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MyTix: NJ TRANSIT's Mobile Ticketing Application

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16. Abstract

The main objectives of this project were to 1) assist NJ TRANSIT in the demonstration of an NJ TRANSIT commuter rail electronic fare technology and 2) conduct an objective third-party evaluation of the selected technology's effectiveness. This report presents in detail the project team's involvement in assisting NJ TRANSIT to evaluate the mobile ticketing application as an impartial entity.

NJ TRANSIT's mobile ticketing application, MyTix, was put into effect on the Pascack Valley Line on April 25, 2013. Currently, MyTix app can be used on all ten NJ TRANSIT commuter rail lines. The research team was involved in the evaluation process of the MyTix app, both in laboratory and field conditions. The team also conducted additional tests independent of NJ TRANSIT to increase the reliability of the results. A 3-stage evaluation process was conducted. Stage 1, which consists of alpha tests performed in laboratory settings, was designed to identify possible usability issues with the earlier versions of the MyTix app. Stage 2, which consists of beta tests, was designed to identify possible usability issues with the MyTix app by evaluating the app in field conditions. Stage 3 was the evaluation of the app both during the pilot test and after it was implemented in other commuter rail lines. User logs were analyzed to estimate the adoption statistics and the frequency of use of the MyTix app.

The overall project was a remarkable success in terms of the successful deployment of this new electronic ticketing application as a result of very close collaboration between NJ Transit and the research team. NJ TRANSIT was able to quickly address some of the deployment issues that were independently identified by the research team as well as their internal project team, and MyTix app was gradually improved. This ensured acceptance of the app by commuters at a very high rate. As of January 2014, MyTix app was downloaded more than hundred and twenty seven thousand times, and about sixty nine percent of those downloads resulted in registered users.

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EXECUTIVE SUMMARY

NJ TRANSIT is one of the nation’s largest, statewide public transit systems, connecting major points in New Jersey, New York, and Philadelphia. NJ TRANSIT consists of 11 commuter rail lines, 116 NJ municipalities with rail services, and 165 rail stations .NJ TRANSIT, along with other transit agencies and companies in the U.S., is interested in adopting electronic fare collection technology.

Impeding many commuter rail systems from adopting EFC is the open, barrier-free layout of many stations, which make implementing an EFC difficult. Originally designed for closed systems, such as subways, and rail systems with infrequent stops, such as Amtrak’s long-distance intercity service, the EFC technology is not suitable for NJ TRANSIT’s need.

This research project was carried out in conjunction with the 3- to 7-year plan, implemented by the strategic team within NJ TRANSIT, to modernize the NJ TRANSIT operations. Mobile phone-based ticketing is the focus of this new plan. Mobile ticketing allows NJ TRANSIT to serve their customers quickly while reducing bottlenecks in ticketing areas. Other payment methods were also considered, yet mobile ticketing became the choice due to a recent NJ TRANSIT customer satisfaction survey that found 99% of rail and bus customers use cell phones and more than 50% owned smart phones.

NJ TRANSIT’s chose the Pascack Valley Line as the test bed for the mobile technology pilot study. This research project is aimed at determining if crew members could sufficiently adopt the new technology while also monitoring customers’ reactions to the new system.

The research team’s role in the implementation of NJ TRANSIT’s mobile ticketing was to conduct an objective evaluation of every phase of this unique implementation project, and also act as an impartial critic of the use, efficiency, and applicability of the selected mobile ticketing technology. The most important tasks were to 1) Review the available technologies and lessons learned from other agencies, 2) Develop a demonstration / evaluation plan, and 3) Evaluate the selected technology.

In order to accomplish these tasks, the research team reviewed the use of handheld devices by transit agencies worldwide with an emphasis on the use of mobile ticketing technologies. In addition, the research team conducted interviews with five American transit agencies. These are Portland TriMet, NY Waterway, AMTRAK, Dallas Area Rapid Transit (DART) and Massachusetts Bay Transportation Authority (MBTA). These interviews were carried out to understand the current state-of-practice in transit agencies and gather information specific to smartphone based mobile ticketing applications.

NJ TRANSIT's mobile ticketing application was named MyTix. NJ TRANSIT decided to contract the mobile ticketing application development work to ACS, a Xerox company. ACS was already the primary fare collection provider for NJ TRANSIT. Therefore, it was rather straightforward to integrate the mobile ticketing application into the current fare collection systems, using a "layered in" approach.

The research team devised a 3-stage evaluation process to test MyTix's use, efficiency, and applicability. Stage 1, which consists of alpha tests in laboratory settings, was designed to identify possible usability issues with the earlier versions of the MyTix app. Stage 2, which consists of beta tests, was designed to identify possible usability issues with the MyTix app by evaluating the app in field conditions. Stage 3 was the evaluation of the app during the pilot test and after it was released on other commuter rail lines. The research team analyzed user logs to estimate the MyTix app adoption statistics and frequency of use.

Laboratory usability test participants were involved in four exercises using the Android and iOS versions of the MyTix app. The research team noted some critical, major and minor problems, observations, and offered suggestions based on the participants experience during the laboratory usability test. These issues included freezing screens or problems related to credit card information not registering properly. The NJ TRANSIT/ACS team fixed all these issue for future users. System Usability Scale (SUS) scores were estimated for both versions of the app. The NJ TRANSIT's MyTix mobile ticketing app scored well above the literature's accepted usability scale of 68.

MyTix was put into effect on the Pascack Valley Line on April 25, 2013. Currently, the MyTix app can be used on all NJ TRANSIT commuter rail lines. In May 2013, a field test was conducted on the Pascack Valley Line. Scanning problems at the fare gates were the biggest issue for the first field test. In addition, network signal issues caused some problems during the field trip ticket activation. After releasing the app to the Main/Bergen line, a second field trip was conducted in October 2013. The research team presented the scanning issue following the first field trip. NJ TRANSIT rapidly resolved this issue and no scanning issues were observed at the Secaucus Junction fare gates. The major issues observed during the second field trip related to weak cellular network signals, with users getting "no network" failures when they tried to determine their exact locations. To overcome this issue, NJ TRANSIT should work with cellular service providers to improve cell service at the stations affected. NJ TRANSIT is also working with Time Warner Cable to install WiFi at its Commuter Rail stations, which will enhance communications capabilities.

As of January 20, 2014, the MyTix app was downloaded more than 127 thousand times. Nearly 69 percent of these downloads resulted in registered users, 70.9 percent being iOS users and 29.1 percent being Android users. Based on the data analysis conducted with the available dataset, 31,174 new users were observed. The daily adoption rate was calculated as 12 per day in May 2013 when the app was available only for the Pascack Valley Line. The overall adoption rate rose to approximately 400 per day in

January 2014, which was when the app became available for all commuter rail lines. The biggest daily adoption rate was observed on the Northeast Corridor Line, with 140 new users per day. As could be expected, the commuter rail lines with a higher number of riders had higher daily adoption rates. In the first several months following the release of the MyTix app, the app usage increased sharply for most commuter rail lines. Following the second and third month, the rates dropped to a lower, steadier level. Based on the transaction data obtained for the Pascack Valley Line, it is expected that the monthly rate of increase in MyTix activation will be about 20 percent for the other commuter rail lines. For one-way tickets, 90 percent of users activate their ticket every 2 or more days. The remaining 10 percent are high frequency users that activate tickets at least once a day. For monthly ticket users, it is expected that about 40 to 50 percent of the subscribers will remain active.

Overall, the project was a great success. NJ TRANSIT was able to quickly address deployment issues identified independent of and by the research team, and the MyTix app was gradually improved. This rapid response ensured commuters would adopt the app at a high rate. About 87K users registered in the first 9 months and 30K users started to purchase their tickets via the app. Based on the adoption data analyzed in the Evaluation Methods & Results section, the MyTix adoption rate will continue to increase. Moreover, given the nation-wide trend of increasing smartphone use, it is anticipated that MyTix will be adopted by an increasingly large number of users.

INTRODUCTION

In the U.S. and abroad, various transit agencies have implemented or are in the process of evaluating handheld devices for on-board smart phone based mobile ticketing applications as a means of electronic fare collection (EFC). Handheld devices allow conductors to validate already purchased tickets, sell new tickets on board using debit / credit cards, and communicate with their supervisors via text messages. The EFC method offers various advantages compared to traditional paper ticket and manual fare collection methods, including improved throughput, reduced fare evasion, enhanced data collection capabilities that support transit operations and planning, and reduced costs incurred by cash management and accounting [(1)].

NJ TRANSIT is one of the nation’s largest, statewide public transit systems, connecting major points in New Jersey, New York, and Philadelphia. NJ TRANSIT consists of 11 commuter rail lines, 116 NJ municipalities with rail services, and 165 rail stations [(2)]. Its rail system serves approximately 291,000 passengers on an average weekday, the fourth average highest in the U.S. It currently uses paper tickets for fare collection media, offering single and multi-trip passes. The fare structure is distance-based, and since the most recent fare increase in May 2010, does not vary by the time of the day (peak, off-peak). The only exception is trips within the Metro-North territory. Passengers can buy tickets from rail station ticket windows and ticket vending machines, or on-board with a surcharge. NJ TRANSIT also sells monthly passes online, which are then mailed, to the customer.

NJ TRANSIT, along with other transit agencies and companies in the U.S., is interested in adopting electronic fare collection technology. As stated in the RFP issued by the NJDOT, “*NJ TRANSIT has proposed a number of demonstration projects to improve point of sale transactions for customers and improve fare collection onboard trains. NJ TRANSIT will use these initial projects to validate the various technologies and seek customer feedback. The main objective of this project is to observe, evaluate, and report on the effectiveness of a mobile phone based electronic ticketing technology*.”

Impeding many commuter rail systems from adopting EFC is the open, barrier-free layout of many stations, which make implementing an EFC difficult. Originally designed for closed systems, such as subways, and rail systems with infrequent stops, such as Amtrak’s long-distance intercity service, the EFC technology is not suitable for NJ TRANSIT’s need. In the U.S., handheld devices have been implemented in several systems, such as New York’s Metro-North and New Mexico’s Rail Runner Express. Philadelphia’s SEPTA recently tested a proof-of-concept EFC system during a demonstration project funded by the Federal Transit Administration. There’s also an ongoing demonstration project testing handheld devices for on board ticket sales and verification on Amtrak's intercity passenger train service operated by the Capitol Corridor Joint Powers Authority in California.

Motivation

This research project was carried out in conjunction with the 3- to 7-year plan, implemented by the strategic team within NJ TRANSIT, to modernize the NJ TRANSIT operations. Mobile phone-based ticketing (henceforth referred to as “mobile ticketing”) is the focus of this new plan. Mobile ticketing allows NJ TRANSIT to serve their customers quickly while reducing bottlenecks in ticketing areas. Other payment methods were considered, including contactless technologies that both reduce the handling of cash by conductors and potentially lead to better revenue accountability. Mobile ticketing became the choice, largely because of a recent NJ TRANSIT customer satisfaction survey that found 99% of rail and bus customers use cell phones and more than 50% owned smart phones (3). Moving forward, mobile ticketing was the anticipation that mobile ticketing would soon be prevalent in transit systems, and NJ TRANSIT preferred to be ahead of the curve, as opposed to playing catch up, in terms of adopting new and more efficient technologies. Moreover, NJ TRANSIT did not want to change their business plan but rather aimed to enhance their operations based on the use of this technology.

Over the years, NJ TRANSIT has provided more options for customers to purchase tickets. Customers traveling on the NJ TRANSIT commuter rail had the option of purchasing their tickets at ticket windows, ticket vending machines, by mail, or, with a surcharge, on-board, Fare gates are utilized for fare collection at only two transfer stations, Secaucus Junction and Newark Liberty International Airport (EWR). Conductors inspect commutation tickets and collect non commutation tickets on-board trains.

Prior to the complete implementation of ticket vending machines, on-board cash fares accounted for 17 percent of ticket revenues. Today, on-board NJ TRANSIT’s commuter rail lines, cash fare revenue accounts for only 1 to 1.5 percent of all ticket revenue. It is NJ TRANSIT’s desire to remove all on-board ticketing and move solely to on-board validation. NJ TRANSIT plans on maintaining a broad array of payment options, including the cost-effective option of mobile ticketing.

NJ TRANSIT’s strategic planning team chose the Pascack Valley Line as the test bed for the mobile technology pilot study. The study aimed to determine if crew members could sufficiently adopt the new technology while also monitoring customers’ reactions to the new system. The proposed mobile ticketing pilot project was one of three pilot projects concurrently being conducted by NJ TRANSIT. The other two pilot projects were a Web Ticketing paper based project, available to rail passengers traveling between NY Penn Station and the Meadowlands, and a Tap and Ride project, which utilized contactless tools such as credit/debit cards and “electronic wallet” based applications.

NJ TRANSIT requested several changes to this project’s scope, mainly because of changes to how the mobile ticketing system would be implemented. NJ TRANSIT also asked the research team to 1) conduct an objective evaluation of every phase of this unique implementation project and 2) act as an impartial critic of the use, efficiency, and applicability of the selected mobile ticketing technology.

Objectives

The main objectives of this project were to 1) assist NJ TRANSIT in the selection and demonstration of a NJ TRANSIT commuter rail electronic fare technology and 2) conduct an objective third-party evaluation of the selected technology's effectiveness. Various tasks had to be completed to realize these objectives. The most important tasks were:

1. **Review the available technologies and lessons learned from other agencies:** This task involves the review of similar point of sale or fare collection technologies in use by other transit agencies both in and outside the U.S. The research team conducted an extensive literature review on the point of sale or fare collection technologies similar to the one envisioned by NJ TRANSIT. The research team also conducted interviews with other transit agencies to gather first-hand information on lessons learned and suggested best practices.
2. **Develop a demonstration / evaluation plan**: This task involves the development of an evaluation plan for the proposed demonstration project for point of sale or fare collection technology. The research team, in coordination with NJ TRANSIT officials, developed an evaluation plan that incorporated factors such as operational effectiveness and customer satisfaction.
3. **Evaluate the selected technology**: This task addresses the actual demonstration of the selected technology in a limited number of trains, as well as evaluating the satisfaction of customers and NJ TRANSIT staff, and the effectiveness of the technology. This task includes: (A) Observing the demonstration of the technology, on one of NJ TRANSIT's commuter rail lines, in coordination with NJ TRANSIT and their vendor(s). (B) Collecting data and conducting interviews with transit riders. (c) Processing the collected data / interview results.

Project Timeline

<u>September 2011 – Project Kick-Off</u>

The scope of the research project was outlined at a meeting of members of the NJDOT, NJ TRANSIT, Rutgers, and New Jersey Institute of Technology, as well as project consultants. The main project objective, as determined at this meeting, was to observe, evaluate, and report on the effectiveness of a selected point of sale or fare collection technology. The research team worked closely with the NJ TRANSIT staff to identify areas of focus. Once the project progressed to the procurement stage, the research team continued to collaborate with NJ TRANSIT. During the project's first task, the research team reviewed similar technologies and their applications, with a specific focus on commuter rail systems that were similar to NJ TRANSIT. NJ TRANSIT was also interested in reviewing what other technologies were being used in other agencies at that time (i.e. handheld devices for on-board ticketing).

February 2012 - Design Review Phase

NJ TRANSIT conducted an industry review of mobile ticketing applications in use in Western Europe and North America to determine what would best suit the agency's needs. NJ TRANSIT considered both stand-alone and cloud based systems. Ultimately, NJ TRANSIT decided to contract the mobile ticketing application development work to ACS, a Xerox company. ACS was already the primary fare collection provider for NJ TRANSIT. Therefore, it would be rather straightforward to integrate the mobile ticketing application into the current fare collection systems, using a "layered in" approach.

Spring / Fall 2012 – App Development

Towards the end of March 2012, ACS had created the functional concept design of the smartphone-based mobile ticketing application. The revenue service for the app was estimated to begin in September 2012 with limited use, first by NJ TRANSIT employees and customer focus groups for one or two months.

A pilot test on the Pascack Valley Line would be used to evaluate the new system in full. NJ TRANSIT anticipated the mobile ticketing application to include all ticket types except student discounts. NJ TRANSIT would use the existing fare collection infrastructure and layer the application on top of it, which required a slight modification to certain components of the existing system. The application would allow NJ TRANSIT to collect customer information, receive feedback from customers, and send push notifications to customers regarding service and ticket related information.

During the app development phase, NJ TRANSIT facilitated in-depth interviews with three volunteers, each of whom were regular commuter rail customers who used smartphones. The objective of these interviews was to understand the customer's perspective and learn of any usability issues so that the early version of the mobile ticketing application could be improved. The research team collaborated with NJ TRANSIT during these interviews, and recorded the finger tap movements of each user while they were trying to complete various exercises related to the mobile ticketing application. These recordings were then used to evaluate the usability of the app. The research team also conducted several other usability tests on the developed mobile ticketing app by using volunteers from Rutgers University and New Jersey Institute of Technology. In order to ensure compliance with accepted best business practices, NJ TRANSIT used an independent third party firm to perform a security, Payment Card Industry (PCI), and vulnerability threat assessment of the mobile ticketing application.

January and March 2013 – Focus Groups

Starting in October 2012, NJ TRANSIT worked with selected customers who agreed to install and use the mobile ticketing application while riding the Pascack Valley Line. After a month of using the app, the participants were invited to focus group meetings organized by NJ TRANSIT. They were asked to evaluate the effectiveness and efficiency of the app. However, because of Superstorm Sandy and its devastating impact on NJ TRANSIT's operations, the commuter rail system was not at its full capacity. Therefore, NJ TRANSIT wanted to wait for the service to be restored before resuming the tests.

Focus group meetings were held in January and March 2013. The research team attended these meetings as independent observers. Later, the research team used the responses obtained from the participants to evaluate the usability of the mobile ticketing app.

Based on the feedback and comments received from the participants at these focus group meetings, the mobile ticketing application was modified and improved by ACS.

April 2013 – Pilot Study at Pascack Valley Line

On April 25, 2013, the mobile ticketing application was made available to NJ TRANSIT customers for use on the Pascack Valley Line. The research team conducted field tests in May 2013 to evaluate the usability of the mobile ticketing application and identify possible issues not detected in laboratory settings.

December 2013 – Extended Use of Mobile Ticketing Application

By late 2013, the mobile ticketing application was in effect for all commuter rail lines, namely Morris-Essex, Main-Bergen, Port Jervis, North Jersey Coast, Raritan Valley, Pascack Valley, Montclair-Boonton, Northeast Corridor, and Atlantic City Lines. The research team conducted field tests in October 2013 on the Main - Bergen Line to evaluate the usability of the mobile ticketing app. In addition, the ticket transaction dataset was analyzed to estimate the adoption rate and frequency of use of the app.

Report Outline

The following sections describe in detail the project team's involvement in assisting NJ TRANSIT to evaluate the mobile ticketing application as an impartial entity. The research team was involved in the evaluation process both in laboratory and field settings, and conducted additional tests independent of NJ TRANSIT's to increase the reliability of the results.

The next section presents the review of fare collection technologies in use by transit agencies in the U.S. and abroad. This section also presents the interviews conducted with other transit agencies to gather first-hand information on lessons learned and suggested best practices.

The following section presents the evaluation process and its results in detail. As described later, the evaluation process involved laboratory usability tests with selected participants (alpha tests), field tests before the pilot test (beta tests), and the pilot test. This section presents the results of the analysis for each stage.

The last section presents the recommendations by the research team for further deployment on other modes provided by NJ TRANSIT.

LITERATURE REVIEW

In use since the early years of rail transportation, paper tickets are still utilized today by many commuter rail systems. Hand-punched by conductors, the paper tickets require conductors to track the tickets they've already checked. There are many weaknesses to this method of fare collection, including a lack of accounting transparency, ridership counting, origin-destination passenger counts, and susceptibility to misuse of multi-ride passes.

Among railroad agencies worldwide, electronic payment methods have become increasingly popular. These electronic methods include mobile ticketing, smart card or ticket validation and on-board ticket purchasing with handheld devices.

This section is organized as follows. The following subsection presents the use of handheld devices by transit agencies worldwide. The second subsection focuses on the specific use of mobile ticketing technologies. The third subsection presents the interviews conducted with certain American transit agencies. These interviews were carried out to understand the current state-of-practice in transit agencies and gather information specific to smartphone based mobile ticketing applications.

Background on Handheld Devices

There's a recent history of handheld devices being used on-board to sell and/or validate tickets. In 2006, for example, Europe's largest railway, German Rail, implemented a new ticket and mobile ticket system using Casio's IT-3000 mobile computer (See Figure 1). Previously, German Rail conductors had to manually type in a 16-digit ticket number whenever an e-ticket was presented. With the new Casio technology, German Rail is now able to sell and print tickets on-board, receive secure payments, and quickly read and validate tickets. Similar implementations can be found in Italy, Slovakia, Japan, and other countries.

