
2016	16			97	90	3.56	2.90	94.31	85.29
2019	19			97	90	4.41	3.62	95.84	87.65

TABLE 9(a) (ii): Cell Phone Adoption Forecast (Bus)

Year	Time (in years) from First Adoption	f (Age <=44)	f (Age >44)	F (Age <=44)	F (Age >44)	y(t) for Age<= 44	y(t) for Age> 44	Prediction (Age <=44)	Prediction (Age >44)
2007	0	0	0	97	90	0	0		
2012	5	73.7	57.17	97	90	1.15	0.55		
2013	6	79.76	59.96	97	90	1.53	0.69		
2016	9			97	90	2.672	1.101	90.73	67.55
2019	12			97	90	3.8123	1.512	94.90	73.74

TABLE 9(b) (i): Smartphone Adoption Forecast (Rail)

Year	Time (in years) from First Adoption	f (Age <=44)	f (Age >44)	F (Age <=44)	F (Age >44)	y(t) for Age<= 44	**y(t) for Age> 44	Prediction (Age <=44)	Prediction (Age >44)**
2007	0	0	0	97	90	0	0		
2012	5	76.52	55.67	97	90	1.32	0.48		
2013	6	81.35	53.72	97	90	1.65	0.39		
2016	9			97	90	2.64	1.23	90.53	69.65
2019	12			97	90	3.63	1.64	94.49	75.38

**Note: For Age >44, the linear part of the curve and its extrapolation for prediction is based on y(t) = 0.14x, which is the slope of the adoption curve for rail riders.

TABLE 9(b) (ii): Smartphone Adoption Forecast (Bus)

Ridership Forecast

Since the technology penetration rates are considerably different for the two age categories, the change in transit ridership in the two different age categories was also projected so that a pragmatic estimate could be made about investing in alternative technologies. However, the net change in any transit ridership is confounded by the increase or decrease in population—a decrease in population can show a decrease in transit ridership even though the transit mode share has not decreased and vice versa. Therefore, it is necessary to separate these two effects to understand the actual increase or decrease in transit riders. In this analysis, the actual change in transit ridership is calculated as:

$$Actual\ change\ in\ transit\ ridership\ = Change\ in\ transit\ ridership - \ Change\ in\ population$$

Change in Transit Ridership

The net ridership change for St. Louis was calculated following the principles of shift share analysis that local share of any industry/sector is the sum of (i) the National Share or NS which measures the change that would have happened at the local level because of changes at the national level; for example, a possible change in the regional employment rate due to growth in the national economy (ii) Industry Mix or IM which measures the part of the regional growth that could be attributed to the growth of the particular sector nationally and (iii) regional growth rate in that industry (Regional Shift or RS) which measures the relative growth of a sector locally as compared to that sector nationally. The analysis is usually done for a 5 year period, but due to the lack of data, this study was based on a 3 year period from 2010 to 2013. The national growth in commuters was used as the national overall growth and the growth in use of public transportation by the commuters in US was used as the national growth in a particular industry/sector. The regional shift was based on use of public transportation by the commuters in St. Louis. All data was obtained from American Community Survey database on means of transportation to work, 2010 and 2013 (American Community Survey, 2010, 2013).

Therefore,

$$\begin{aligned}\Delta Transit\ Ridership\ at\ St.Louis \\ &= NS(based\ on\ change\ in\ national\ commuting) \\ &+ IM(based\ on\ national\ change\ in\ use\ of\ public\ transportation) \\ &+ RS(based\ on\ change\ in\ use\ of\ public\ transportation\ at\ St.Louis)\end{aligned}$$

The National Share (NS) was calculated as:

$$\begin{aligned}(Local\ public\ transportation\ share\ at\ base\ year) \\ &\times (all\ US\ commuters, at\ the\ end\ of\ analysis\ period) \\ &/(all\ US\ Commuters, at\ base\ year)\end{aligned}$$