Figure 1. Casio IT-3000 mobile computer [4]

Although the technology currently available allows for the use of handheld devices to sell and validate tickets on board, most agencies still favor non-electronic multi-use tickets or passes. The barrier-free design of commuter railways and their complex fare structures require electronic fare collection solutions that are different from those used in gated transit systems. A recent FTA commuter rail survey of 24 rail agencies found that 13 agencies have no on-board sales, requiring passengers to purchase tickets prior to boarding [1]. The other 11 agencies in the survey allow for on-board ticket purchases, with eight of them levying a surcharge if there is a ticket vending machine or ticket window available to the passenger before boarding. Only two agencies utilize smart-card technology for fare collection: the Sounder commuter rail in Seattle and the Coaster rail service in San Diego.

The Sounder commuter rail in Seattle, WA, implemented the ORCA contactless smart card system in March 2009. Smart cards are sold at station's ticket vending machines (TVM). Value can be added to the smart cards by mail, phone, online, or at retail outlets. Passengers pay by tapping their cards at a standalone fare transaction meter, as shown in Figure 2, before boarding, and again by tapping at their arrival station. Failure to tap at the arrival station results in a deduction of the maximum fare. Conductors validate payment on-board using handheld devices through random inspection.

(a) (b)

Figure 2. (a) ORCA fare meter, (b) Handheld ORCA reader Sounder commuter rail, Seattle [5]

In San Diego, Coaster uses a similar contactless smart card technology called Compass Card, with fare validation devices deployed on each station platform. Passengers use their smart cards to tap in at the validation device prior to boarding and tap out on arrival. These systems are similar to the NJ TRANSIT Bus and rail systems in that they are also open systems.

In the Quebec province of Canada, a contactless smart card technology called Opus Card has been used in the public transit systems since the fall of 2008 [6]. Only used by five transit agencies initially (Agence métropolitaine de transport [7], Société de transport de Montréal[8], Société de transport de Laval[9], Réseau de transport de Longueuil[10], Réseau de transport de la Capitale[11]), now 16 agencies are using the OPUS card. The OPUS card can be used for monthly passes or train tickets for different zones. The card can be refilled at train stations, bus stations, or at various vendors. Figure 3a shows the OPUS card reader and Figure 3b shows an OPUS card refilling station.

(a) (b)

Figure 3. (a) Opus card reader (b) Card recharging station [6]

Unlike other transit systems, the New Mexico Rail Runner Express [12] does not offer ticket sales via TVM or ticket windows. Passengers can purchase tickets online or directly from conductors on-board using debit/credit cards. Figure 4 shows a daily ticket printed by the handheld device operated by the conductor. Online tickets can be validated by conductors using handheld scanners. Handheld devices are brought into the office nightly and cleared into a central financial database. This system is very similar to NJ TRANSIT rail, where the tickets are validated on board by conductors.

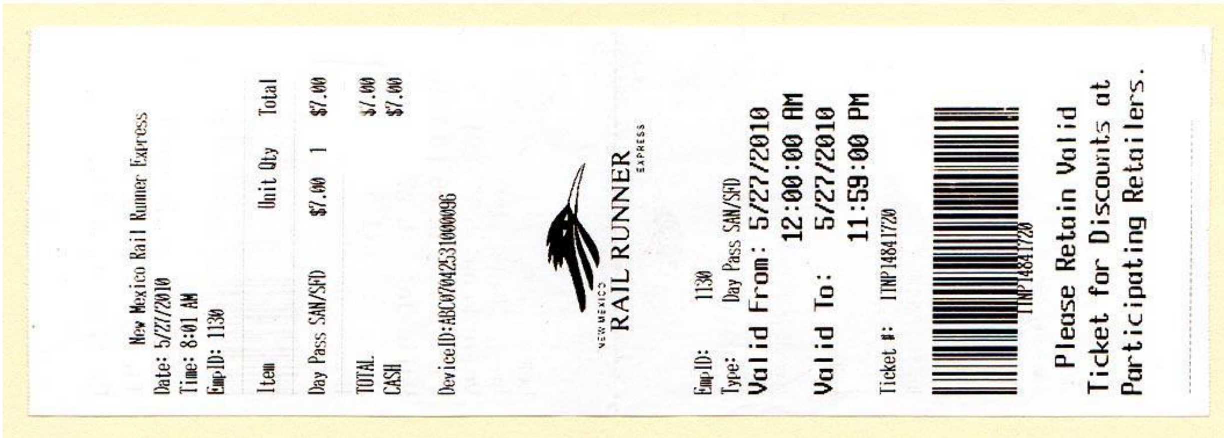


Figure 4. New Mexico Rail Runner Express daily pass

A commuter rail operation similar in scope and design to NJ TRANSIT, the Metropolitan Transit Authority (MTA) Metro-North[13] sells tickets at TVMs, ticket windows, and online. Conductors also sell tickets on-board with a surcharge, using handheld devices. These devices can print tickets and store fare data. Currently, on-board purchases are made with cash, with plans to eventually accept debit/credit cards. Ridership and fare information are downloaded into a central accounting database when the conductor docks the device. The handheld devices connect to Verizon's cellular network, through which supervisors can send conductors text messages and debit/credit cards can be authenticated. The devices communicate using Bluetooth technology connected to small printers that print receipts. To achieve a balanced budget, the MTA Metro-North November 2009 to 2012 financial plan eliminated the expansion of these handheld units [13].

Recently, the Southeastern Pennsylvania Transportation Authority (SEPTA) developed a proof of concept for an electronic fare payment system for commuter rail services as a part of the Regional Rail On-Board Electronic Payment project funded by the Federal Transit Administration. The purpose of this project was to develop a non-proprietary, Plug and Play multi modal transport payment application, i.e. cash, credit card, contactless smartcard, and multi day passes. Figure 5 shows the logic flow of the front-end interface for a handheld device. On June 12, 2008, a demonstration of the system's hardware and software was performed for SEPTA, highlighting its interoperability with SEPTA's back-end process. This developed system remains only as a proof of concept [5].

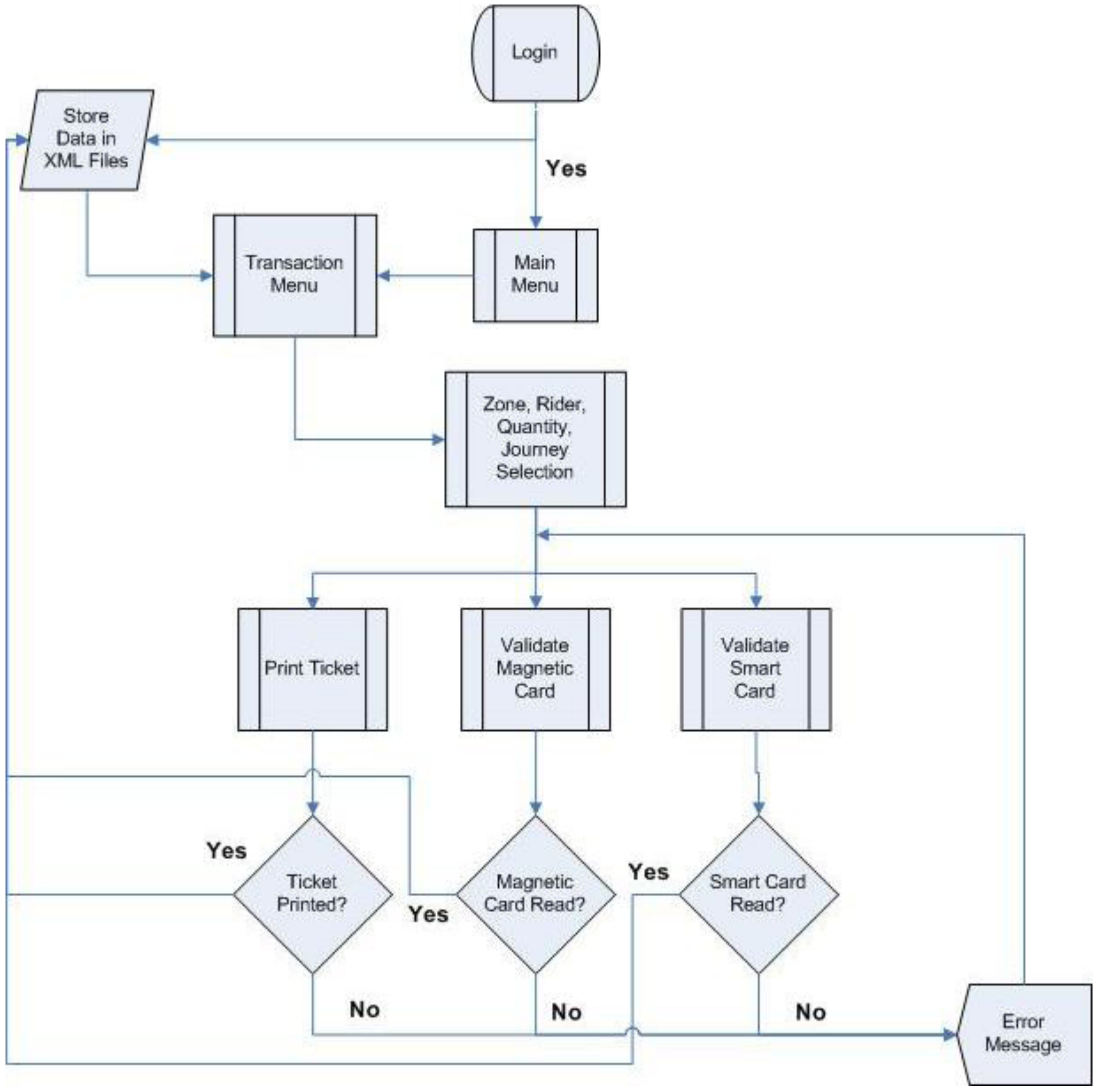


Figure 5. Transaction control flow designed for SEPTA [(5)]

In California, Amtrak is currently implementing an electronic ticket validation evaluation program to replace the manual process. The new program will implement an electronic handheld device that both validates and issues tickets electronically. This program is designed to increase on-board revenue collection and deter credit card fraud by providing a real-time connection between the point of sale/ticket validation and the Amtrak revenue system. The project is currently in the evaluation phase and being tested with 15 conductors on Amtrak's intercity passenger train service operated by the Capitol Corridor Joint Powers Authority in California. The hardware for this evaluation project is the Motorola MC70 handheld computer, MSR7000-100R snap-on magnetic stripe reader, and the Zebra MZ220 portable printer, as shown in Figure 6. Ticket validation is performed using a laser barcode scanner integrated in the handheld device. Ticket sales are made using cash, credit card or money orders. Figure 7 presents the validation and sales transaction as it appears on the handheld device screen. The pilot program is being coordinated between Amtrak, Caltrans, and federal law enforcement agencies and costs 1.35 million dollars [14]. This project has advanced through the development process and the pilot phase for conductor field testing and revenue management. However, the software enhancements that will improve the field performance of the handheld devices are still being developed [15].

Figure 6. Handheld device components for on-board ticket sale and validation [14]

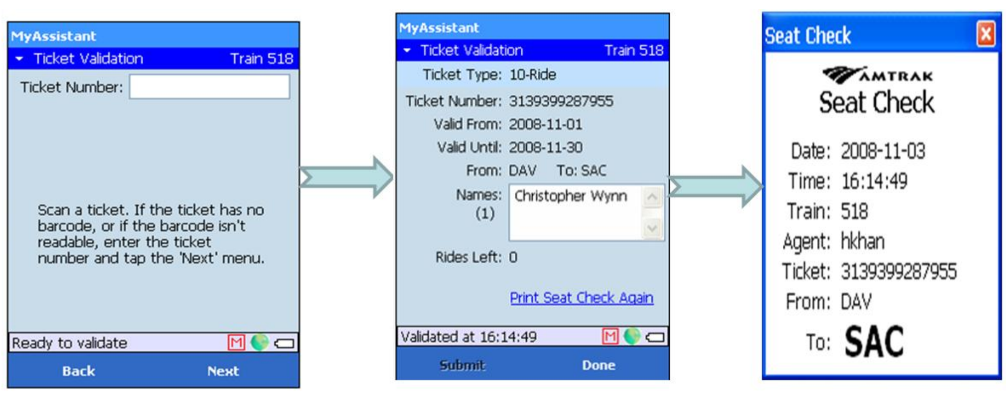


Figure 7. Ticket validation [14]

Mobile Ticketing Applications

As smartphones are more widely adopted by transit customers, transit agencies have an opportunity to conduct ticket sales via the customers' mobile phones. By reducing the reliance on TVM and ticket windows, and reducing the amount of cash and coins handled in transactions, agencies are able to realize significant cost savings. Despite their advantages, however, mobile ticketing systems have not yet been widely implemented. As a recent Accenture study [16] points out, there are three main reasons why: (1) Agencies wish to provide a satisfactory return on taxpayers' investments; (2)

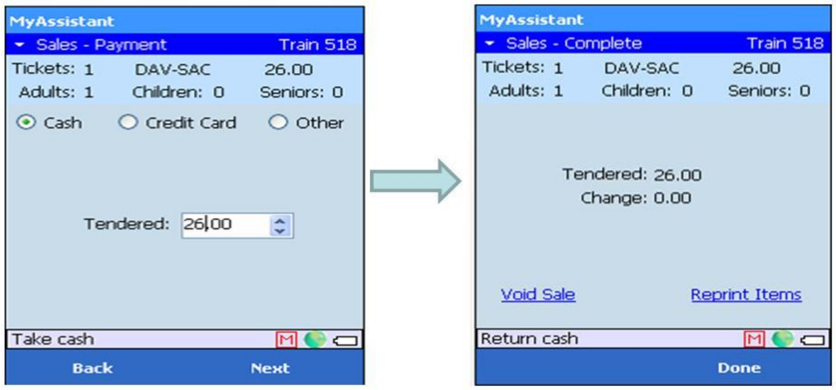
the technology is rapidly changing; and (3) security measures must prevent the duplication of mobile tickets.

The following are the mobile ticketing applications used in America and abroad.

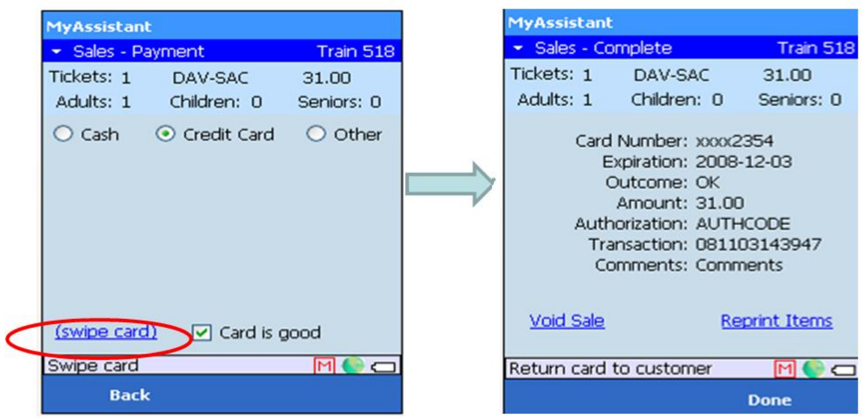
The transit authority for Portland (TriMet)[(17)] is expected to perform a beta test for a mobile payment method called TransitSherpa. TransitSherpa allows commuters to purchase and use transit tickets with an iPhone, Android, or Blackberry smartphone. Commuters can get real-time arrival information for the next bus or train, calculate the fare for their destination, and receive alerts about service disruptions. TransitSherpa uses a unique combination of color, code, time and date stamps, animation, and 3rd party verification to ensure the security of a ticket. Figure 8 shows the electronic ticket produced by TransitSherpa [(18)].

In Figure 9, number (1) indicates the animated TransitSherpa image used for checking the authenticity of a ticket. Number (2) shows a 4-digit authorization code consisting of numbers and letters. In case of a network outage, this authorization code created on TransitSherpa.com and/or the application can be stored for up to 3 days. These codes are sent to the Transit agency so that they can be passed on to the fare inspectors. By tapping on the wheel image (3), the ticket flips over to reveal a Digital Certificate signature provided by Verisign (4). This signature verifies that this ticket was created by the TransitSherpa Ticket Manager system on TransitSherpa.com and provides a means for Tri-met to verify the ticket purchase, usage, and authenticity [(18)].

In 2010, Skånetrafiken, the Swedish transport authority covering the southern part of Sweden, AB Östgötatrafiken, and Östergötland, has launched a new mobile ticketing solution powered by Boomerang [(19)]. Boomerang is a customer relationship management suite specifically made for public transit agencies that integrates automatic fare collection systems with public transit systems. With a focus on personalization, Boomerang integrates with the mobile ticketing server and the payment service provider such that passengers can use the personal section of the website to set up and manage their preferred way of using the system. Figure 10 shows an example of a traveler’s personalized home page.



(a)



(b)

Figure 8. (a) Cash transaction (b) Credit transaction [14]

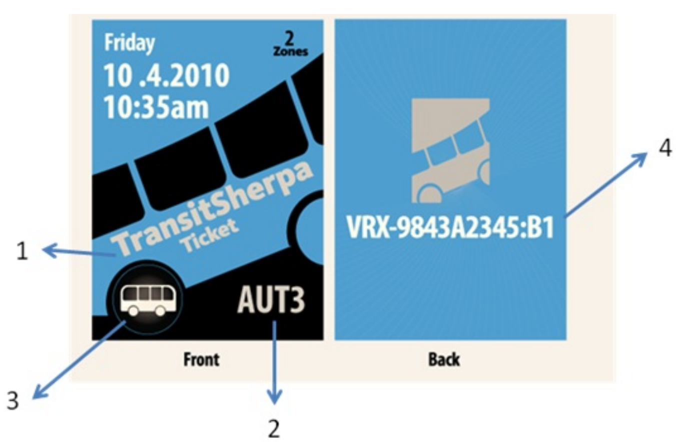


Figure 9. TransitSherpa Ticket [18]

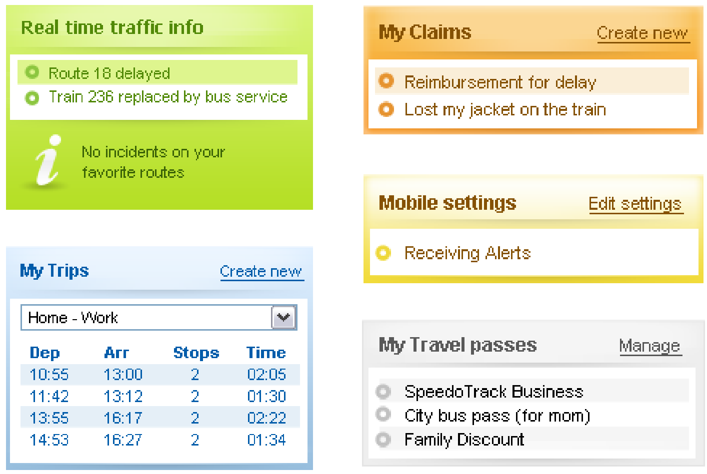


Figure 10. Traveler's personalized home page [19]

According to a recent NFC Forum white paper (2011), several major transit agencies have tested a new technology called Near Field Communication [20]. Tests have been carried out by Transport for London (See Figure 11), Deutsche Bahn (Germany), San Francisco Bay Area Rapid Transit (BART) and Rhein-Main-Verkehrsverbund (Frankfurt, Germany). NFC is a short-range wireless connectivity technology that enables simple two-way interactions between cell phones or other electronic devices. This technology enables contactless transactions, access to digital content, and connectivity between NFC-enabled devices. Compatible with the contactless standards already being used by transit agencies, existing equipment can interact with the NFC-enabled mobile devices. As identified in the NFC Forum, the three possible transit uses of NFC are connection, access, and transactions. An example incorporating all three uses: a user with a NFC-enabled phone can connect to a NFC kiosk and download his/her ticket, or the ticket can simply be sent directly to the phone over the air. The phone can then tap a reader to redeem that ticket and gain access. The main idea behind this technology is to use the media that the commuters already have, namely cell phones. A similar idea has been implemented by NJ TRANSIT in the Tap>Ride pilot study. The Tap>Ride pilot payment program allows commuters to pay their fare with a tap of their contactless credit, debit, prepaid card, or mobile device.

Recently, the Finnish rail system implemented a mobile ticketing system developed by Accenture [16]. The system is a modular and flexible Java-based application that was aligned with the railway's electronic architectures and standards, designed to run on a Web-based infrastructure. This system then integrated with various internal Finnish Rail systems, as well as with external systems belonging to banks, credit card companies, and the Finnish Post. The solution supports the entire customer service process, from ticket ordering through sales service to customer billing and accounting.

Figure 11. Using an NFC-enabled phone to exit a London Train Station [20]

Malaga is the first Spanish city to offer customers the chance to pay their bus fare with their mobile phone using a solution developed by Gavitec [21]. Commuters can pay for a ticket or top up their season tickets by using their mobile phone. Using the Mobipay payment system, travelers can purchase and receive bus tickets as unique 2D codes (Data Matrix) via one text message (SMS) on their mobile phone. The ticket price is charged to the phone bill or deducted from the pre-paid phone card. The code displayed on the mobile phone screen has to be presented to the EXIO (scanner) on the bus, which then uses general packet radio service (GPRS) to check off the ticket in coordination with a centralized ticket management system. Once validated, the EXIO scanner prints out a ticket confirmation and beeps a validation confirmation.

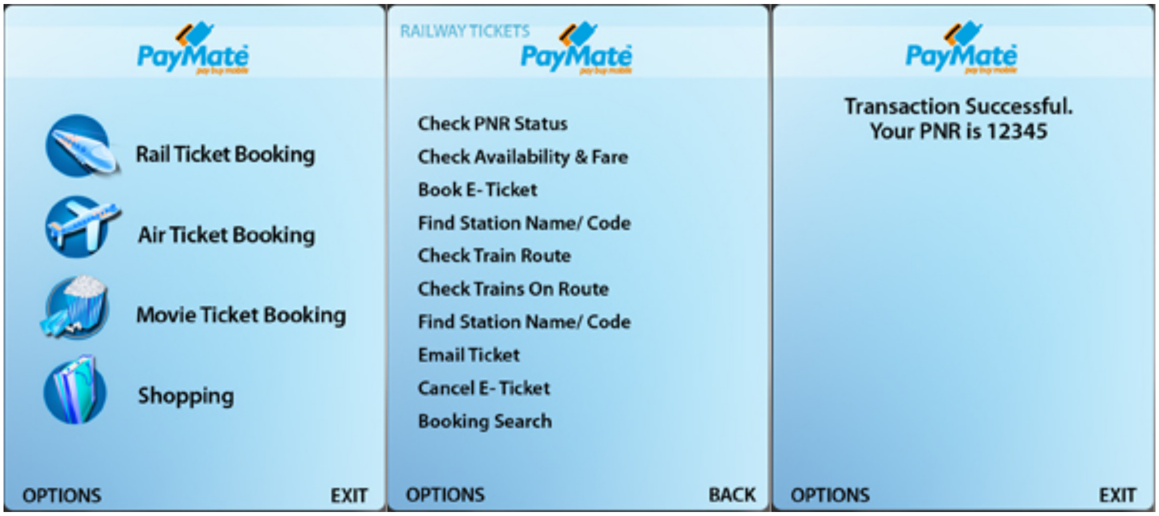
Plusdial Mobile Ticketing Service has been in use by the Helsinki City Transport since 2000 [22]. Commuters using this system will write a SMS message containing a keyword to specify a ticket type, such as bus or train stop, to a service number. The reply message will be the mobile ticket, which the commuter can then show to an inspector or driver. The ticket is charged to the phone's account.

The train ticketing company My Train Ticket (MyTrainTicket.co.uk) has teamed up with Mobiqa, a mobile phone ticketing specialist, to provide mobile ticket delivery capabilities to the UK's rail companies and their passengers [23]. Launched in April 2010, MyTrainTicket.co.uk sells tickets for all the UK train companies to all the National Rail destinations and London Underground stations. MyTrainTicket.co.uk's mobile tickets are delivered as SMS Web Links, Email Web Links or by MMS, and contain a scannable barcode as well as the passenger's travel itinerary (See Figure 12). The barcode held within the message is scanned and validated at the station or onboard the train.

Figure 12. mytrainticket.co.uk Mobile Application (23)

Working under Textus, their parent company, in 2004, Mobimatics launched a mobile ticketing solution (M-Ticket) for the inter Belfast-Dublin Aircoach (24). Mobimatics's mobile system enables customers to buy a ticket using a credit card or debit card via their telephone, their mobile phone, or over the Internet. They can also visit convenience stores and buy "pay-as-you-go" M-Ticket top-up vouchers in the same manner as current 'pay-as-you-go' mobile phone tariff top-ups. The purchased ticket is sent to the mobile phone in the form of a 2D bar code. This barcode can be printed and scanned, or barcode stickers can be added to existing concessionary tickets in circulation. At the same time, the ticket data is sent to all the Mobimatics-enabled ticketing machines. At a ticket machine, the machine's scanner can validate a user's mobile phone. All the software and hardware components within the Mobimatics ticketing system communicate with each other in real-time via GPRS.

Indian Railway (IRCTC) and PayMate(25) launched the "Search.Book.Pay service" for Indian Railway tickets using the PayMate's mobile payments application (see Figure 13). Commuters download PayMate's app on their mobile phone to search, book and pay for any Indian Railway tickets directly from the phone (a). The app works on most JAVA enabled phones with GPRS activated. Using the app, commuters can book their ticket, pay from their mobile, cancel the ticket, check passenger name record (PNR), and more (b). Confirmations are sent to the commuter via SMS and email with the transaction details (c).



(a) (b) (c)

Figure 13. PayMate App [25]

Unwire is a mobile ticketing technology used by transit agencies in Scandinavian countries [26]. Interacting with Unwire's mobile technology, customers can order tickets through SMS or a dedicated mobile application. Once delivered to the customer's mobile phone, the ticket is presented when entering a vehicle or during a random ticket inspection. This technology supports a variety of interaction channels, including apps, SMS and mobile web, to meet the needs of different types of commuters. This system allows customers to pay for their tickets via credit cards, premium SMS, invoicing, or a bank account. First introduced in 2008 by Storstockholms Lokaltrafik (SL), the technology originally offered customers the option of paying for a ticket by SMS [27]. In 2009, various Copenhagen transport companies implemented ticket payments via SMS through the Unwire technology. In 2010, DSB, Movia and Copenhagen Metro launched the mobile site 1415.dk. This website allows passengers to buy tickets with a smartphone.

Developed for the UK intercity Rail network, CrossCountry's Train Tickets app allows customers to look up train schedules and ticket prices, check real-time running information, and purchase train tickets [28]. It is available for multiple platforms including the iOS, Blackberry, Symbian and Android platforms. The tickets purchased from the mobile application CrossCountry Advance Ticket can either be delivered straight to the app or they can be collected from a self-service ticket machine at the station. Figure 14 shows the redemption of a train ticket at a gate.

Figure 14. CrossCountry Ticket App [28]

In 2012, NY Waterway introduced a mobile app for mobile payments and ticketing. Developed by Bytemark, the free app is currently available for all Android and Apple iOS devices [29] (see Figure 15). This technology allows NY Waterway customers to purchase and use a ticket as well as store multiple tickets and monthly passes on their mobile devices. The NY Waterway app does not require code scanners and it generates visually verifiable virtual (V3) tickets. The app's special security features allow NY Waterway management to change images and ticket details. This feature can be particularly useful for large groups, which deckhands can validate with one ticket to speed boarding time. The system also collects ridership information anonymously and, in the future, will provide targeted advertising to customers based on where they are embarking or disembarking. The app also allows customers access to ferry schedules, real time advisories for service changes and emergencies, route maps for ferries on both the Hudson and East River, and a global positioning system (GPS) bus locator to track connecting buses.

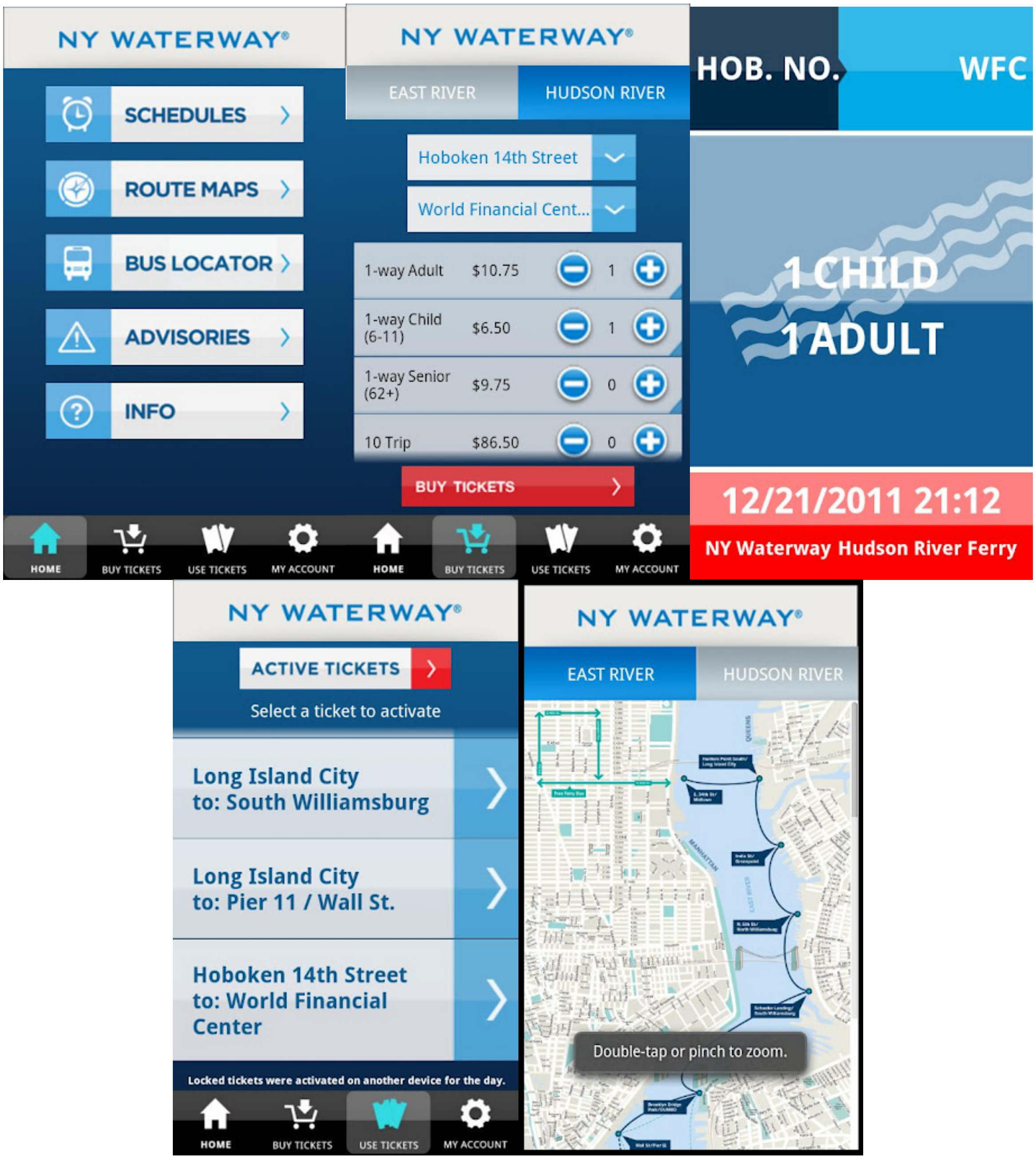


Figure 15. NY Waterway App [30]

Table 1 summarizes the deployment location and capabilities of each of these technologies. Table 2 shows the technologies identified in the NJ TRANSIT report [3]. Note that fourteen more systems are identified by the research team in addition to the NJ TRANSIT report.

Table 1. Current ticketing technologies identified by the research team

Technology	Region	Description / Capabilities	Scanning Method	Used Modes	Type of System	Status
Mobile Computer	Germany	On-board ticket purchasing. Scans and validates train ticket. Secure payments.	Handheld computer	Train	Open	Deployed
Mobile Computer	California	Validation is performed using a laser barcode scanner integrated in the handheld device. Ticket sales are done using cash, credit card, or money orders.	Handheld reader	Train	Open	Pilot
Smart Card	Seattle (ORCA)	Money value can be added by mail, phone, online or at retail outlets.	Fare mater	Train, Bus, Ferry	Closed	Deployed
	San Diego (COMPASS)	Passengers pay by tapping their cards at a standalone fare transaction meter.	Handheld reader	Bus, Train	Open	Deployed
	Quebec, Canada		Turnstile	Train	Closed	Deployed
Near Field Communication (NFC)	Transport for London	Enables contactless transactions, accessing digital content and connecting to another NFC-enabled device.	NFC Readers	Train	Closed	Deployed
	Deutsche Bahn (Germany)	NFC-enabled phone can connect with a NFC kiosk and download a ticket, or the ticket can be sent directly to the phone over the air.		Train	Closed	Pilot
	San Francisco Bay Area Rapid Transit (BART)	The phone can then tap a reader to redeem that ticket and gain access.		Train	Closed	Pilot
	Rhein-Main-Verkehrsverbund (Frankfurt, Germany)			Bus, Train	Closed	Deployed
Online/On-board	New Mexico	Passengers can purchase tickets online or directly from conductors on-board using debit/credit cards. Online tickets can be validated by conductors using handheld scanners	Handheld reader	Train	Open	Deployed
Online/On-board	Metro North	On-board handheld devices can print tickets and store fare data.	Visual inspection	Train	Open	Deployed
Online (Boomerang)	Sweden (Östgötatrafiken)	Integrates automatic fare collection systems with public transit systems.	Visual Inspection	Bus	Open	Deployed
Online (Accenture)	Finland	Java-based application that integrates various internal Finnish Rail systems, as well as with external systems belonging to banks, credit card companies and the Finnish Post.	Visual Inspection	Train	Open	Deployed

		The solution supports the entire customer service process, from ticket ordering through sales service to customer billing and accounting.				
Online/Mobile (Mobimatics)	Belfast-Dublin, Ireland, Germany (Rhein-Main-Verkehrsverbund Handy Ticket)	Enables customers to buy a ticket using a credit card or debit card, via their telephone, their mobile phone, or over the Internet. The ticket is sent to the mobile phone in the form of a 2D bar code.	Ticketing machine Handheld reader	Bus	Open	Deployed
SMS (Plusdial)	Helsinki, Finland	Commuters send an SMS message containing a ticket-specific keyword ("bus" or "tram stop"). Commuters then send the order message to a service number. A reply message includes the mobile ticket.	Visual inspection	Bus, Train	Open	Deployed
SMS (Mobipay)	Malaga, Spain	Commuters can pay for a ticket or top up their season tickets by using their mobile phone. Tickets are received as 2D codes (Data Matrix) via one text message (SMS) on their mobile phone.	Ticketing machine	Bus	Closed	Deployed
SMS/MobileApp (Unwire)	Stockholm, Sweden Copenhagen, Denmark	Ticket is delivered to mobile phone. Multiple payment options are available. Multiple platforms are supported.	Visual inspection	Train, Bus	Open	Deployed
MobileApp (CrossCountry)	UK	Mobile tickets are delivered as SMS Web Links, Email Web Links or by MMS and contain a scannable barcode as well as the passenger's travel itinerary. The barcode within the message is scanned and validated at the station or onboard.	Handheld reader	Train	Open	Deployed
MobileApp (CrossCountry)	UK	Check train schedules, check real-time running information, get prices and purchase train tickets for the whole UK Rail network. The tickets can be delivered to the mobile app or collected from a self-service ticket machine at the station.	Ticketing machine	Train	Closed	Deployed
MobileApp (Paymate)	India	The app works on most JAVA enabled phones with GPRS activated. Commuters can select the app icon and follow the instructions to book their ticket, pay from their mobile, or cancel a ticket.	Visual inspection	Train	Open	Deployed
MobileApp (TransitSherpa)	Portland	Purchase and use transit tickets with smartphones including an iPhone, Android, or Blackberry. Real-time arrival information for the next bus or train Service Alerts.	Visual inspection	Bus, Train	Open	Planned

MobileApp (NY Waterway)	New York	Purchase and use tickets with an Android or iOS device; real-time advisories for service changes and emergencies; access to ferry schedules and route maps; and a GPS bus locator to track the status of connecting buses.	Visual Inspection	Ferry	Open	Deployed
MobileApp (MBTA)	Boston	The app is called mTicket. Used to purchase transit tickets with iPhone and Android phones.	Visual Inspection	Train, Ferry	Open	Deployed

Table 2. Technologies identified in the NJ TRANSIT Report [3]

Technology / System Provider	Agency / Region
Contactless Card	PATH, Port Authority of NJ/NY, SEPTA
Magnetic Stripe Card	MTA
MasterCard Worldwide	NJ TRANSIT, MTA and PATH
Google Wallet (NFC)	New York, San Francisco
VISA	LA Metro
VeriFone	NJ TRANSIT, MTA and PATH
Masabi (Mobile App)	UK Chiltern Railways
ACS (System Integrator)	NJ TRANSIT, MTA and PATH
Ready Credit	LA Metro
Accenture (System Integrator)	MTA, WMATA, CTA, AMTRAK, Transport London, PRESTO (Ontario), Trans Link (Netherlands)
Cubic (System Integrator)	NJ TRANSIT, NYCT, WMATA, CTA, TfL, PATCO, BART, CalTrain, Rhein-Main-Verkehrsverbund

Interviews with Agencies

The research team conducted interviews with five American transit agencies to gather information relevant to smartphone-based mobile ticketing applications. The goal of the interviews was to obtain information that, because mobile ticketing applications are an emerging technology, might not otherwise be available. Table 3 presents the overview of the interviews.

It should be noted that these interviews reflect the implementation of mobile ticketing technology as of March-July 2012, and that since then the agencies interviewed may have adopted or expanded technologies.

Table 3. Overview of interviews with transit agencies in US

Agency	Date	Interviewee	Title
Portland TriMet	March 20, 2012	Tom Strader	Policy Analyst
NY Waterway	April 5, 2012	Arthur Imperatore, Jr.Augie Pagnozzi Micah Bergdale	Executive Vice President Senior Vice President Bytemark, CEO
AMTRAK	May 2, 2012	Matt Hardison	Chief, Sales Distribution and Customer Service
DART	June 4, 2012	David Leininger	Executive Vice President/Chief Financial Officer
MBTA	July 5, 2012	Josh Robins	Director of Innovation

Portland TriMet

The research team conducted an interview with TriMet on March 20, 2012. TriMet plans to upgrade their current fare collection system by implementing an open-standard based electronic fare collection (EFC) capable of accepting a variety of media. The new fare system will be implemented on all TriMet buses and at all rail lines. The new fare payment system will enable TriMet to accept contactless payment cards (both open and closed loop cards) and payment-capable mobile phones that support near-field communications.

As a part of their “fare system migration” TriMet is working with GlobeSherpa, a start-up company that specializes in mobile ticketing applications, to develop an application through which commuters purchase and use transit tickets with a smartphone. Commuters can get real-time arrival information for the next bus or train, calculate the fare for their destination and receive alerts about service disruptions. TransitSherpa uses a unique combination of color, code, time and date stamps, animation, and 3rd party verification to ensure the security of a ticket.

During the interview, Tom Strader mentioned that TriMet is in the early stages of the fare simplification and restructuring process, with the aim of replacing zones with a flat fare. The current zone-based fare system, he said, is confusing to commuters. This fare simplification and restructuring process is intended to pave the way for an open electronic fare collection system down the road.

Tom Strader also provided a brief overview of the TriMet system. TriMet consists of light rail, commuter rail and bus systems. The monthly ridership on the light rail, commuter rail, and bus system are 3.2 million, 40,000, and 4.9 million passengers, respectively. The commuter rail is only 15-mile long with four stations, operating with two train cars. The light and commuter rails use proof-of-payment systems, where fare inspectors inspect tickets randomly on-board. Passengers can buy tickets at retail outlets, TriMet ticket offices, ticket vending machines (TVM) and online (mail-in). On the buses, passengers are able to use cash to purchase tickets.

Mr. Strader also said they were approached by GlobeSherpa in late 2010 and that TriMet was interested in their proposed mobile ticketing application. The agency envisions this application not as a complete replacement but as a means to takeover some transactions currently being handled by the TVMs, particularly for the light rail. He mentioned that it is costly to the agency to collect and count cash and coins, and that the TVMs require extensive maintenance.

TriMet wants to use this application as a Flash Pass on all of the modes where passengers are not required to own NFC-enabled smartphones and the agency does not need to invest in NFC readers.

Tom Strader emphasized the fact that TriMet does not yet have a fully developed product. Development has been slow because of GlobeSherpa, since they're a start-up company that only recently acquired enough resources to complete the product. At this point there is no concrete time-line for implementation, but Mr. Strader thinks it will take five years before this system is implemented on all modes.

According to a survey they conducted in 2010, TriMet found that 24 percent of their customers owned a smartphone and 10 percent were planning to get one in the future. Mr. Strader believed that the penetration of smartphones will continue to increase. TriMet will move towards EFC technology as it's convenient for customers and reduces the costs of fare collection.

In Mr. Strader's view, the implementation of an NFC-based EFC is a challenge because of the required investment in infrastructure. While mobile ticketing does not require its own infrastructure, it nonetheless engenders security and duplication issues that need to be resolved. Currently, Mr. Strader envisions the inspection of flash-passes with a security code or a short animation that the conductors can verify by visual inspection.

Snapshot:

- TriMet is in the early stages of the fare simplification and restructuring process, with the aim to eventually replace zones with a flat fare.
- There is no concrete timeline for the implementation of the proposed mobile ticketing application.

NY Waterway

The research team conducted an interview with NY Waterway on April 5, 2012. NY Waterway officials stated that they partnered with Bytemark to develop a smartphone mobile ticketing application. Beginning application development in June 2011, Waterway offered the app to customers as soon as January 2012.

NY Waterway conducted a pilot study with one-hundred users, mostly employees and friends, during November and December of 2011. During this period they observed the crash report rate to be approximately one percent. The system was fully operational in January of 2012.