Similarly, Industry Mix was calculated as:

$$\left[(Local\ public\ transportation\ share\ at\ base\ year) \times \frac{US\ commuters\ who\ use\ public\ transport, at\ the\ end\ of\ analysis\ period}{US\ Commuters\ who\ use\ public\ transport, at\ base\ year}\right] - NS$$

And, the Regional Shift was calculated as:

$$\begin{aligned}(Local\ public\ transportation\ share\ at\ base\ year) \\ &\times [\frac{local\ public\ transportation\ share, at\ the\ end\ of\ analysis\ period}{local\ public\ transportation\ share, at\ base\ year} \\ &- \frac{US\ commuters\ who\ use\ public\ transport, at\ the\ end\ of\ analysis\ period}{US\ Commuters\ who\ use\ public\ transport, at\ base\ year}]\end{aligned}$$

The analysis was done for both the age groups and Table 10(a) and Table 10(b) show the results of the calculations.

	Years	Local Public Transport Share	US Commuter Share	US Public Transport Share among Commuters	National Share (NS)	Industry Mix (IM)	Regional Shift (RS)
	(1)	(2)	(3)	(4)	(5)= (2a)x(3b)/(3a)	(6)=[(2a)x(4b)/4(a)] –(5)	(7)=(2a)x[(2b)/(2a)-(4b)/(4a)]
(a)	2010	61.4	56.6	63.8	61.7	-0.1	1.4
(b)	2013	63.0	56.3	64.0			

TABLE 10 (a) Shift Share Analysis for Age group =<44 years

	Years	Local Public Transport Share	US Commuter Share	US Public Transport Share among Commuters	National Share (NS)	Industry Mix (IM)	Regional Shift (RS)
	(1)	(2)	(3)	(4)	(5)= (2a)x(3b)/(3a)	(6)=[(2a)x(4b)/4(a)] -(5)	(7)=(2a)x[(2b)/(2a)-(4b)/(4a)]
(a)	2010	38.6	43.5	36.2	38.7	-0.3	-1.5
(b)	2013	37.0	43.7	36.1			

TABLE 10 (b) Shift Share Analysis for Age group >44 years

From the analysis, public transportation use in the age group <= 44 years shows an increasing trend in St. Louis which is similar to the national trend. However, there is a decreasing trend in the use of public transportation in the age group>44 years although there is an overall positive trend in the use of public transportation across the nation. The increase rate is 1.4 % for the people in the age group =<44 years over a period of 3 years while the decrease rate is 1.3 % for people in the age group of >44 years for the same time period.

Change in Population

Again, population data from the American Community Survey were used for estimating the national rate of population growth in the two age groups considered for this analysis. We attempted to use St. Louis specific data, but the trends were too noisy to allow prediction.

Of the age categories, the age group of 15 to 44 years was used to determine the trend of population growth in the group age ≤ 44 while the other group was calculated as (100% – percent in the age group 15 to 44 years – percent in the age group 5 to 14 years). This was to maintain a compatibility between the commute data and the population data as the commute data does not include people below the age of 16. Data from 2005 through 2012 were plotted and regression models for both the age groups showed high R-squared values (0.98 and 0.92 for age group ≤ 44 and age group > 44 respectively) (Figure 9). The growth rates based on the fitted models were -0.1% for age group ≤44 and 0.3% for age group > 44.