Bytemark said the app has received 20,000 downloads. The current daily ridership of the NY Waterway is 30,000-40,000 passengers. Bytemark noted that there are close to one thousand ticket activations per day, including monthly riders. Bytemark also noted that 25 percent of users are purchasing tickets and the remaining 75 percent of app users are using the app to find service information and trip schedules.

The NY Waterway mobile ticketing application generates visually verifiable virtual (V3) tickets and does not require code scanners. The application has special security features NY Waterway management can use to change images and ticket details for the deckhands to easily validate tickets. To reduce boarding times, it allows the boarding of multiple passengers in one ticket. The app also allows customers access to ferry schedules, real time advisories for service changes and emergencies, route maps for ferries on both the Hudson and East River, and a GPS bus locator to track connecting buses.

The application is currently available to both Android and iPhone users, the latter whom constitute 75 percent of all users. NY Waterway is planning to include free WiFi services and boost cellular signals at terminals for improved customer satisfaction. NY Waterway mentioned that they did not conduct any focus groups for application usability tests.

Snapshot:

- NY Waterway implemented the first mobile ticketing application in the US. The application is available for iPhone and Android users.

AMTRAK

The research team conducted an interview with AMTRAK on May 2, 2012. At the time of the interview with Amtrak, their e-ticketing application was available to users on the following five intercity rail lines:

- City of New Orleans (Chicago – New Orleans)
- Downeaster (Portland, ME – Boston)
- Capital Corridor (Sacramento – San Jose)
- San Joaquin (San Francisco Bay Area- Bakersfield)
- Heartland Flyer (Oklahoma City - Fort Worth)

Matt Hardison, Chief of Sales Distribution and Customer Service at AMTRAK, said they are putting the finishing touches on their e-ticketing solution and expect to roll it out fully by the end of summer, 2012. Currently, e-ticketing is available for all Amtrak train routes.

Mr. Hardison also noted that the e-ticketing solution will only apply to their intercity rail lines, as there are still challenges Amtrak needs to overcome to implement a commuter rail line e-ticket solution. Amtrak had spoken with various US transportation agencies, and it seems the consensus among agencies is that there is no ideal, single form payment solution for commuter rails.

As it stands now, customers can either print out their tickets at home and display the barcode on-board, or simply display the barcode on their smartphones. In addition, customers can modify their reservation directly through the AMTRAK application.

Conductors equipped with an iPhone coupled with a high-speed scanner can scan e-ticket barcodes and periodically update the reservation system through the cellular system. Conductors' iPhones also include the mobile application MobileIron, which monitors the cell phone activity to prevent unauthorized device activity and updates the scanner software automatically.

AMTRAK found that it takes less time to scan tickets than to manually punch paper tickets. Another advantage of the e-ticketing method was that it reduced fraud on Amtrak intercity passenger rail lines, particularly with monthly passes.

Moreover, the new system distributes ticket revenue credit to Amtrak at the point of scan, much earlier compared to manually verifying paper tickets. The new system also allows AMTRAK to validate the on-board tickets collected against its reservation system, thus providing a more accurate view of available seats. On-board employees have so far been quite supportive of the new mobile technology.

Mr. Hardison mentioned that they had initial problems with the cellular network and scanning, but they quickly solved these issues. However, he did not offer the specifics of these problems.

He also mentioned that Amtrak conducted focus groups to obtain feedback on the e-ticketing application; however, due to concerns relating to confidentiality, he did not want to share the specifics of this feedback.

Currently the application is available to iPhone, Android, Amazon and Windows Phone users.

Snapshot:

- AMTRAK currently offers e-ticketing solutions at all intercity rail lines.

DART

On June 4, 2012, at the APTA Rail Conference in Dallas, DC Agrawal interviewed David Leininger, Executive Vice President/Chief Financial Officer for Dallas Area Rapid Transit (DART). The interview dealt with DART's plans regarding rail service mobile ticketing. DART operates bus, light rail and commuter rail services in the Dallas area with their bus and LRT services being the more popular offerings. Of its 220,000 total daily ridership, the bus lines carry 125,900; LRT carries 71,600, and commuter rail (Trinity Rail Express) carries only 8,500. (The balance uses paratransit services).

DART fares are derived per-ride, with great variety in fares based on the system and region. System fares allow one to ride on all DART bus, LRT and TRE' services to the Dallas airport. Regional fares allow one to ride on the TRE to Fort Worth, as well as the bus system. Fares are generally single trip or monthly, with occasional other fare options offered in conjunction with various marketing efforts.

DART sells its rail tickets at station ticket vending machines. Tickets are then shown to a revenue agent for verification. Single ride rail tickets are valid for 90 minutes.

DART has been exploring the use of mobile ticketing options to serve its customer needs. It is currently in the process of selecting a vendor or multiple vendors to meet its needs. It expects to complete this process by July 31, 2012 and give a NTP to a vendor in September 2012. (In February of 2014, DART provided users a mobile ticketing app: GOPASS.)

DART is interested in selecting a vendor with an open system technology as it does not wish to get tied down to a specific vendor and its technology. It is looking at "smart card" closed systems for both its bus and LRT needs. It has 4G on its buses and is looking for a validator for mobile ticketing on its buses. The commuter rail system ridership is quite small; moreover the commuter rail does not pose any specific requirements, as its fare system is similar to its LRT system.

Snapshot:

- In the time of the interview DART was in the process of selecting a vendor for implementing mobile ticketing on their bus system. GOPASS is selected for mobile ticketing in February, 2014)

MBTA

The research team conducted an interview with Massachusetts Bay Transportation Authority (MBTA) on June 5, 2012. The MBTA commuter rail serves approximately 60,000 passengers each day. In 2006, MBTA introduced the CharlieCard, a contactless card for their bus and subway system. The implementation of the CharlieCard for the commuter rail system was estimated to cost between 50 and 70 million dollars. The MBTA then issued a request for information for a possible mobile ticketing application in December 2011. They partnered with Masabi to develop a smartphone-based mobile ticketing application for their commuter rail system.

The mobile application is currently under development. Josh Robins, Director of Innovation at MBTA, said they envision a system where customers can purchase tickets on the go and display their tickets on their smartphones. Conductors will validate the tickets visually, and do random scans for fraud protection.

The main motivations to developing the mobile ticketing application are customer convenience and reduced costs, the latter of which will result from eliminating vending machines and reducing the volume of cash handling.

They conducted surveys to find passengers for focus group studies. The studies consisted of 5-minute question and answer sessions with each participant. MBTA is currently seeking participants for their pilot study. Josh Robins noted the mobile ticketing application would be available to iPhone, Android and Blackberry device users.

Snapshot:

- In the time of the interview, MBTA was developing a smartphone based mobile ticketing application. They planned to conduct a pilot study at the end of summer, 2012. As of August 2014, the mTicket app is available for all MBTA users.

EVALUATION METHODS & RESULTS

NJ TRANSIT's mobile ticketing application, MyTix, was put into effect on the Pascack Valley Line on April 25, 2013. Currently, the MyTix app can be used on all NJ TRANSIT commuter rail lines.

This section presents the evaluations conducted by the research team, from the app development phase until it was available for all commuter rail lines. The following subsection briefly describes the MyTix app and its capabilities. In the following sections the evaluation stages, methods, and results are presented.

MyTix Mobile Ticketing Application

The MyTix mobile ticketing application is currently available on the iOS and Android mobile operating systems. The app is free to download. When users open the app, they can either register a new account or proceed with a registered account's username and password. To register a new account, users need to provide a valid e-mail account, a zip code, and a password. Figure 16 shows the screenshots of the app interface as of March 2013.

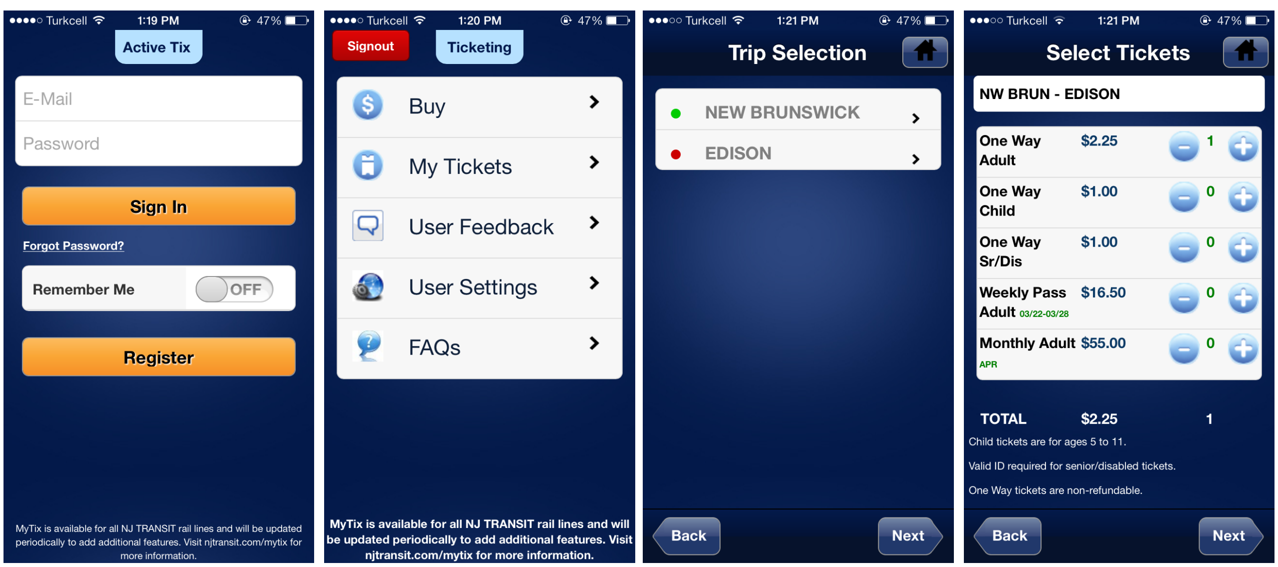


Figure 16. MyTix Mobile Ticketing Application ticket purchase

After the e-mail account is verified by the app, users can purchase tickets by specifying their origins and destinations, and select the ticket type and ticket amount. The available ticket types are one-way adult, one-way child, one-way senior / disabled, weekly pass adult and monthly adult tickets. Users then enter their credit card information to finalize their purchase. Credit card information can also be entered after the registration process.

Once the ticket is purchased it stays a non-active ticket in the My Tickets section of the app. Figure 17 shows the screenshots of active ticket information and activation confirmation screens of the app as of March 2013. To activate the mobile ticket, users select My Tickets, tap the desired ticket(s), and then tap to activate. The app asks users to confirm that they want to activate the selected ticket(s). Tickets must be activated prior to boarding the train to display to the conductor for validation. An Internet connection is required to activate tickets. However, once activated, mobile tickets can be displayed without an Internet connection. Users can purchase as many one-way tickets as they want; however, they can activate only up to five one-way at a time for multiple riders of the same origin and destination.

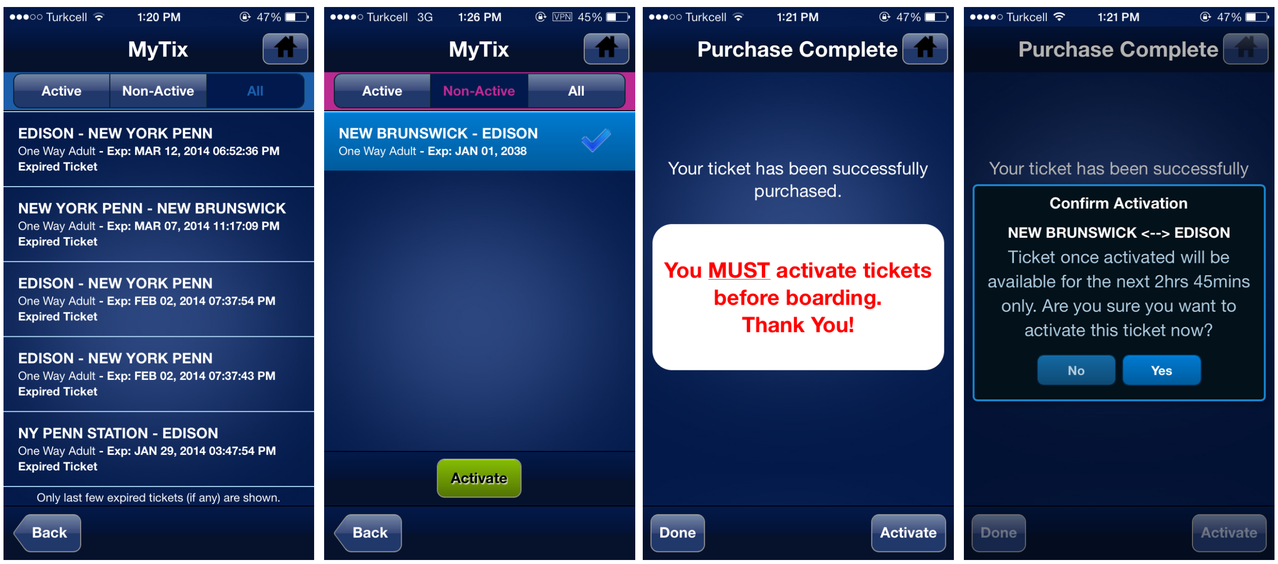


Figure 17. MyTix Mobile Ticketing Application ticket activation

Once activated one-way tickets expire in two hours and forty-five minutes. A monthly mobile ticket activates automatically at midnight on the first day of the month and expires at noon on the first business day of the next month. A weekly pass automatically activates at 12:01 a.m. on Saturday and expires at 6:00 am the following Saturday. Users who have monthly or weekly mobile tickets can also purchase one-way tickets for friends and family members traveling with them.

Conductors validate mobile tickets on board visually. Once tickets are activated there is a simple animation that proves that the ticket is valid. In addition, there's a two-dimensional (2D) barcode on each mobile ticket that conductors may scan and verify with a handheld device. Users who travel through the faregates at the Secaucus Junction or Newark Liberty International Airport must scan the 2D barcode on the faregate reader for each passenger passing the gates.

Although the MyTix app is for commuter rails only, if a monthly rail ticket is valued at $54 or more, users can use it on any NJ TRANSIT light rail or bus up to the number of zones indicated on the ticket. If users have a weekly rail ticket, they can use it for a one-zone ride on any NJ TRANSIT light rail line or bus.

Evaluation Stages and Results

NJ TRANSIT requested the research team to conduct an objective evaluation of the MyTix app and act as an impartial critic of the use, efficiency, and applicability of this technology. To that end, the research team devised a 3-stage evaluation process.

Stage 1, which consists of alpha tests in laboratory settings, was designed to identify possible usability issues with the earlier versions of the MyTix app. Stage 2, which consists of beta tests, was designed to identify possible usability issues with the MyTix app by evaluating the app in field conditions. Stage 3 was the evaluation of the app during the pilot test and after it was released on other commuter rail lines. The research team analyzed user logs to estimate the MyTix app adoption statistics and frequency of use.

The summary of the 3-stage evaluation process conducted by the research team is as follows.

Stage 1 – Alpha Tests

- Heuristic evaluation: Conducted by a small set of one to three evaluators, regular commuters of NJ TRANSIT rail lines, to identify major usability problems.

- Usability Tests and retests with participants in a laboratory environment until the selected metric criteria had been met.

Stage 2 – Beta Tests

- Usability field tests with the participants, regular commuters of NJ TRANSIT rail lines who were selected by NJ TRANSIT, and with the research team.

- Survey of selected participants.

Stage 3- Roll Out

- General evaluation of the MyTix app by using the automatic ticket transaction data.

Table 4 lists the exact dates of the evaluation tests, along with the dates of the technical memoranda provided to NJ TRANSIT for their review and feedback.

Table 4. Dates of technical items and activities

Item / Activity	Date
Technical memorandum on Alpha Test 1 conducted on September 26 and 27, 2012	October 5, 2012
Technical memorandum on Alpha Test 2 conducted on January 10 and 11, 2013	January 29, 2013
Technical memorandum presenting the research team's observations, comments and suggestions regarding the overall NJ TRANSIT mobile application	January 29, 2013
Technical memorandum on Alpha Test 3 conducted on February 8 and 9, 2013	February 15, 2013
Technical memorandum detailing the field tests at Pascack Valley Line	April 11, 2013
Field Tests on Pascack Valley Line	May 20, 23 and May 29, 2013
Technical memorandum presenting the results of the field tests on Pascack Valley Line	June 4, 2013
Technical memorandum presenting the analysis of preliminary ticket transaction data and updated field test results	June 13, 2013
NJ TRANSIT's comments on the tech memo sent on June 13	June 21, 2013
Updated technical memorandum on Item X the tech memo sent on June 13	July 23, 2013
Field Tests on Main / Bergen Line	October 28, 2013

Figure 18 demonstrates the timeline of the evaluation stages along with the timeline of MyTix app development and release for various NJ TRANSIT commuter train lines. The evaluation process made use of the Usability Testing in the first two stages. Usability Testing is an evaluation technique wherein representative users test a product. In the test, users try to complete a number of tasks outlined by developers, while observers watch, listen, and takes notes. The goal is to identify any usability problems, and collect quantitative and qualitative data on the participants' performance as it related to selected metrics. Usability testing lets the design and development teams identify problems with the mobile application.

Table 5 offers a description of each stage of the usability test. A detail of the evaluation of the new technology and the release dates of the mobile app is shown on the timeline in Figure 18.

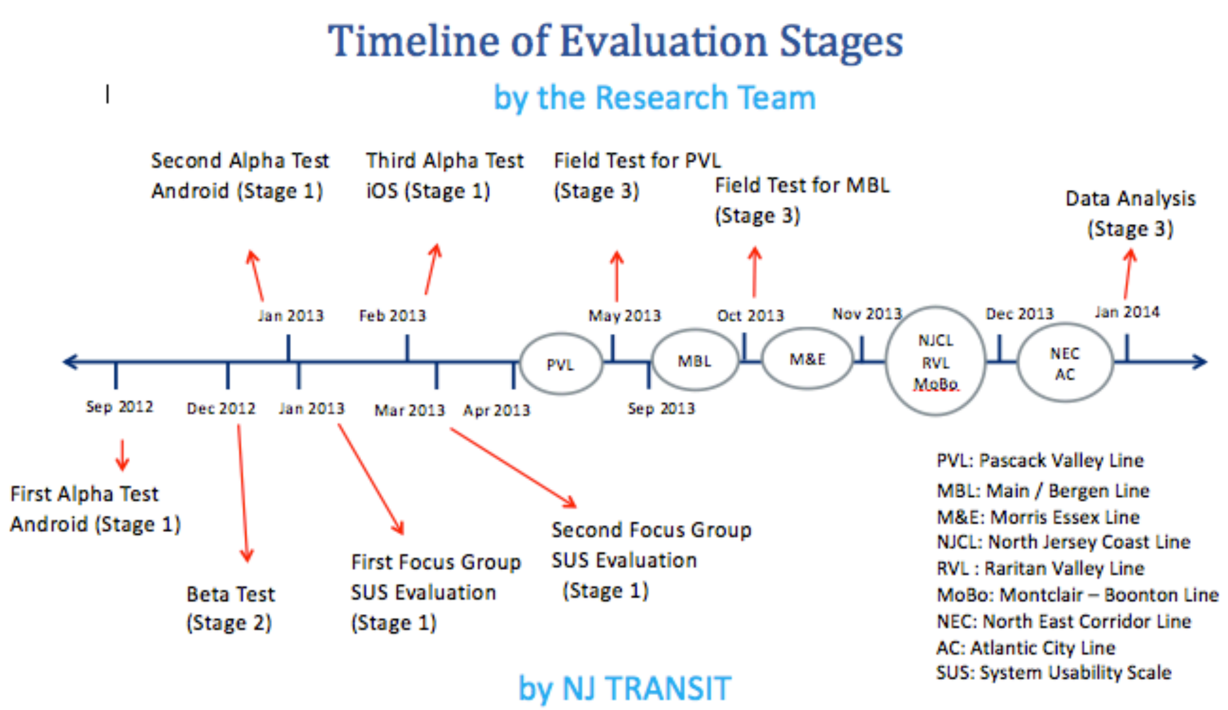


Figure 18. Timeline of evaluation stages

Table 5. Stages of usability tests

Technique	Description	Test Stage
Observation	User behavior is observed through the whole usability testing process	Stage 1
Interview (optional)	User's verbal report is collected using brief interviews after test completion	Stage 1
Questionnaire	User characteristics and demographics are collected before the test	Stage 1
Think Aloud Protocol	User's thought are collected through his/her audible expression using test procedure	Stage 1
Video Recording	User Interaction (e.g. finger tapping, facial expressions) are collected through video / audio recordings	Stage 1
Surveys	User Surveys	Stage 2 Stage 3
Diaries	Selected participants keep a written log of various problems they encounter during pilot test	Stage 2
Data-Logging	User's actions is tracked via data logging software applications	Stage 2 Stage 3
Data-Processing	Usage data are analyzed for adoption and frequency.	Stage 3

The following subsections present each stage of the evaluation process as well as the results.

Stage 1 – Alpha Tests: Evaluation Method

Stage 1 was designed to identify possible usability problems with the mobile ticketing application before it was released to candidate users. Tests within Stage 1 are also called Alpha Tests. Small set of one to three evaluators were used to define major problems. Based on these problems, participants were tested and retested in a laboratory environment until selected metric criteria had been met.

A review of the literature showed that the best results come from testing 5-8 participants for *qualitative* analysis. Nielsen and Landauer [31] developed a formula that presents the usability problems found in a usability test with *n* users as:

$$UP = N * [1-(1-p)^n] \quad (1)$$

Where
UP = Usability problems found
N = Number of total usability problems
p = Percentage of usability problems discovered while testing a single user

Results for a typical value of p=0.30 suggest that the marginal gain between 6 and 10 participants is 10 percent. Figure 19 shows the number of usability problems found versus the number of participants (N=20).

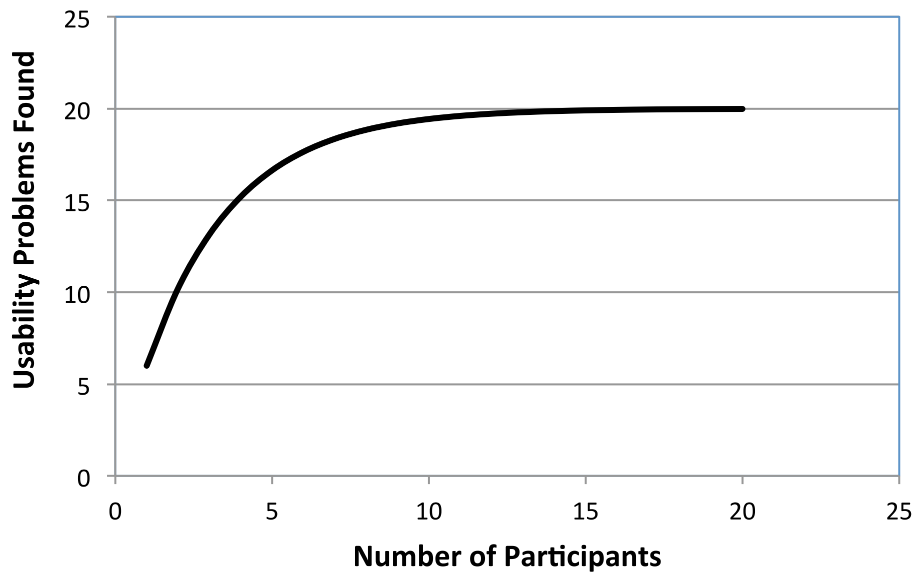


Figure 19. Number of participants versus the of usability problems found

<u>Conduct Laboratory Usability Test</u>

Lab usability tests measure a user's ability to complete tasks. Some of the tasks created by the development team included purchasing tickets, checking schedules, and providing feedback. As test subjects work on their tasks they talk out loud about their thoughts and actions. A moderator observes while taking notes on the user's actions, and records whether the participant is able to complete the task, in what length of time, and what steps the user takes. The moderator limits their interaction with the participant until the end of the task or maximum time allocated for the task. After each task, participants are asked to rate the difficulty of the task.

Test Setup & Equipment

Each participant will be given an iPhone and/or an Android phone. Each participant's screen taps and facial expressions will be recorded simultaneously to measure time between tasks, frustration, where they have problems, etc. There are several ways to synchronize the video images from two different cameras. Figure 20 shows setup examples for the laboratory usability tests of mobile apps.

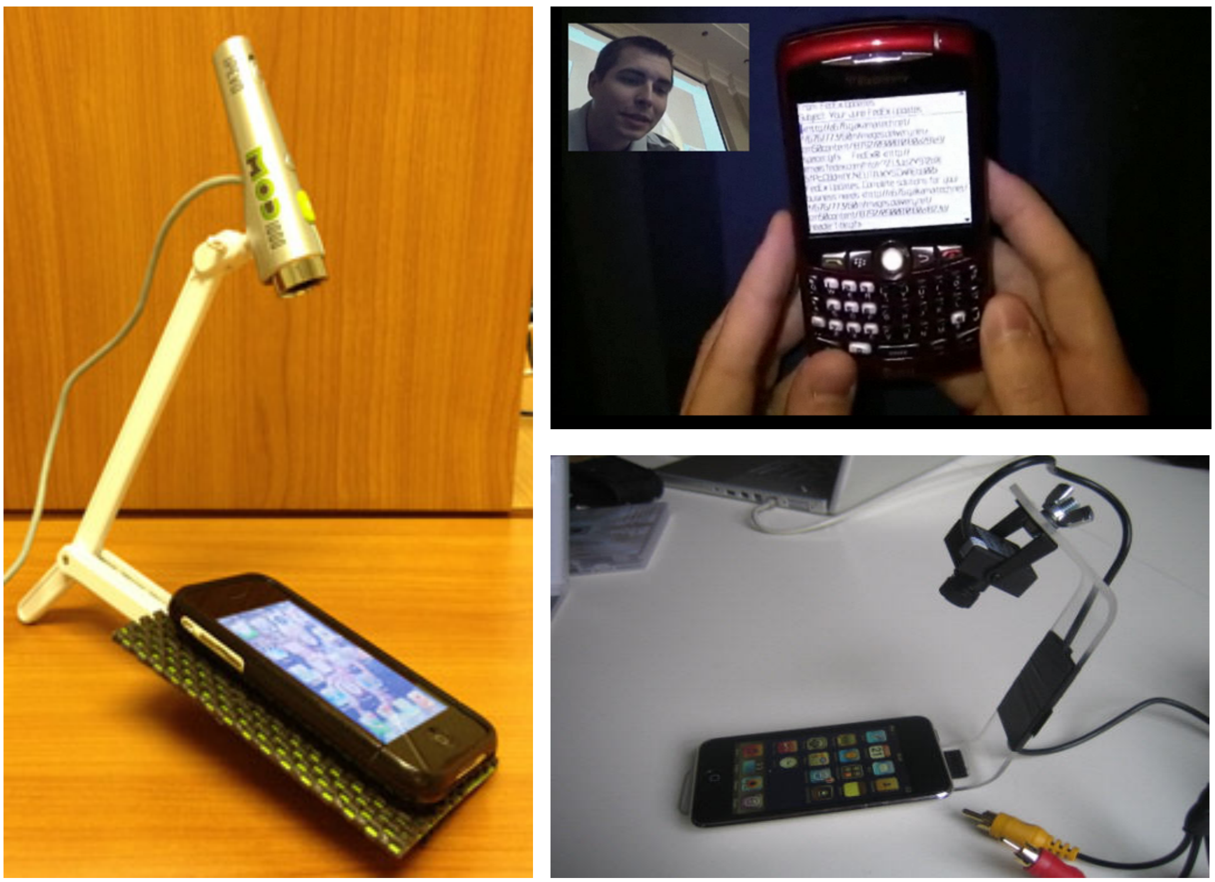


Figure 20. Equipment setup for laboratory usability test [32]

An exit questionnaire is given to each participant to measure user satisfaction. The research team used the System Usability Scale (SUS). The SUS is a simple, ten-item scale that provides a global view of subjective assessments of usability.

Figure 21 shows the system usability test for users [33]. A special technique is used to score this test and define the performance of the system. For odd-numbered questions, subtract one from the user's response. For even-numbered questions, subtract the user's response from 5. Then, add up the converted responses for each user and multiplying that total by 2.5. This converts the range of possible values from 0 to 100. The average SUS score from all 500 studies is a 68 [34]. According to the literature, a SUS score above a 68 is considered above average and anything below 68 is below average [34].

$$SUS = 2.5 * \left[\left(\sum R_i - 5\right) + \left(25 - \sum R_j\right)\right] \quad (2)$$

$$R_i = Response\ score\ for\ odd\ questions\ \{i = 1,3,5,7,9\}$$

$$R_j = Response\ score\ for\ even\ questions\ \{j = 2,4,6,8,10\}$$

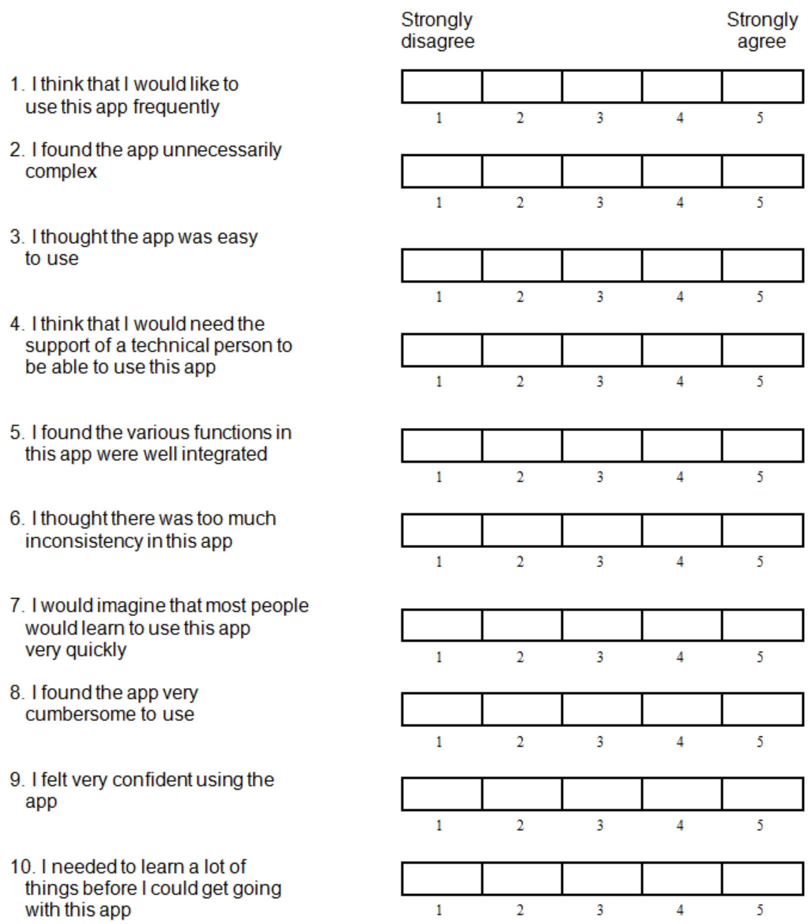


Figure 21. System usability scale (SUS) [33]

Analysis of Data

After each participant finished the usability test, the observer tallied up the success and failure for each task. To do so, he/she identified what was the core root cause for the failure. Based on this identification, the problems were categorized by severity and frequency. Each problem was categorized and scaled into three categories: Critical problems, major problems, and minor problems.

Stage 1 – Alpha Tests: Results

Evaluation tests of Stage 1 were performed at three different times.

Alpha Test 1

NJ TRANSIT strategic planning group conducted the first test on September 26-27, 2012. Three participants participated in exercises and answered questions/provided comments on the smartphone based mobile ticketing application on an Android device, lasting approximately two hours each. Details of these tests were provided to the research team for further analysis.

The research team analyzed the video recordings of participant's finger taps. Table 6 shows the times per exercise.

System Usability Scale (SUS) is based on the 10-item exit questionnaire given to each participant (Figure 21). An average SUS score of 81.7 was measured based on the answers given by the three participants, where individual scores are 92.5, 87.5 and 65. As stated earlier, the average SUS is score is reported as 68 in the literature [34].

Table 6. Time on task – Android Version

Participant	Exercise 1	Exercise 2	Exercise 3	Exercise 4
1	2:23	5:40	2:00	1:01
2	1:17	3:17*	1:38	0:52
3	4:02**	5:50	1:49	2:14

*Participant 2 had the opportunity to get familiar with the exercise before the registration issue got resolved

** Participant 3 registered again and purchased the ticket instead of proceeding as a guest.

The research team also noted problems encountered in the tests and categorized and scaled each problem, based on severity, as (1) Critical, (2) Major, and (3) Minor. Below are the observed problems for each category, and some potential suggestions.

Critical

- During Exercise #2, participant 2 could not register on the main screen although he tried nearly for 6 minutes. The participant was told that the problem is not related to the app but rather a phone issue. The problem was resolved by the ACS personnel after approximately 2 minutes with the phone.
    - *Suggestion: Consider conducting more usability tests on different devices to see if the error reoccurs.*

- During Exercise #2, participant 3 could not register since the phone did not respond even though he tried many different buttons. Later on he was given another phone.
    - *Suggestion*: Review logs and determine if it was in fact a phone issue, or a bug in the app.

Major

- In the home screen, the space for the email and password confused the participants.
    - *Suggestion:* The main window should be a simple “Sign into My Account (or simply “My Account”) “Create an Account” and “Proceed as Guest” buttons. The E-mail and Password can appear when the user taps on the My Account icon.
- In Exercise #2 once all the necessary fields are filled out, users cannot submit the form unless the keyboard is retracted. The submit button appears only when the keyboard is removed.
    - *Suggestion:* Once all the fields are filled out, the Submit button gets lit up and becomes active, whether the keyboard is on or not.
- After the purchase was complete, participants were confused by the Activate screen. This issue was also observed by the NJ TRANSIT research team.
    - *Suggestion:* Instead of expecting users to go to the ‘Non Active Tickets’ option of the main menu, the screen should have “Activate” and “Activate Later” options.
- After completing the purchase and activating the ticket, participants got confused with the ticket.
    - *Suggestion:* A “Present to Conductor” instruction near or on the ticket.
- There is only a Sign Out button on the Ticketing page. One participant had to use the Sign Out button to start the exercise.
    - *Suggestion*: There should be a Home button on the Ticketing page.
- Only a Back button is available on the Ticket page.
    - *Suggestion:* There should be a Home button on the Ticket page

Minor

- App buttons look very narrow inside a lot of empty space.
    - *Suggestion:* Buttons could be designed to be more user-friendly.
- Sometimes the screens would slide in from the left or the right.
    - *Suggestion:* When moving back they should slide left->right, when moving forward ("Next") they should slide right->left.
- The color of the NJ TRANSIT button is white when the user starts the app from the home screen, but it is blue when the user continues to use the app from the Ticketing page.
    - *Suggestion:* The same color scheme should be used throughout the app.

- In the Select Tickets page, participants had some difficulty tapping the plus and minus signs.
    - *Suggestion:* There is enough space on the screen and these buttons can be bigger.

The problems listed above were presented in a technical memorandum first and then discussed with the NJ TRANSIT officials. The ACS developers modified the app accordingly.

Alpha Test 2

The research team conducted usability re-tests on January 10 and 11, 2013 with three Android users from Rutgers University. Participants completed the same four different exercises that were used in September 2012, using the Android version of the mobile ticketing app. Using the recorded finger tap movements the research team measured the time-on-task statistics and categorized problems they encountered. In addition, a 10-question SUS questions was used to measure the universal usability score of the enhanced app.

It should be noted that the following items are intended to improve the quality and usability of the MyTix mobile ticketing app by raising only the problems and issues observed by the re-test participants. The same usability metrics were reported:

1) SUS score for the mobile app, and

2) The times per exercise as shown in Table 7.

An average SUS score of 66.7 was measured based on the answers given by the three participants, where individual scores were 75, 42.5 and 82.5 for participants 1, 2 and 3, respectively. The average SUS is reported as 68 in the literature [34].

Table 7. Time on task - Android Version

Participant	Exercise 1	Exercise 2	Exercise 3	Exercise 4
1	2:52	4:10	2:17	n/a*
2	2:18	5:41	0:44	n/a**
3	2:48	2:46	1:30	n/a**

*The app gave a “No Server Communication” error when the Buy Ticket option was selected. Exercise 4 could not be completed.

** Participant 2 and 3 proceeded as guests; monthly tickets were not available to unregistered users.

The research team also noted usability related problems encountered in the tests and categorized and scaled each problem, based on severity, as (1) Critical, (2) Major, and (3) Minor. The team also provided some potential suggestions. The reason for pointing out these problems and providing suggestions was to improve the usability of the app.

Critical

- During Exercise #4, participant 1 could not proceed to the Buy Ticket stage because the app gave a "No Server Communication" error.
    - *Suggestion*: This error used to appear in the earlier versions of the app. We suggest an investigation of the operational logs of Participant 1. Participant 1 participated in the re-tests on January 12, 2013 between 16:10 and 17:15.

Major

- Before the main screen appears, there is a time lag of about 15 seconds when a user clicks on the mobile ticketing app icon.
    - *Suggestion*: This could be due to the capability or memory of the participants' phones, but it would be prudent to look into it.
- The app does not keep the user logged in. Every time a purchase is made the user needs to enter their password again.
    - *Suggestion*: This is most likely a security issue; therefore, we will leave this issue's resolution to NJ TRANSIT.
- When proceeding as a Guest, there is an active Sign Out button.
    - *Suggestion*: The Sign Out button should be removed when the Proceed as Guest option is selected.
- When buying a ticket, any error in the credit card information (e.g. wrong zip code) appears many steps after the information is entered.
    - *Suggestion*: The validity of credit card information should be checked immediately after a user enters them.
- There is no information on how users can quickly fix the errors regarding credit card information.
    - *Suggestion*: The error message should navigate the user as to how to fix this problem (e.g. go to User Settings in the Home Menu and select Update Payment Profile).

Minor

- The Fare amount is dim, and it misleads the user to believe there is an error with the purchase.
    - *Suggestion*: The fare amount should be in bold fonts.
- When selecting the credit card expiration date, the month and year columns are in different places when proceeding as guest or a registered user.
    - *Suggestion*: For the sake of uniformity, the month should be on the left and the year should be on the right column.
- Users suggested that it takes a long time to enter the full e-mail address to log in.
    - *Suggestion*: The user name option should be allowed to log in.
- When credit card information is filled out and completed, there is no Done or Proceed button. Users need to tap outside the screen to move on.
    - *Suggestion*: Once all the credit card information is completed, there should be a Done button, which checks the validity of the entered information and prompts error or proceed messages.

The problems listed above were presented in a technical memorandum first and then discussed with NJ TRANSIT officials. ACS developers modified the app accordingly.

Alpha Test 3

The research team conducted another usability re-test on the iOS version of the NJ TRANSIT MyTix mobile ticketing app on February 8 and 9, 2013. The participants were selected from graduate students and staff at Rutgers University. Based on the re-tests that were conducted for the Android version of the app, it was observed that the time on task values are much shorter for the iOS version. The times per exercise are shown in Table 8. In the re-test of the Android version, the average time on task for exercises 1, 2 and 3 were 2:39, 4:12, and 1:30, respectively. These results show that users completed exercises 1 and 2 much faster than users of the Android version, whereas the time on task for Exercise 3 does not vary significantly.

Table 8. Time on task for iOS Version

Participant	Exercise 1	Exercise 2	Exercise 3	Exercise 4
1	1:01	2:18	1:28	2:15
2	0:56	2:15	1:23	0:56
3	1:29	3:05	2:01	n/a*
4	1:19	2:27	1:16	1:14
5	1:58	3:14	1:33	1:07
6	2:09	3:50	1:44	0:59
Average	*1:17*	*2:52*	*1:34*	*1:18*

* After Participant 3 selected the monthly ticket and tapped the Next button, the screen froze. Therefore, exercise 4 could not be completed.

An average SUS score of 83.3 was measured based on the answers given by the six participants. The individual scores were 85, 85, 97.5, 82.5, 67.5 and 82.5 for participants 1 through 6, respectively. The average SUS score was reported to be 68 in the literature [34]. The results suggest that the iOS version of the MyTix mobile ticketing app performed well above the accepted usability scale.

As in the re-tests of the Android version, the research team noted usability related problems encountered in the tests. These problems were categorized and scaled based on their severity as either (1) Critical, (2) Major, or (3) Minor. The research team provided suggestions to solving these issues. These suggestions were intended to improve the quality and usability of the MyTix mobile ticketing app.

Critical

- During Exercise #4, participant 3 selected the monthly ticket, tapped the Next button, and the screen froze. Therefore, exercise 4 could not be completed.

- *Suggestion*: This error appeared only once; however, the developer team should still explore this issue's potential cause.

Major

- When users register and enter credit card information the button that allows users to save the credit card information should be automatically active. Users did not tap this button in Exercise 2; in subsequent exercises they had to enter the credit card information every time they needed to purchase tickets, even if they were logged in.

  - *Suggestion*: The Save credit card information button should be active at all times.

Stage 2 – Beta Tests

Following the first alpha test conducted by NJ TRANSIT in September 2012, NJ TRANSIT worked with select customers who agreed to install and use the mobile ticketing application on the Pascack Valley Line. After a month of using the app, the participants were invited to express their opinions and evaluate the effectiveness and efficiency of the app. However, due to Superstorm Sandy and its devastating impact on NJ TRANSIT's operations, the commuter rail system was not at its full capacity. NJ TRANSIT therefore wanted to wait for the service to be restored before resuming testing.

The first focus group meeting was held on January 15 and 17, 2013. The research team attended these focus group meetings as observers. During the discussions, the participants were given the same, previously mentioned 10-item SUS questions that were given to the usability test participants. The average SUS score was calculated to be **75.4**. This overall score is higher than the average SUS score of 68 reported in the literature. Note, though, that the single ticket holders gave a higher SUS evaluation of 95.0, which was significantly higher than the SUS score of 63.1 given by the monthly ticket holders.