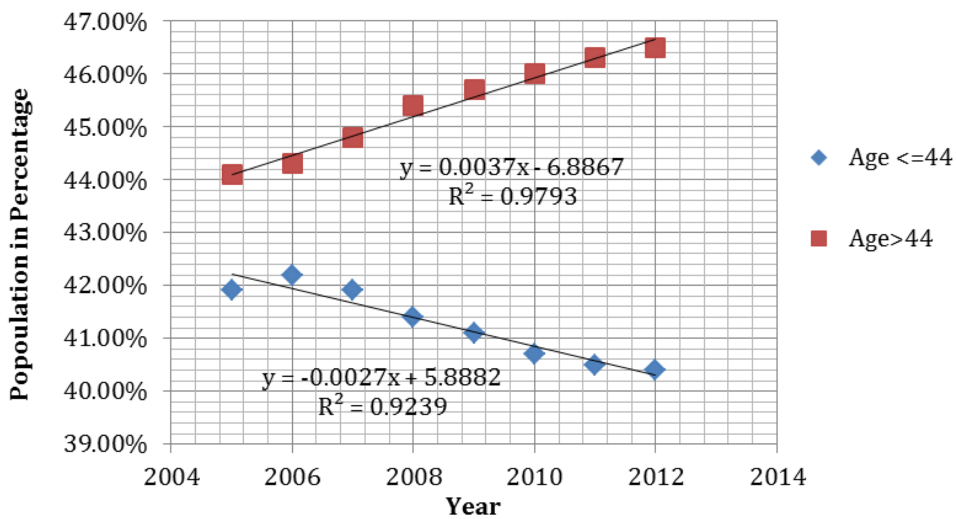


FIGURE 9 National Population Trend

As mentioned earlier, the actual change in ridership is a combination of both population growth and change in ridership. Combining the results of the last two sections,

$$\Delta actual\ ridership\ for\ people \leq 44\ years = \ 1.4 + (-0.1) = +1.3\%\ per\ year$$

Similarly, for the other group,

$$\Delta actual\ ridership\ for\ people > 44\ years = \ -1.5 + (0.3) = -1.2\%\ per\ year$$

Therefore, in the future, St. Louis Metro is likely to have a greater portion of riders in the age group <=44 years than the >44 years age group. The riders in this age group are also more likely to own and use smartphones for RTI as well as other purposes. Hence, it can be strongly suggested that it will be worthwhile for transit agencies to continue to invest in smartphone based technologies as more and more riders will have access to such technologies soon.

However, as seen from the technology penetration study, the people in the >44 years age group are less likely to own a smartphone than the people in the <44 years age group and for this particular analysis, the technology penetration rate indicated that 25% of the users will not have access to smartphone technology by the year 2019. Literature also suggests that technology penetration can never reach 100% for people in the age group above 60 years (Blackman 1974). Therefore, supplemental technologies are recommended in the near-term to ensure equity in user information. For this age group in particular, interactive voice response is one means to provide information to the maximum number of riders using the system.

CONCLUSION

Transit information can be accessible from not only smartphone applications but also a wide variety of technologies. However, improvements in mobile technology are becoming increasingly oriented around smartphone applications. Recognizing and providing riders the means to access information, make fare purchases, and provide feedback on cell phones, as well as computers, helps ensure that the benefits of mobile access are felt by as many users as possible.

This study investigated how accessible mobile devices and other supplementary technologies are to transit riders. In recent years, not only have smartphones and other alternative technologies become increasing available to riders of our case study agency, St. Louis Metro, but this trend has been true among other transit agencies' riders as well as the general population across the nation. In 2013, a notable majority of Metro riders own smartphones, however, it was also found that certain demographic groups are less likely to own a smartphone, including riders who are not employed or a student and White / Caucasians. Riders over 40 years old were shown to be less likely to own a smartphone when compared to younger riders.

For riders who will not have access to smartphone, many supplementary technologies, such as SMS, IVR, mobile-based websites, and computer-based websites are often an option. Based on the availability of these technologies among non-smartphone owners and the information each provides, it was concluded that computer-based websites and IVR are the best supplementary technologies to smartphone applications. Results from the analyses illustrated that IVR is widely available to transit riders without access to smartphone applications. Specifically in 2013, using St. Louis Metro as a representative case study, cell phones were available to 74% of bus and 81% of rail riders without smartphones.

However, this optimal balance between information and availability is also influenced by the individual's preference for using a technology. One user may prefer to send and receive a text message while another rider may find it easier to check a website before heading to a bus stop. Whether a rider is en-route to a stop, planning a trip, or waiting at a station may have influence on their preferred technology as well. A study of riders in Calgary, Canada stated that browsing a website was the most preferred method for planning a trip and that preferences could change depending on whether the customer is planning a trip or already en-route (Rahman, Wirasinghe, & Kattan, 2013). It is therefore recommended that agencies continue to invest in websites that can be accessed by both traditional computers and mobile devices as another alternative to smartphone applications.