The second focus group meeting was held on March 7, 2013, with the purpose of evaluating the improved version of the MyTix mobile ticketing application. The improved version of the app included not only the MyTix application but also other functionalities present in the NJ TRANSIT mobile application. These features included a trip planner, the train schedules, departure vision, service nearby, alerts and advisories, and a system map. It should be noted that during Stage 1, the research team reviewed the overall NJ TRANSIT app that included MyTix feature and submitted their review to NJ TRANSIT in a technical memorandum on January 29, 2012 (included in Appendix A). Similar to the first focus group meeting, an SUS test was given to the participants. An average SUS score of **74.8** was achieved based on the answers given by the 14 participants. The result of this test was **75.4** in the January focus group. As previously mentioned, the average SUS score reported in the literature was **68**. This result shows that participants were pleased with the MyTix piece of the NJ TRANSIT app. In usability re-tests, the SUS score was **66.7** for the Android and **83.3** for the iOS version. It should be mentioned that some participants could have filled out the questionnaire to evaluate the full NJ TRANSIT app, thus not increasing the overall score. This conclusion aligns with the feedback from the focus group, which indicated that participants were not particularly pleased with the other features of the integrated app, but were pleased with the MyTix piece.

After receiving the feedback from the focus group participants, NJ TRANSIT decided to separate the MyTix app and the NJ TRANSIT app, and postpone the rollout until late April.

Stage 3 – Roll Out

As a pilot test, NJ TRANSIT's MyTix mobile ticketing application was made available to users on Pascack Valley Line on April 25, 2013. The objective of this pilot test was to observe and evaluate the effectiveness and efficiency of the MyTix app in actual field conditions.

The evaluation process included field tests conducted by the research team as well as analyses of the ticket transaction data to estimate the adoption rate and frequency of use of the MyTix application. The following sections describe in detail the evaluation process of Stage 3.

Pascack Valley Line (PVL)

This subsection presents the research team's preliminary evaluation of the MyTix's pilot tests on the Pascack Valley Line (PVL). The analyses were conducted using two datasets: (a) the Field test data collected in May 2013 and (b) the MyTix transaction data collected between April 25, 2013 and January 31, 2014.

The research team conducted field tests of the NJ TRANSIT mobile ticketing application "MyTix" on the Pascack Valley Line on May 20, May 23 and May 29, 2013. The test team consisted of 14 participants from Rutgers University and 2 participants from the New Jersey Institute of Technology.

Figure 22 shows the tested stations of the PVL. Table 9 shows an example of the field trip plan of the research team. The detailed results of the field tests are presented in Appendix B. Overall, the app performed very well in terms of purchasing and activating tickets on the PVL during the three-day field tests. Various problems were observed during the field tests. These included the following: (a) Issues scanning mobile tickets at the Secaucus fare gates because of the scanners' low sensitivity (28 out of 247 tests: 10.9 percent overall; 27.7 percent at fare gates); (b) a limited and time-consuming process during ticket activation (11 out of 247 tests: 4.4 percent); and (c) a weak phone service network at some spots within the New York Penn Station and the Secaucus Junction Station (8 out of 247 tests: 3.2 percent). In addition to these issues there were several issues that occurred during the purchase and use of tickets within the MyTix App. These issues are explained in Appendix B.

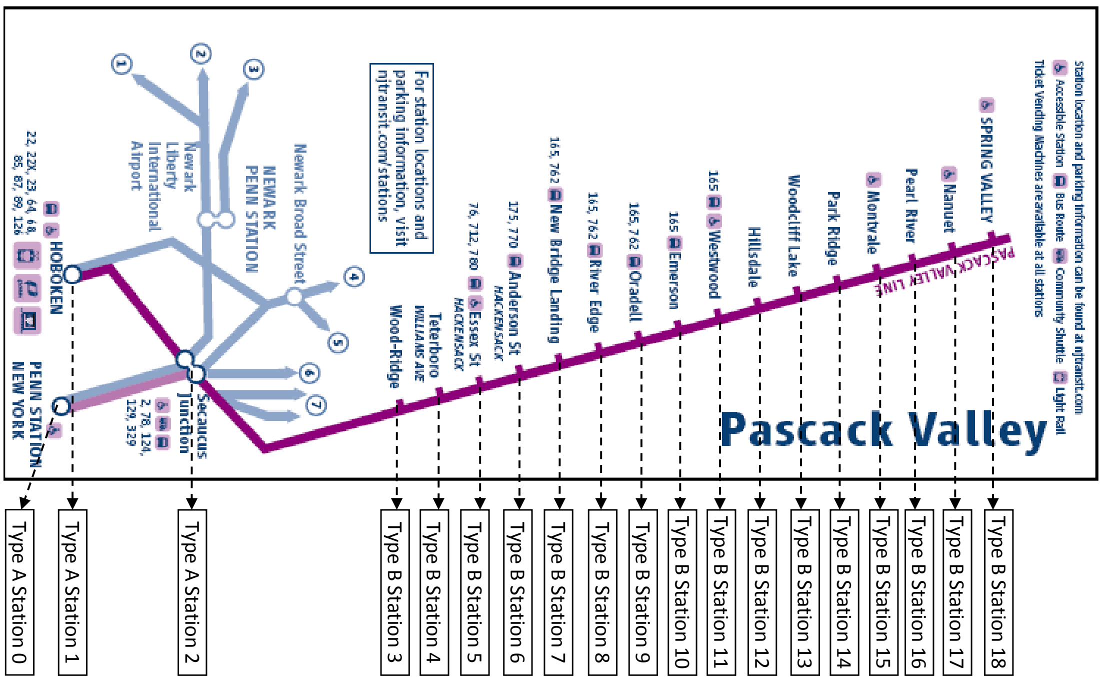


Figure 22. Tested stations of Pascack Valley Line [35]

Table 9. Sample trips for field tests on PVL

Test 1	Depart. Station	Depart. Time	Arrival Station	Arrival Time	Change Train?	Purchase Start Time	Purchase End Time	Performance of App (e.g., App crashed 1 time; Cannot access to network; Ticket checker cannot scan; Cannot finish purchase by App; Missed train due to buy ticket...)
Trip 1	18	6:50am	14	7:06am	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 2	14	7:28am	9	7:42am	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 3	9	7:54am	6	8:06am	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 4	6	8:19am	2	8:39am	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 5	2	9:05am	6	9:22am	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 6	6	10:20am	15	10:47am	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 7	15	11:02am	8	11:21am	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 8	8	12:48pm	1	1:30pm	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 9	1	1:50pm	17	2:57pm	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 10	17	3:51pm	1	5:02pm	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 11	1	5:35pm	2	5:45pm	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 12	2	6:05pm	10	6:40pm	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 13	10	7:00pm	13	7:10pm	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 14	13	7:36pm	16	7:45pm	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 15	16	8:00pm	18	8:12pm	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other
Trip 16	18	9:10pm	2	10:18pm	Y			☐App crash ☐Cannot access network ☐Miss train ☐Fail to buy ☐Cannot scan ☐Other

Main / Bergen Line (MBL)

A group of Rutgers University students (6 participants) tested the application for the Main/Bergen line on October 28, 2013 (Monday). A Total of 201 trips were completed between 25 Main/Bergen Line stations. Figure 23 shows the details for these stations. Table 10 shows an example of the field trip plan of surveyor. A field test could not be conducted at the Port Jervis Line Stations due to MTA maintenance.

Unlike the previous field test at the Pascack Valley Line, there were no scanning issues observed at the Secaucus Junction faregates. Before the latest field test, NJ TRANSIT officials had resolved the issue. All participants could pass through during the first trial of scanning at both the entry and exit faregates at Secaucus Junction. Based on the 201 trips among the MBL stations, the test team recorded 17 issues in terms of application performance. (The detailed results of the field tests are presented in Appendix B.)

Participants observed the following issues during the Main/Bergen field trip:

The most frequent issue was a network error. Besides 13 "*no network*" issues, there were 6 reports of a "*network is weak*" error. Of the 13 "*no network*" issues, one was recorded by a Sprint user; four by T-Mobile users; and one by an AT&T user. In terms of purchasing tickets, AT&T provided the best network performance among the three carriers used in this study.

Participants recorded signal power for each station. Based on the frequency and type of network issues, the Secaucus Junction lower level and Hoboken station were found to offer users the weakest network signal. Unlike previous field trips, during this trip each participant recorded the signal bar and Internet coverage for each station.

Another major issue observed by users was that the MyTix app was not responsive and/or users could not sign in to the app because it had crashed. It's possible that these issues were caused by weak or faulty network connections.

The participants also noted some minor issues. These included, a problem with the search function of app, transaction error, activation limit, purchase limit and mobile device based issues. All these issues are offered with snapshots and more detailed explanations in Appendix B.

In addition to these issues, one of the NJ TRANSIT conductors offered his/her ideas about the new application. His/her concerns about the new application were as follows:

- Cell phones run out of power or network connectivity (customers asking for additional time).
- Cell phones are not dependable.
- Easy to falsify (video recording of valid ticket).

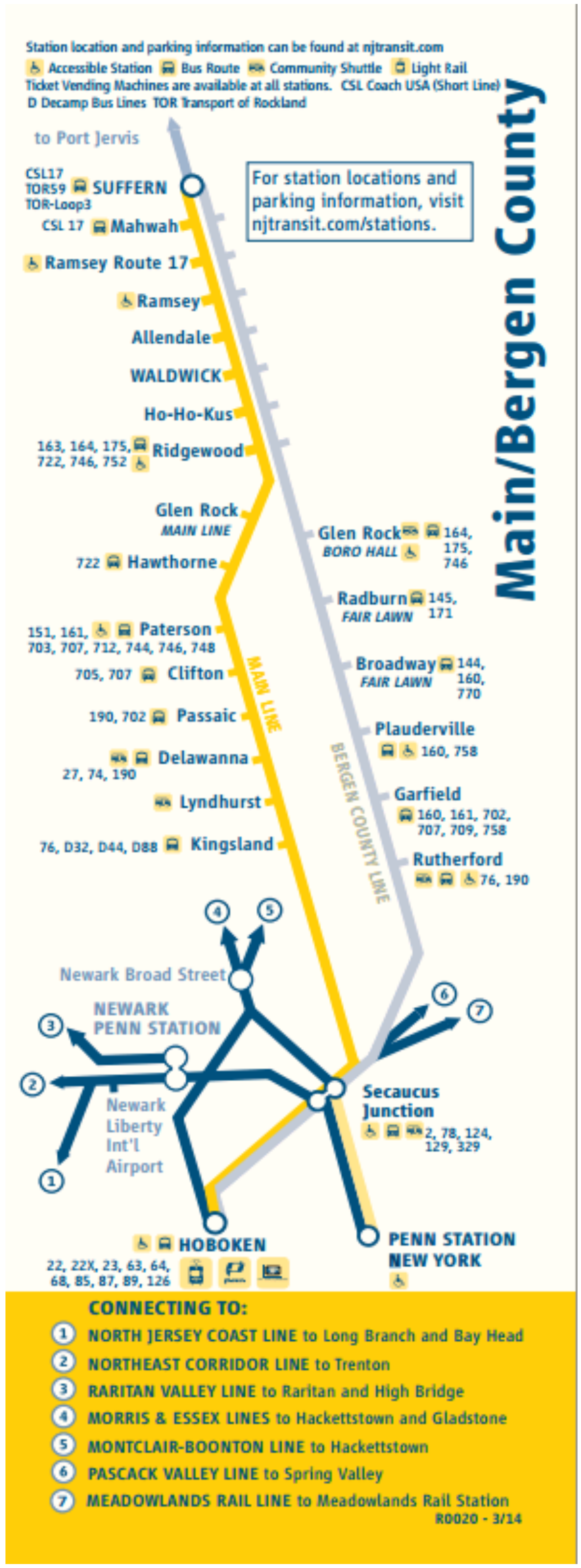


Figure 23. Tested stations of Main Bergen Line [36]

Table 10. Sample trips for field tests on MBL

Test 1	**Start**	**Trip1**	**Trip2**	**Trip3**	**Trip4**	**Trip5**	**Trip6**	**Trip7**	**Trip8**	**Trip9**	**Trip10**	**Trip11**	**Trip12**	**End**
Start St.	New Br.	Secaucus	New York	Secaucus	Suffern	Port Jervis/Main	Secaucus	New York	Secaucus	Hoboken	Secaucus	Ridgewood	Suffern	Secaucus
End St.	Secaucus	New york	Secaucus	Suffern	Port Jervis	Secaucus	New York	Secaucus	Hoboken	Secaucus	Ridgewood	Suffern	Secaucus	New Br.
Departure	6.32	7.26	7.53	8.09	9.06	11.31	14.09	16.16	16.49	17.13	17.37	18.19	19.00	20.17
Arrival	7.15	7.39	8.02	8.59	10.39	13.50	14.24	16.28	17.02	17.23	18.11	18.45	19.56	21.07
Station1	New Br.	Secaucus	New York	Secaucus	Suffern	Port Jervis	Secaucus	New York	Secaucus	Hoboken	Secaucus	Ridgewood	Suffern	Secaucus
Station2	Secaucus	New york	Secaucus	Rutherford	Sloatsburg	Otisville	New York	Secaucus	Hoboken	Secaucus	Rutherford	Ho-Ho-Kus	Mahwah	New Br.
Station3				Garfield	Tuxedo	Middletown					Garfield	Waldwick	Ramsey RT17	
Station4				Plauderville	Harriman	Campbell Hall					Plauderville	Allendale	Ramsey	
Station5				Broadway	Salisbury Mills	Salisbury Mills					Broadway	Ramsey	Allendale	
Station6				Radburn	Campbell Hall	Harriman					Radburn	Ramsey RT17	Waldwick	
Station7				Glen Rock Boro	Middletown	Tuxedo					Glen Rock Boro	Mahwah	Ho-Ho-Kus	
Station8				Ridgewood	Otisville	Sloatsburg						Suffern	Ridgewood	
Station9				Ho-Ho-Kus	Port Jervis	Suffern							Glen Rock ML	
Station10				Waldwick		Mahwah							Hawthorne	
Station11				Allendale		Ramsey RT17							Paterson	
Station12				Ramsey		Ramsey							Clifton	
Station13				Ramsey RT17		Allendale							Passaic	
Station14				Mahwah		Waldwick							Delawanna	
Station15				Suffern		Ho-Ho-Kus							Lyndhurst	
Station16						Ridgewood							Kingsland	
Station17						Glen Rock ML							Secaucus	
Station18						Hawthorne								
Station19						Paterson								

Analysis of Transaction Data

Mobile Ticketing App Download and User Registration Statistics

Based on the download statistics provided by NJ TRANSIT, as of January 20, 2014, there were a total of 127,289 app downloads. 90,263 of the total downloads were on iOS devices (70.9%) and 37,026 were Android devices (29.1%). 87,709 of these were downloads from registered users (68.9%). Figure 24 and Figure 25 show the monthly statistics for the app downloads. Readers are advised to refer to timeline of evolution stages shown Figure 18 to pinpoint the reasons for the sudden changes in the app downloads.

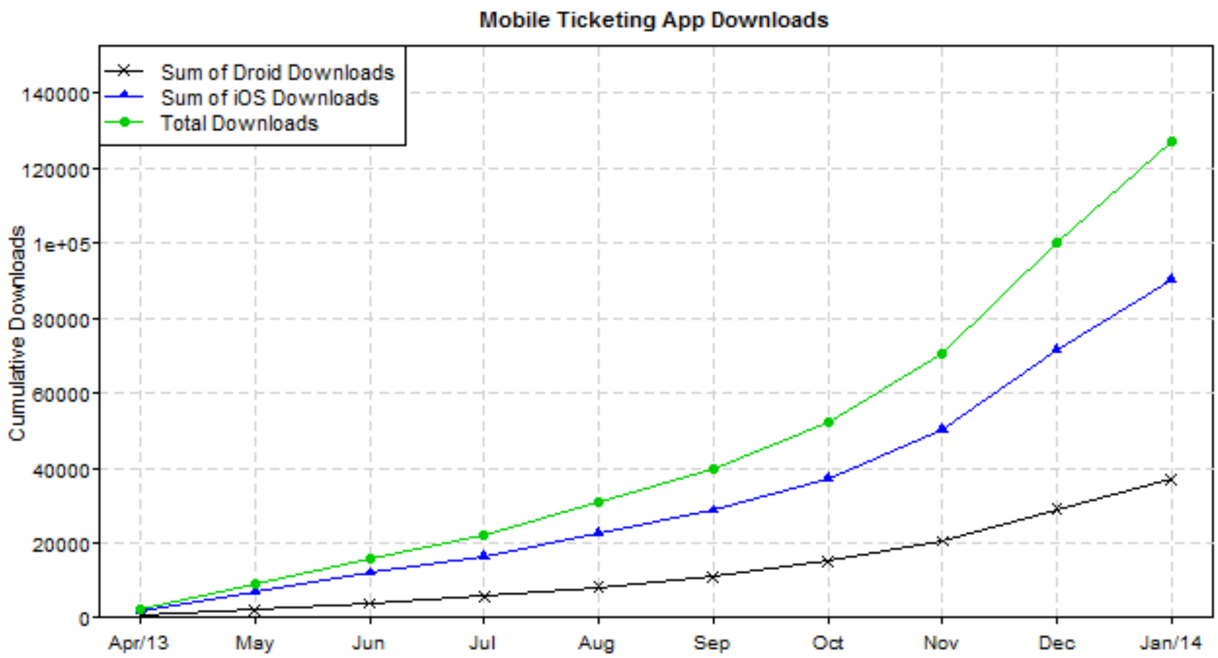


Figure 24. Monthly cumulative downloads

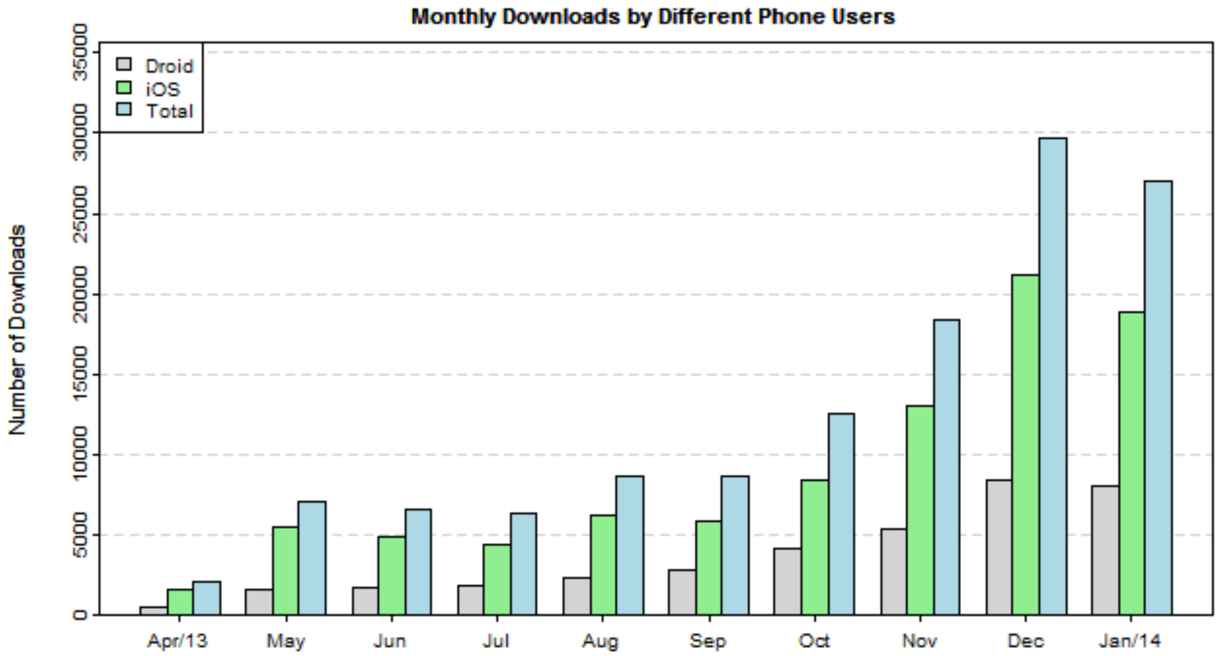


Figure 25. Monthly number of downloads

As seen in the figures, after September 2013 and November 2013 there were sharp increases in MyTix app downloads. This increase was caused by the availability of the MyTix app to additional commuter lines.

More than 68 percent of the MyTix app downloads resulted with a MyTix app registration. Figure 26 and Figure 27 show the cumulative and separate monthly changes in the number of MyTix app registered users, respectively. After September 2013 and November 2013, there was a significant increase caused by the app becoming available to additional commuter rail lines.

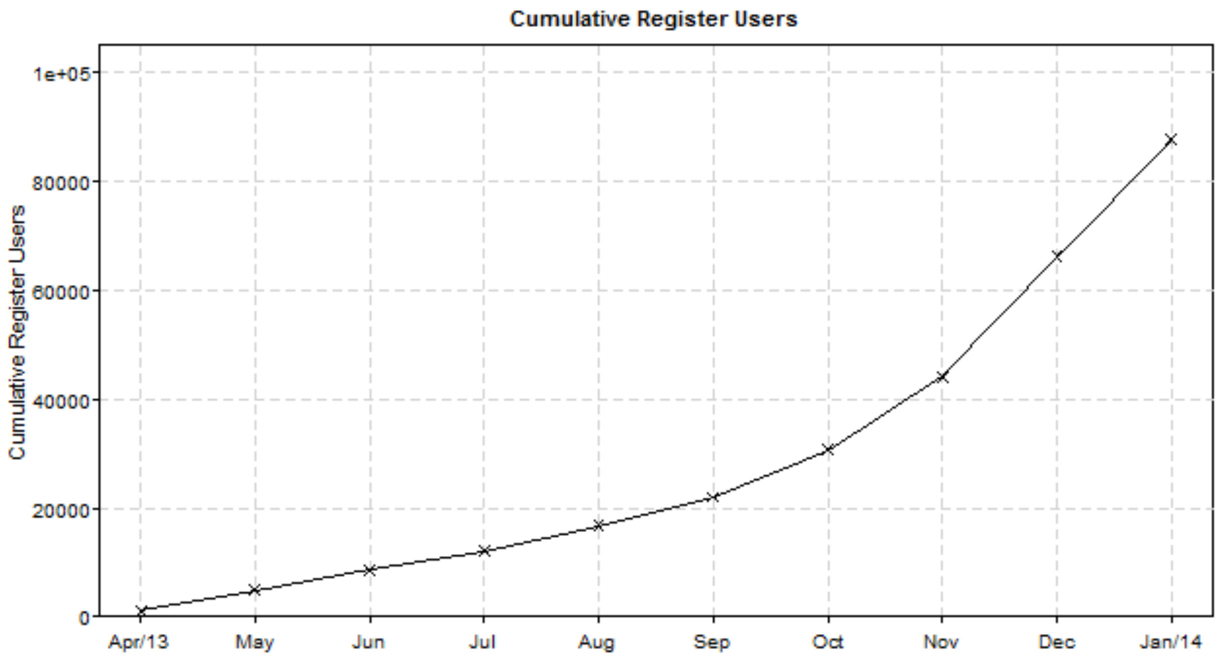


Figure 26. Cumulative registered users

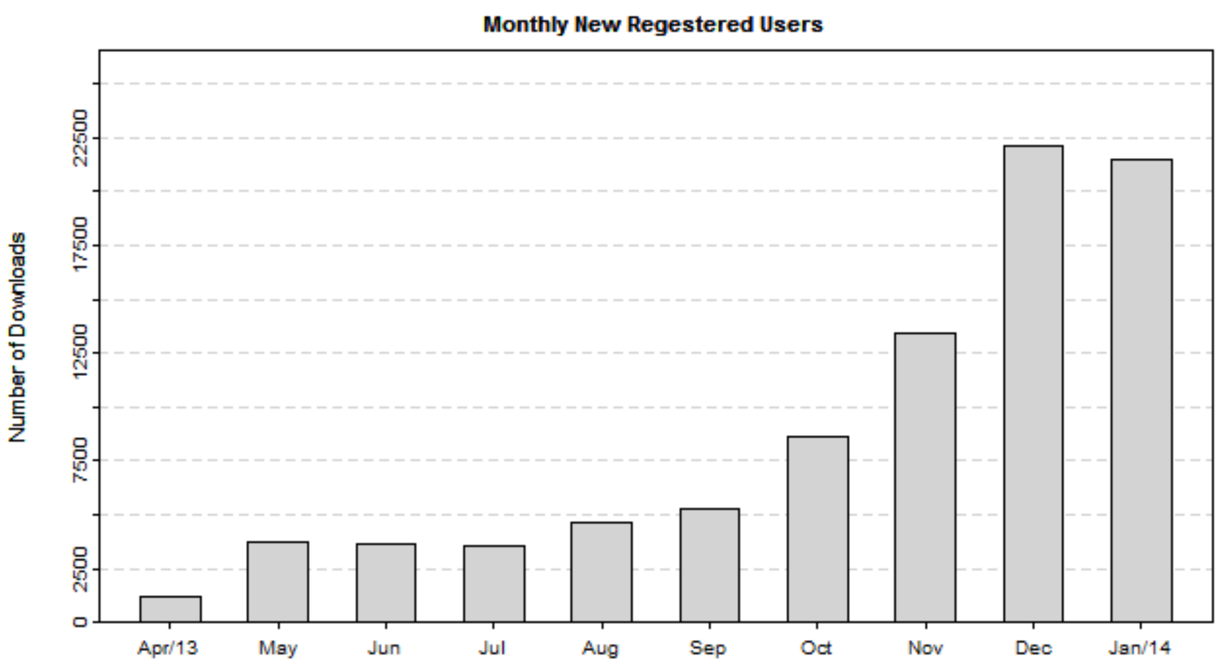


Figure 27. Monthly number of new registered users

Overall MyTix App Adoption Characteristics

“Adoption” in this research report is defined as a behavior wherein a passenger installs the MyTix app on his/her mobile phone and uses it at least once to purchase a mobile ticket or tickets. The status of “adopting” is not affected if the user does or does not activate the ticket. The only criteria for adoption is if the ticket has been purchased through the app. Based on detailed ticketing information, there were 31,174 adoptions from 04/25/13 00:00:00 to 01/20/13 23:59:59. Figure 28 shows MyTix app adoptions for each month (left plot) as well as the cumulative adoptions (right plot). The MyTix app was first released on April 25, 2013, for the Pascack Valley line, NYC Penn Station, and Meadowlands (Secaucus Junction). Therefore, the number for April in Figure 28 only represents the adoptions for the remaining days of April. Similarly, the number for adoptions in January 2014 only shows the adoptions of the first 20 days of that month. Generally speaking, the adoptions increased as the app became available for additional commuter rail lines.

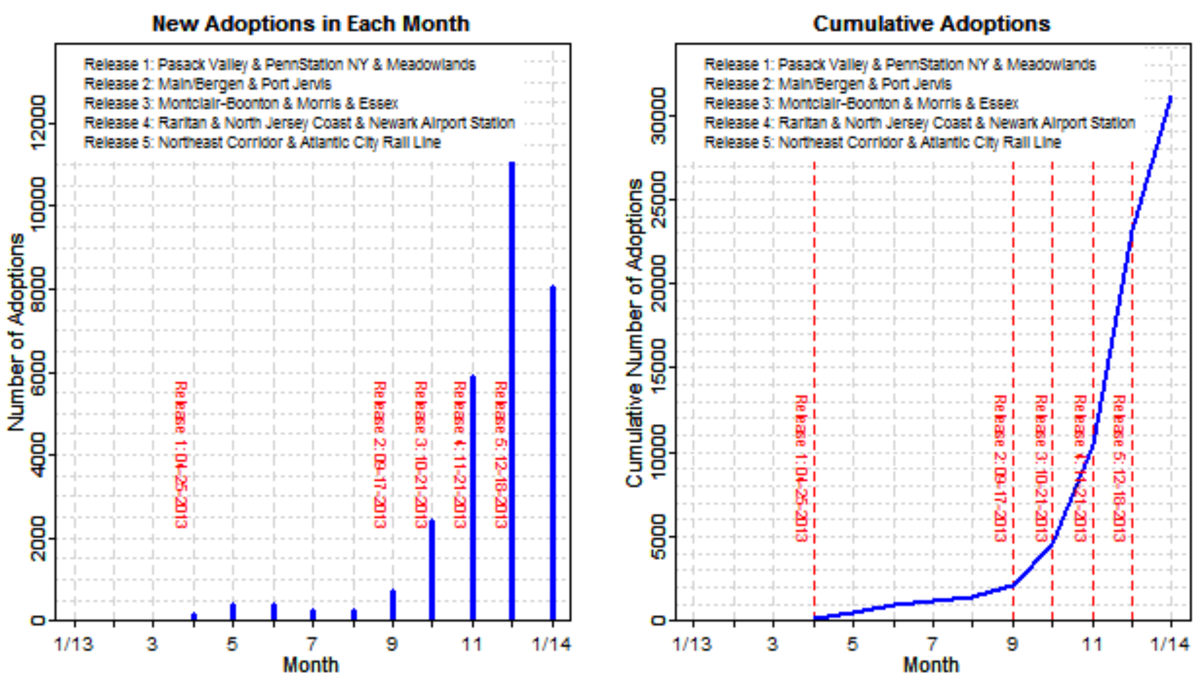
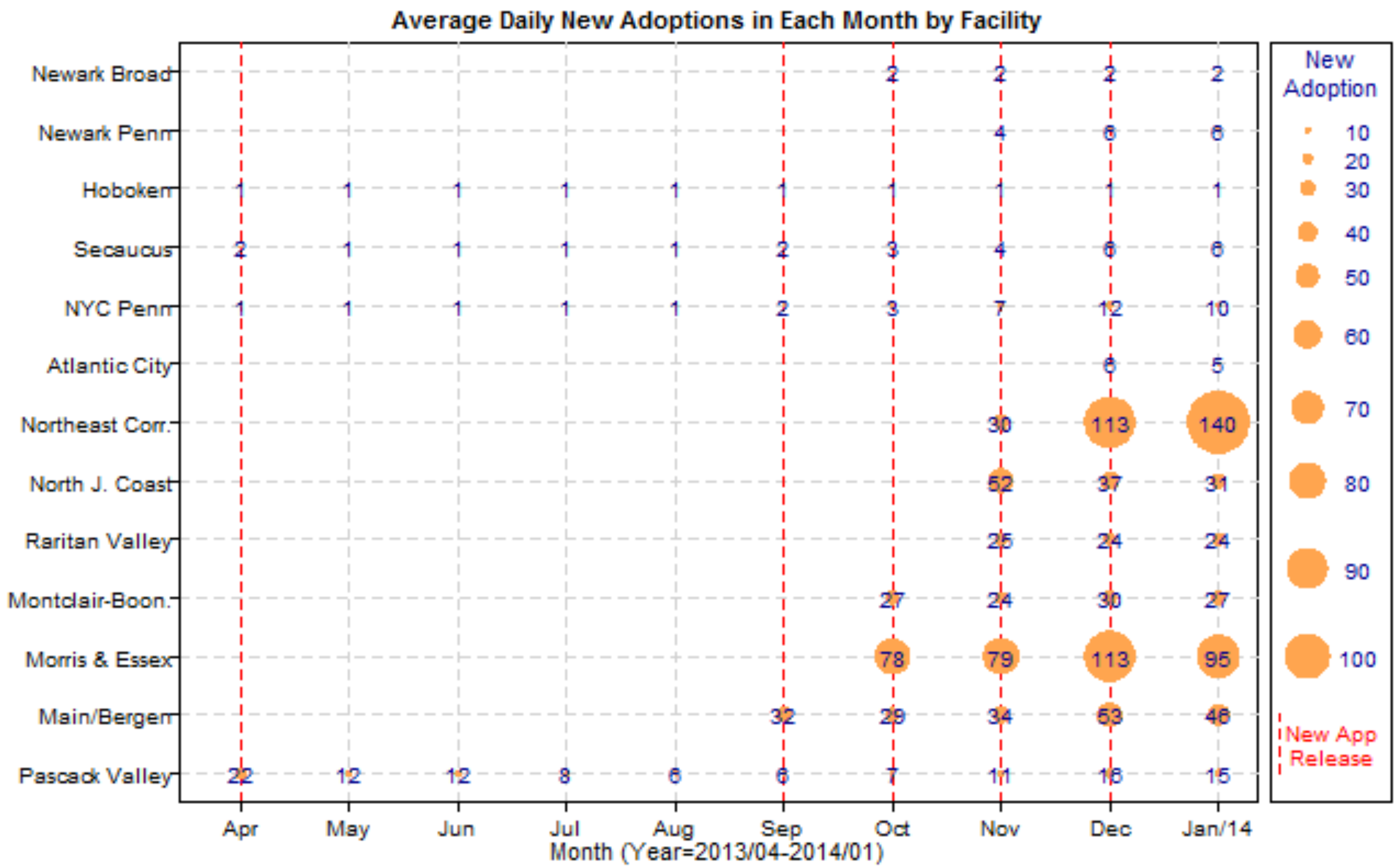


Figure 28. The adoptions of the MyTix App

Figure 29 shows the daily average adoptions for each month for each commuter rail line and major station. The MyTix app was made available to the Pascack Valley Line on April 25 2013. Between May and January 2014, the daily adoptions were less than 20. The MyTix mobile ticketing application was available at the Main/Bergen County on September 17 and its daily adoption was between 29 and 53 during the months thereafter. Despite the fact that the MyTix app was available at the same time, the Montclair-Boonton Line had lower adoption numbers than the Morris & Essex Line. The Raritan Valley Line had a similar trend following the release of the MyTix app on

November 21 as both the Montclair-Boonton Line and North Jersey Coast (NJC) Line. In the first 10 days, the North Jersey Coast Line attracted 52 new subscribers daily. It then maintained a level of about 30 monthly adoptions thereafter. Although the MyTix app was available to the Northeast Corridor (NEC) Line on December 18, passengers using the NEC were able to use the app on the NJC Line in November. This availability was the result of NEC and NJC sharing several stations, including Newark Liberty International Airport, North Elizabeth, Elizabeth, Linden, and Rahway. NJ TRANSIT classifies these stations as being a part of the NEC Line. Thus, the daily adoption of NEC Line in November 2013 represents those who registered as users on the NJC Line but in fact used the app for these dual-stations on the NEC Line.



Note: The numbers associated with each terminal only represent those who are from that terminal as the origin to another terminal as the destination.

Figure 29. Average daily adoptions in each month for each line & major terminals

Spatial Distribution of MyTix Activations

Figure 30 shows the spatial distributions of the activations associated with the users from each zone (zip code). Clearly, more users hailed from the zones in North Jersey and Central Jersey close to the NJ TRANSIT lines. Since South Jersey is hardly linked with the NJ TRANSIT commuter rail lines, there were few users from that region. Since the Port Jervis Line and the Spring Valley station are linked with New York State (NYS), many NYS travelers came from the zones close to the two lines. Other than the NJ and NY users, there were some users from other states though the percentage of these users was not significant.

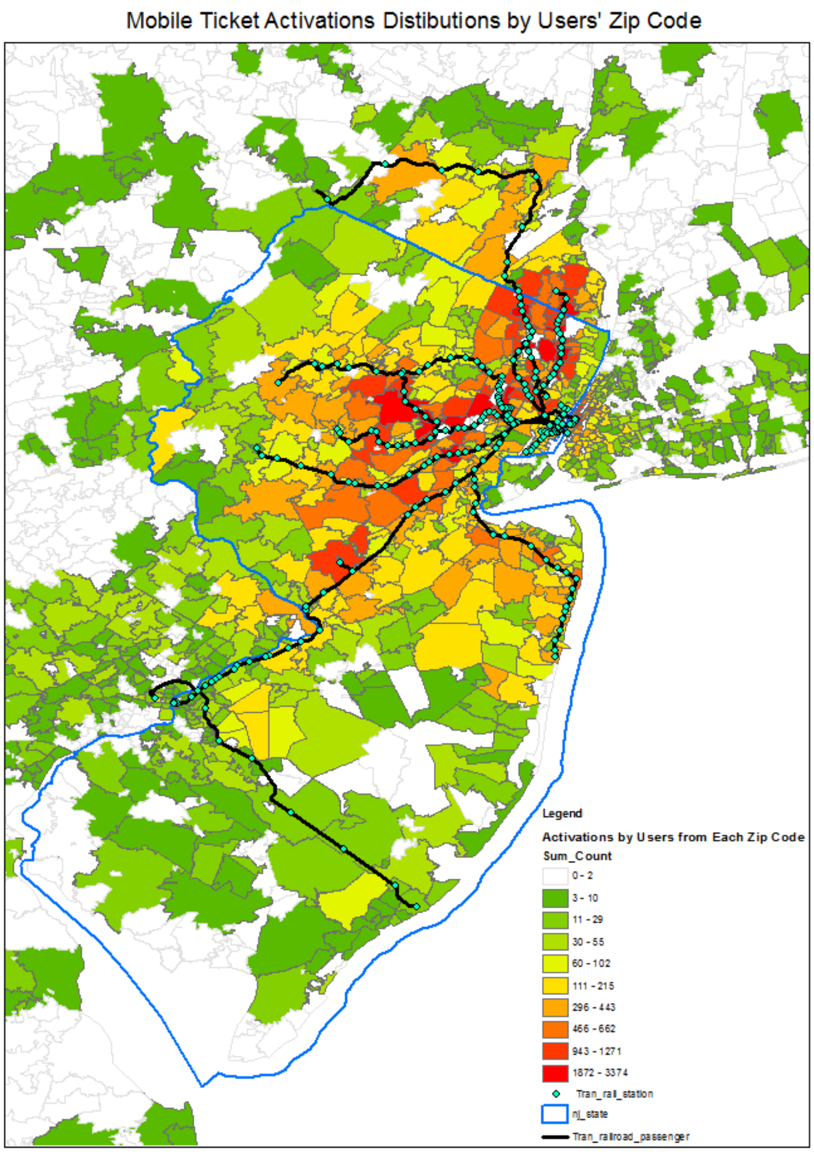


Figure 30. Activations distributions by users original zip code

MyTix Usage by Ridership

Since the ridership of each line is different, the MyTix usage numbers are not comparable across lines. To accommodate this line variability, the MyTix activations are normalized by the daily ridership of each line [35]. Since there is no clear way to track how many times the subscribers use their weekly tickets or monthly tickets, these subscribers are excluded from this analysis. Only the activations associated with one-way tickets are examined.

For all lines and terminals, there were 194,046 activations for one-way tickets. Since the ridership data for travel between the terminals are not available, one-way MyTix activations (16,641) associated with travel between the terminals are not examined. Thus the remaining 177,405 one-way activations associated with the eight NJ TRANSIT Lines are further analyzed.

The left diagram in Figure 31 shows the average daily activations of these one-way tickets for every 1000 boarding on each NJ TRANSIT Line. Note that the actual usage of the MyTix app on each line steadily grew after its initial release. For example, the Pascack Valley Line's average daily usage increased from 2.5 activations per one thousand riders in April to 28.6 activations /1K riders in January 2014. Similarly, the Main/Bergen County Line usage reached 17.2 activations /1K riders in about four months, which is more than eight times higher than the first month usage. In about three months, the Montclair-Boonton Line and the Morris & Essex Line usages increased from less than 5 activations /1K riders to 15.9 activations /1K riders and 19.1 activations /1K riders, respectively. For the remaining four lines (Raritan Valley, North Jersey Coast, NEC, and Atlantic City Line), increases were also observed. Since the MyTix app was released in either November or December on these lines, there are still very limited observations from which to draw conclusions.

The diagram to the right in Figure 31 shows the monthly increase rates of the MyTix usage compared to the previous month. It's interesting to note that, in the early months of use, the MyTix usage sharply increases for most lines. After two or three months, the rate of increase gradually slowed down. For the lines with longer observation periods (i.e., the Pascack Valley line and the Main/Bergen Lines), the monthly increase rate is about 20 percent after several months since the app's release.

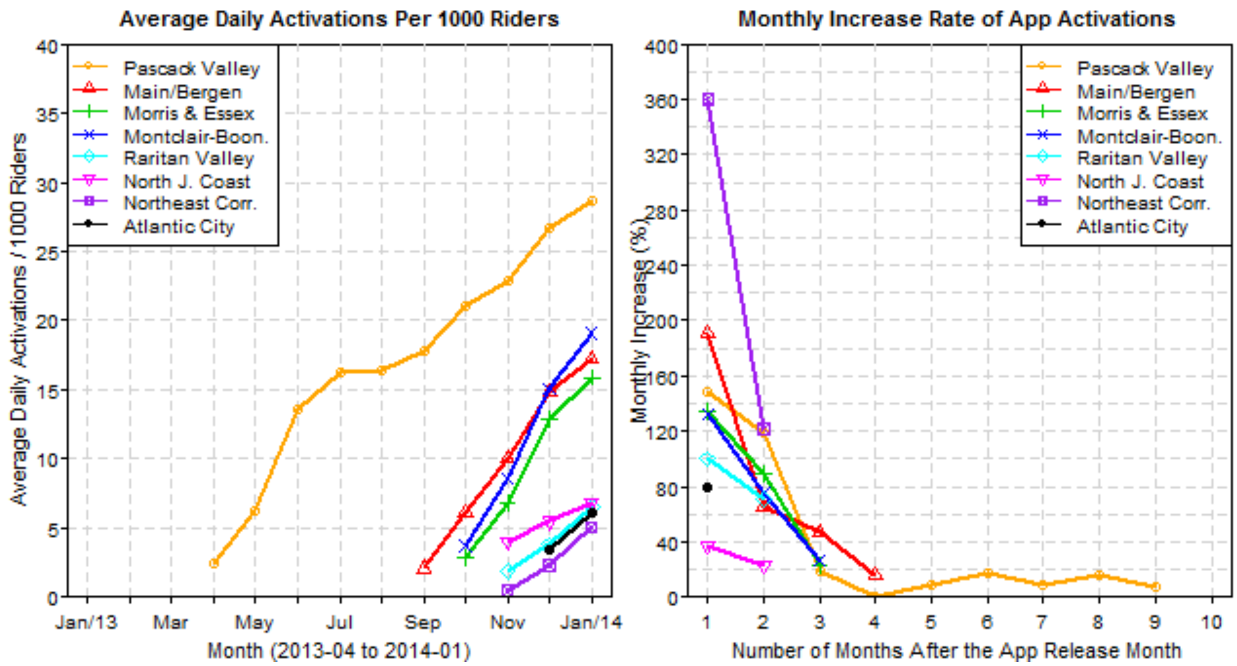


Figure 31. Average daily activations of one-way tickets per 1000 riders

Activations Frequency of Since Initial Use (One-way Ticket Users)

The historical activation records of each subscriber were examined to investigate how frequently each subscriber used the MyTix app. The observation period for each user is defined as the time period between the date of the initial activation of the purchased ticket and January 20, 2014. Figure 32 shows the characteristics of the individual subscribers' use of the MyTix app during the observation period. The left diagram shows each user's total number of activations during the observation period. Note that the majority of the users were observed when the MyTix app was available to most of the commuter rail lines. The right diagram shows the average daily activations by users. About 90 percent of subscribers used the MyTix app once every two or more days. The remaining 10 percent of users used the app with a higher frequency.