Finally, in high ridership areas, especially those with high levels of out-of-town visitors or older residents, digital signage can be used to supplement mobile information for 100% penetration of riders. The placement of these fixed signs can be strategic, optimizing where they are located based on the demographics of the riders and ridership at specific stops.

Although these supplemental technologies are recommended in the short term, additional analysis was undertaken to understand the future technology penetration of smartphones to predict the need for supplemental technologies in the longer term. Again using St. Louis Metro as a case study, the smartphone penetration rate was calculated based on an S curve of innovation diffusion and the existing adoption rate of cellphones. The forecast showed that while almost all riders in the age group <= 44 years will have access to smartphone in 2018, about 25% of the riders in the age group >44 years will not have access to smartphones. However, a projection of transit ridership in the two age groups also show that St. Louis Metro will see 1.2% increase in transit ridership among the younger age group who will have access to smartphone based applications and a decline of 1.3% among transit riders in the older age group who may not have smartphone access. Therefore, it becomes more relevant for the agency to invest in a smartphone based platform as a large majority of its users will own and use smartphones by 2018.

In all, smartphones and other technologies are becoming increasingly available and popular among transit riders. However, many transit agencies do not regularly survey their riders to inquire about technology penetration (Bregman, et al. 2015). Using regular rider surveys to assess technology ownership and usage, transit agencies can understand how many riders have access to various technologies and which demographic groups are left out to target applications and supplemental technology to their riders.

References

American Community Survey (2013). *Means of Transportation to Work by Selected Characteristics*. Retrieved May 2015 from http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_13_1YR_S0802&prodType=table

Barry, K. (2014). The Race is on for the transit ticket of tomorrow, CityLab, Retrieved from http://www.citylab.com/commute/2014/03/race-transit-ticket-tomorrow/8594/

BART Marketing & Research Development. *Bart Mobile Applications - Rider Survey*, 2009. http://www.bart.gov/docs/Mobile%20Survey.pdf. Accessed November 15, 2012.

Blackman, A. W. (1974). The market dynamics of technological substitutions.Technological Forecasting and Social Change, 6, 41-63.

Brakewood, C., Rojas, F., Robin, J., Sion, J., Jordan, S. (2014). Forecasting Mobile Ticket Adoption on Commuter Rail. *Journal of Public Transportation*,17(1), 1-20.

Bregman, S., Watkins, K., Xu, Y. & Coffel, K. (2015) Who's Online… and Who Isn't Equity Considerations for Web-Based Feedback and Transit, *Transportation Research Board Annual Meeting*

Chicago Transit Authority. *Developer Center*. http://www.transitchicago.com/developers/. Accessed July 9, 2013.

Dickens, M., Neff, J., & Grisby, D. (2012). *2012 Public Transportation Fact Book, 63rd Edition.* Washington, D.C.: American Public Transportation Association.

Duggan, M., & Rainie, L. (2012). *Cell Phone Activities 2012.* Pew Research Center's Internet & American Life Project. Retrieved December 9, 2012, from http://pewinternet.org/~/media//Files/Reports/2012/PIP_CellActivities_11.25.pdf

Dunlop, I. N., Casello, J. M., & Doherty, S. T. (2015). Tracking the Transit Rider Experience: Using Smartphones to Measure Comfort and Well-Being Throughout the Trip. In *Transportation Research Board 94th Annual Meeting*(No. 15-5944)..

Dziekan, K., & Kottenhoff, K. (2007). Dynamic at-stop real-time information displays for public transport: effects on customers. *Transportation Research Part A: Policy and Practice, 41*(6), 489-501.

Ferris, B., Watkins, K., & Borning, A. (2011). Behavioral and Satisfaction Changes Resulting from Providing Real-Time Arrival Information for Public Transit. 91st *Transportation Research Board Annual Meeting.* Washington, D.C.

Fonzone, A., Schmöcker, J.D. (2014). Effects of transit real-time information usage strategies, Transportation Research Record: Journal of the Transportation Research Board , 2417, 121-129.

Gan, H.C. (2015). To switch travel mode or not? Impact of Smartphone delivered high-quality multimodal information. IET Intelligent Transport Systems, 9(4), 382-390.

Gooze, A., K. Watkins, and A. Borning. Benefits of Real-Time Transit Information and the Impacts of Data Accuracy on the Rider Experience. *Proceedings of the 2013 Transportation Research Board Annual Meeting,* 2013.

Handy, S. L., & Mokhtarian, P. L. (1996). Forecasting telecommuting. *Transportation*, *23*(2), 163-190.

Infogroup / ORC. (2009). *King County Metro Transit 2009.* Retrieved November 15, 2009, from http://metro.kingcounty.gov/am/reports/2009/2009-RNRFinal.pdf

Metro - Los Angeles County Metropolitan Transportation Authority. *Developer: Metro's Official Blog of Transit Data and Technology*. http://developer.metro.net/. Accessed July 9, 2013.

Metropolitan Transportation Authority. *Developer Resources*. http://www.mta.info/developers/. Accessed July 9, 2013.

Rahman, M., Wirasinghe, S. C., & Kattan, L. (2013). Users' views on current and future real-time bus information systems. *Journal of Advanced Transportation, 47*, 336-354.

Rainie, L. (2013). *Cell phone ownership hits 91% of adults.* Pew Research Center's Internet & American Life Project. Retrieved July 5, 2013, from http://www.pewresearch.org/fact-tank/2013/06/06/cell-phone-ownership-hits91-of-adults/

Rainie, L., & Smith, A. (2013). *Tablet and E-Reader Ownership Update.* Pew Research Center's Internet & American Life Project. Retrieved October 29, 2013, from http://pewinternet.org/~/media//Files/Reports/2013/PIP_Tablets%20and%20e-readers%20update_101813.pdf

Rogers, E. M. (2010). Diffusion of innovations. Simon and Schuster.

Smith, A. & Page, D. (2015).*The Smartphone Difference*. Pew Research Center's Internet & American Life Project. Retreived May 2015, from http://www.pewinternet.org/files/2015/03/PI_Smartphones_0401151.pdf

Smith, A. (2013). *Smartphone Ownership - 2013 Update.* Pew Research Center's Internet & American Life Project. Retrieved July 5, 2013, from http://www.pewinternet.org/~/media/Files/Reports/2013/PIP_Smartphone_adoption_2013.pdf

Tang, L., & Thakuriah, P. V. (2012). Ridership effects of real-time bus information system: A case study in the City of Chicago. *Transportation Research Part C, 41*(6), 489-501.

U.S. Census Bureau. (2011). *Adult Computer and Adult Internet Users by Select Characteristics: 1995 to 2011.* Retrieved December 18, 2012, from http://www.census.gov/compendia/statab/2012/tables/12s1158.xls

Watkins, K., Bregman, S., Coffel, K. (2015). Use of Web-based Customer Feedback to Improve Public Transit Services. TCRP Report 179.

Windmiller, S. (2013). *Alternatives to smartphone applications for real-time information and technology usage among transit riders.* Atlanta: Georgia Institute of Technology. Retrieved from http://hdl.handle.net/1853/50369

Windmiller, S., Hennessy, T., & Watkins, K. (2014). Accessibility of Communication Technology and the Rider Experience: A Case Study of St. Louis Metro. *2014 Transportation Research Board Annual Meeting.* Washington, D.C.

Zhao, F., Pereira, F. C., Ball, R., Kim, Y., Han, Y., Zegras, C., & Ben-Akiva, M. (2015). Exploratory Analysis of a Smartphone-Based Travel Survey in Singapore. In *Transportation Research Board 94th Annual Meeting* (No. 15-4343).