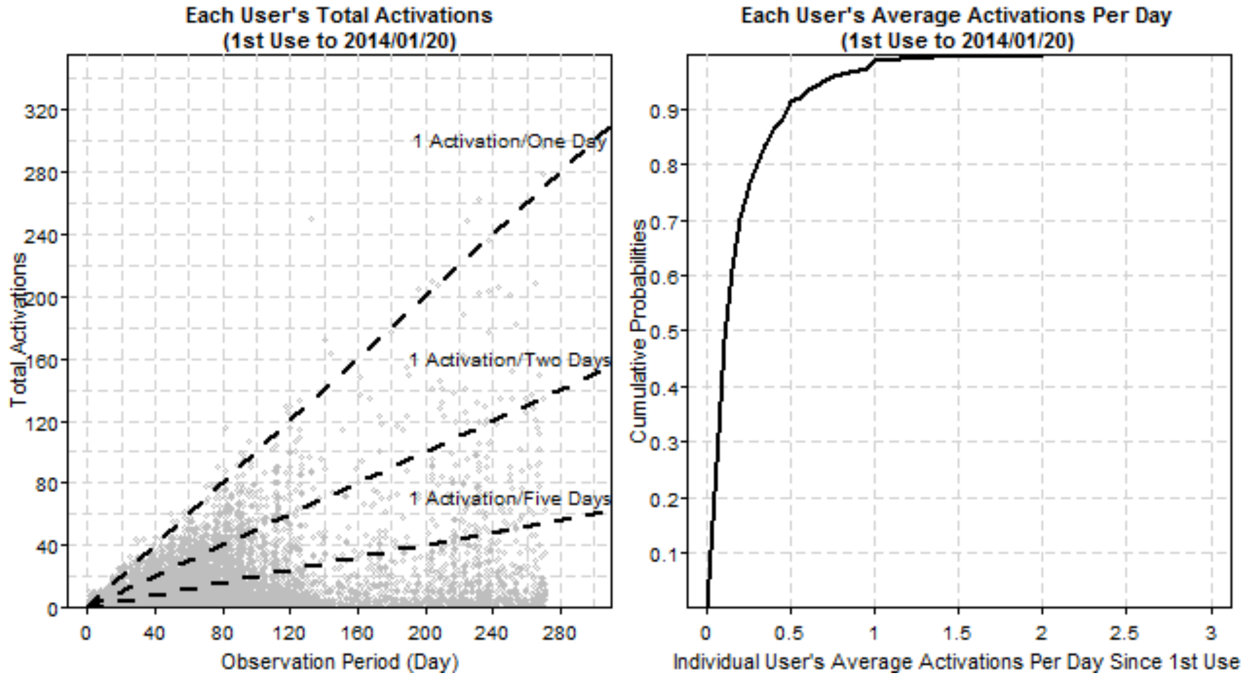


Figure 32. Characteristics of individual subscribers' use of the MyTix app during the observation periods

Monthly Ticket Users

There were 4,917 MyTix users that activated a monthly ticket at least once between May 2013 and January 2014. In all, they activated 9,632 monthly tickets. Figure 33 shows the reactivations of the monthly tickets following the initial subscription for a given month. For instance, in May 2013, there were 118 new MyTix monthly ticket users. In the second month, 71 percent of these users were still using the app to activate their monthly tickets. In the third month, 61 percent of users were using the app to activate their monthly tickets. After three months, about 50 percent of the new users were using the app for activating the monthly tickets each month.

Similar pattern was observed for the new users in June and July. For those who used the monthly tickets in August and September, less than 50 percent were still using the app for monthly ticket activations after three months.

Among the new MyTix monthly ticket users in October and November, around 70 to 80 percent still used the app thereafter. Among the new users in December, 80 percent used the app for the monthly ticket in the month thereafter.

Based on the records with longer observation periods, around 40 to 50 percent of the monthly ticket subscribers remain active after 4 months.

At the present it is not straightforward to pinpoint the exact reasons why only 40 to 50 percent of monthly users remain active. Further research is required to understand the underlying reasons and how NJ TRANSIT can retain these customers.

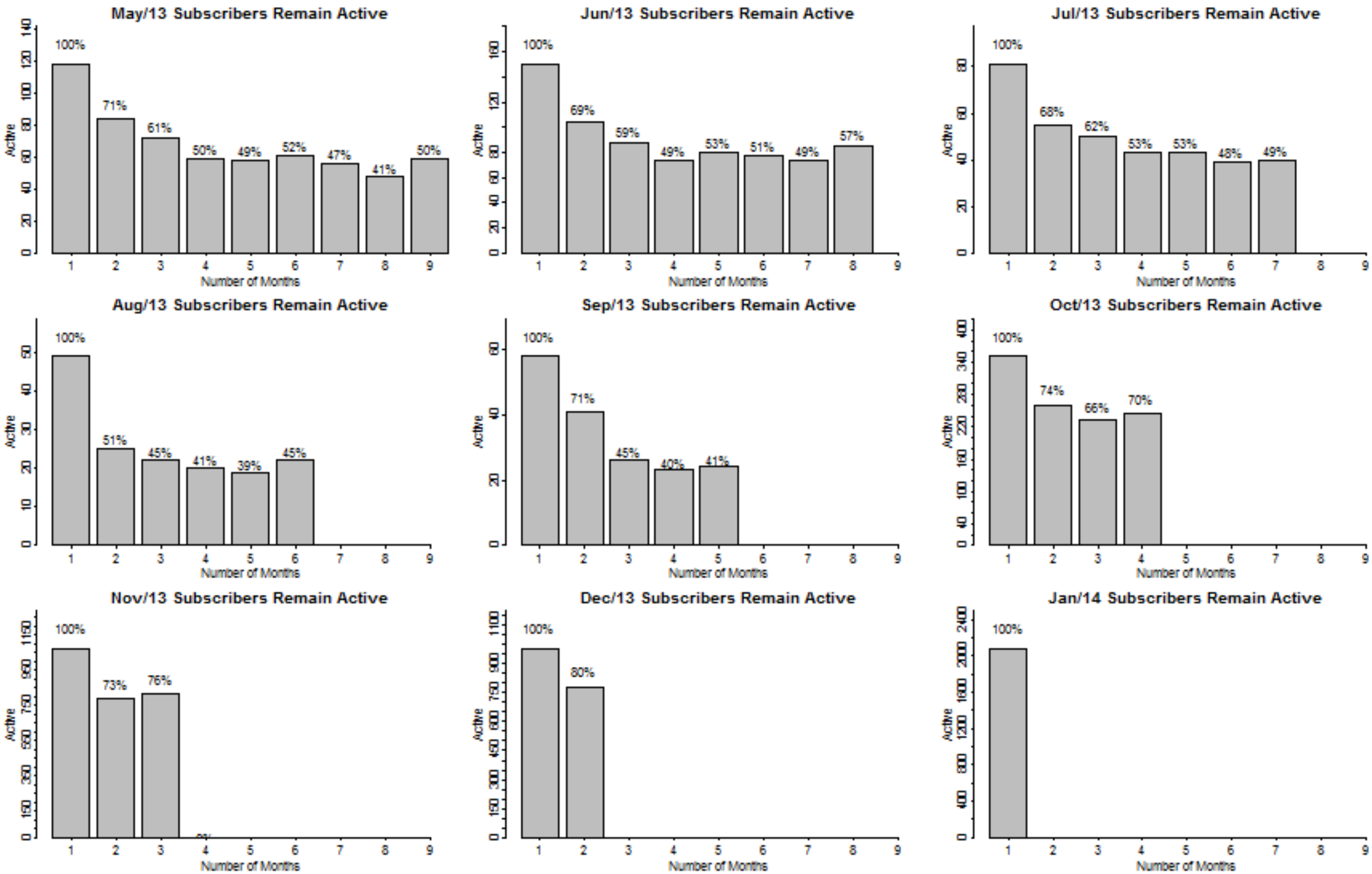


Figure 33. New monthly ticket subscribers - usage over time

CONCLUSIONS

With the aim of improving the quality and efficiency of the NJ TRANSIT MyTix app, the research team investigated the app's usability. A comprehensive literature review was supplemented by interviews with various transit agencies to achieve a thorough understanding of electronic ticketing, with an emphasis on smart phone based mobile ticketing applications. To evaluate this new technology, the research team conducted laboratory usability tests and field tests. Usage data were also analyzed to better understand major and minor problems before proposing suggestions and reaching statistical conclusions.

Laboratory usability test participants were involved in four exercises using the Android and iOS versions of the MyTix app. The research team noted some critical, major and minor problems, observations, and offered suggestions based on the participants experience during the laboratory usability test. These issues included freezing screens or problems related to credit card information not registering properly. The NJ TRANSIT/ACS team fixed all these issue for future users. SUS scores were estimated for both versions of the app. The NJ TRANSIT's MyTix mobile ticketing app scored well above the literature's accepted usability scale of 68[(34)].

In May 2013, a month after the app was released, a field test was conducted on the Pascack Valley Line. Scanning problems at the fare gates were the biggest issue for the first field test. In addition, network signal issues caused some problems during the field trip ticket activation. After releasing the app to the Main/Bergen line, a second field trip was conducted in October 2013. The research team presented the scanning issue following the first field trip. NJ TRANSIT rapidly resolved this issue and no scanning issues were observed at the Secaucus Junction fare gates. The major issues observed during the second field trip related to weak cellular network signals, with users getting "no network" failures when they tried to determine their exact locations. To overcome this issue, NJ TRANSIT should work with cellular service providers to improve cell service at the stations affected. NJ TRANSIT is also working with Time Warner Cable to install WiFi at its Commuter Rail stations, which will enhance communications capabilities.

As of January 20, 2014, the MyTix app was downloaded more than 127 thousand times. Nearly 69 percent of these downloads resulted in registered users, 70.9 percent being iOS users and 29.1 percent being Android users. Based on the data analysis conducted with the available dataset, 31,174 new users were observed. The daily adoption rate was calculated as 12 per day in May 2013 when the app was available only for the Pascack Valley Line. The overall adoption rate rose to approximately 400 per day in January 2014, which was when the app became available for all commuter rail lines. The biggest daily adoption rate was observed on the Northeast Corridor Line, with 140 new users per day. As could be expected, the commuter rail lines with a higher number of riders had higher daily adoption rates. In the first several months following the release of the MyTix app, the app usage increased sharply for most commuter rail lines. Following the second and third month, the rates dropped to a lower, steadier level. Based on the transaction data obtained for the Pascack Valley Line, it is expected that the monthly rate of increase in MyTix activation will be about 20 percent for the other commuter rail lines. For one-way tickets, 90 percent of users activate their ticket every 2 or more days. The remaining 10 percent are high frequency users that activate tickets at least once a day. For monthly ticket users, it is expected that about 40 to 50 percent of the subscribers will remain active.

Overall, the project was a great success. NJ TRANSIT was able to quickly address deployment issues identified independent of and by the research team, and the MyTix app was gradually improved. This rapid response ensured commuters would adopt the app at a high rate. About 87K users registered in the first 9 months and 30K users started to purchase their tickets via the app. Based on the adoption data analyzed in the Evaluation Methods & Results section, the MyTix adoption rate will continue to increase. Moreover, given the nation-wide trend of increasing smartphone use, we anticipate MyTix will be adopted by an increasingly large number of users.

The MyTix app has several important advantages over traditional tickets. It saves commuters time during ticket purchase and allows commuters to avoid surcharges typically incurred when purchasing tickets on-board. For NJ TRANSIT, this app will reduce agency costs, give the agency a better understanding of commuter behavior, and allow the agency to make their services more efficient. Finally, for both commuters and NJ TRANSIT, the MyTix electronic ticketing application offers new opportunities for multi-modal ticket usage and very effective trip planning.

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APPENDIX A

January 29, 2013

Handheld Devices on Rail for Fare Collection and Communication

NJ TRANSIT Mobile Application – January 2013

This memo presents the Rutgers Team's observations, comments, and suggestions regarding the NJ TRANSIT Mobile Application. Three participants tested the NJ TRANSIT app using their personal Android phones. Their comments, opinions and suggestions are presented below.

PARTICIPANT 1

1) Trip Planner

- Easy/simple to understand and use.

- Price of trip shown in results.

- Results show step-by-step instructions to the destination including walking directions.

- Overall seems a bit slow especially when scrolling but address lookup is quick.

- Is it advised to turn on GPS when using 'my location' feature? Majority of the time I get a message that walking distance is too far (even when I set it to max). Personally I would not use this feature because I almost never get it to work and I know the location of the stops/ stations anyway.

- When looking at one of the possible trip choices (results), the words inside the rectangles such as "walk" and "bus" may be a bit hard to read by someone with bad vision.

- When looking at one of the possible trip choices (results), there should be the ability to view the walk segments on a map. There are a lot of people that are directionally challenged and especially if someone is in a new area saying "walk north to XYZ street" is pretty useless unless the person has a compass and/or a map with them. Even if they do have a smartphone it will be mildly annoying to retype stop/station names and street names into a map app.

- When looking at one of the possible trip choices (results), there are buses that need exact change. It says exact change but doesn't say how much it actually costs.

2) Train Schedules

- Overall seems a bit slow especially when scrolling.

- Why do train schedules get their own button? I usually take the bus to NYC and there is no button for bus schedules. Shouldn't there be a general 'schedule' button where you can access all schedules, whether it be a bus, train, or light rail.

3) Departure Vision

- Easy to read.

- All information is clearly shown (departure time, track, status, stop times, etc.).

- My favorite part of the app and the one I will use the most. I like having the ability to check how much time there is until the train arrives or whether I missed it. And the ability to check when the train is arriving at certain stations makes the trip go by faster knowing how much time is left and whether the train is on schedule.

- Is it really necessary to write 'station' after every name on the list?

- What is the difference between EWR Newark Airport Station and Newark Airport Rail Station?

4) Service Nearby

- I input a stop ID near my house and it brought up bus lines and the nearest arrival times. Why is only the next arrival time listed and not the next 5 or 10? How do I access the bus schedule for the whole day, like I can access the train schedule for the whole day? Why does it say exact fare but not say what the exact fare is? Why does it not show the price of the ticket?

- This feature also has information about the PATH and subways. None of this is apparent. It should be made available to the user.

5) Alerts and Advisories

- Numbers should be bigger, more easily visible. And the colored circles + numbers remind me of subway line markers. Are the colored circles really necessary?

6) System Map

- Blurry when zoomed in, doesn't get any better even after waiting 10~30 seconds.

7) About the app

- I like it.

OVERALL

- Alphabet scroll bar needs to be pressed on in exactly the right spot, which is very annoying because most of the time I end up pressing the station name underneath. The scroll bar is too narrow and should be wider.
- App crashed when I had a phone call while using it.

PARTICIPANT 2

-The launch screen should be the menu to choose what function you want instead of the schedules.

- Service nearby stop ID is the default, which doesn't make sense. Also nothing happens when you click around and there is nothing to enter. For stations, some bring up an error when you select them, and the ones that work in the list are not very intuitive or attractive.

- Lag is a big issue.

- Back and Menu buttons on the Android device are not integrated with the app.

- I like when apps give you an option to quit (typically on Android apps pressing back enough will bring up a “Are you sure you want to quit?” where you can select Yes) but this one has no back functionality.

- Way to look up fairs?

- Link to NJ TRANSIT website?

PARTICIPANT 3

1) Trip Planner

"Depart At" shows time like this "03:10:PM", is the second ":" a mistake?

2) Train Schedules

- The list of possible schedules was quite long, as I scrolled there was no indication of how far down the list I was (scrollbars are needed, or something similar).

- Tapping a schedule should produce some sort of feedback (like a button is depressed when tapped). This helps the user feel like the user is having an interaction with the application.

3) Departure Vision

- I like what this feature does, but the name could be changed. I thought I was going to see a webcam from the station I selected (because of the word "vision").

- Some of the colors are quite bright, may want to consider if they represent what they need to or just "dull" the brightness.

4) Service Nearby

- I entered a random number as a stop id, an error occurred saying please try again later or contact us (a link). I tapped contact us, the application failed and closed.

5) Alerts & Advisories

- Good feature, no complaints.

6) System Map

- Good feature, no complaints.

7) About the App

- Similar to comment in 2). When tapping the buttons the user does not get any "device feedback" indicating the tap had been registered. The white background of the button should perhaps be a different color, or appear depressed (like the back button does).

My biggest issue with the app is its poor responsiveness, and this is on a high-end device. For example, when using the date selection tool I regularly overshoot the option I'm looking for because of the lag.

APPENDIX B

Overview (Pascack Valley Line)

The research team conducted field tests of the NJ TRANSIT mobile ticketing application "MyTix" on Pascack Valley Line on three weekdays in May 2013 (Monday, May 20; Thursday, May 23; and Wednesday 29, 2013). The test team consisted of 14 participants from Rutgers University and 2 participants from the New Jersey Institute of Technology.

It should be noted that the following items are intended to improve the quality and usability of the NJ TRANSIT mobile ticketing app by raising only the problems / issues observed by the re-test participants.

Table 11 presents the summary of the tested stations and the number of tests conducted during the evaluation process.

Table 11. Field tests at each station

ID	Test Station	Number of Tests
1	Hoboken	12
2	Wood-Ridge	9
3	Teterboro	7
4	Essex Street	6
5	Anderson Street	15
6	New Bridge Landing	10
7	River Edge	5
8	Oradell	7
9	Emerson	8
10	Westwood	13
11	Hillsdale	8
12	Woodcliff Lake	2
13	Park Ridge	8
14	Montvale	11
15	Pearl River	8
16	Nanuet	2
17	Spring Valley	15
18	Secaucus Junction (Entry)	60
19	Secaucus Junction (Exit)	33
20	NYC Penn Station	8
Total	-----	*247*

Table 12 shows the model of phones and the corresponding network carriers tested in the field.

Table 12. Phones and carriers tested in field

ID	Phone Model	Carrier	Number of Tests
1	HTC EVO 4G	Sprint	35
2	iPhone 3GS	AT&T	57
3	iPhone 4	AT&T	46
4	iPhone 5	AT&T	66
5	iPhone 5	Verizon	19
6	Samsung Galaxy Exhibit 4G	T-Mobile	10
7	Sony TL30AT	AT&T	14

Performance of MyTix

At each trip, a mobile ticket was purchased at the originating train station. The issues that arose during the purchase and the use of the MyTix App were recorded. The results are summarized in Table 13. As noted in the table, 21.8 percent (56 out of 247) of the tests had various performance issues, described in more detail in the following sections. Notable issues related to scanning, activation, the cellular network and payment.

Table 13. Summary of performance when purchasing and using MyTix

ID	Performance	Frequency
1	Scanning	28
2	Ticket Activation	11
3	Phone Network	8
4	Register and Login	4
5	Other Issues	3
6	No Issues	193
Total Test	-----	247

<u>Issue 1 - Scanning</u>

The most notable issue was the scanning of the mobile tickets at the Secaucus Junction Station fare gates, where passengers of the Pascack Valley Line from/to New York City Penn Station need to scan the MyTix barcode to transfer between lines. In 28 of 247 tests (28 out of 101 at faregates), users could not successfully scan the barcode at their first attempt. After trying multiple times or changing scanners/gates, the barcodes were eventually recognized. As with any new technology, a user's learning curve will have a dramatic impact on the user's success in using the technology. Hopefully, as customers become more familiar with the technology, the customer will have more success.

Figure 34 shows a user scans a mobile ticket at the gate. When the scanner did not recognize the barcode, it showed the invalid ticket information on the screen of the gate. This might have been caused by the angle of the phone with respect to the reader. This will likely become less of an issue as users become more familiar with the app.

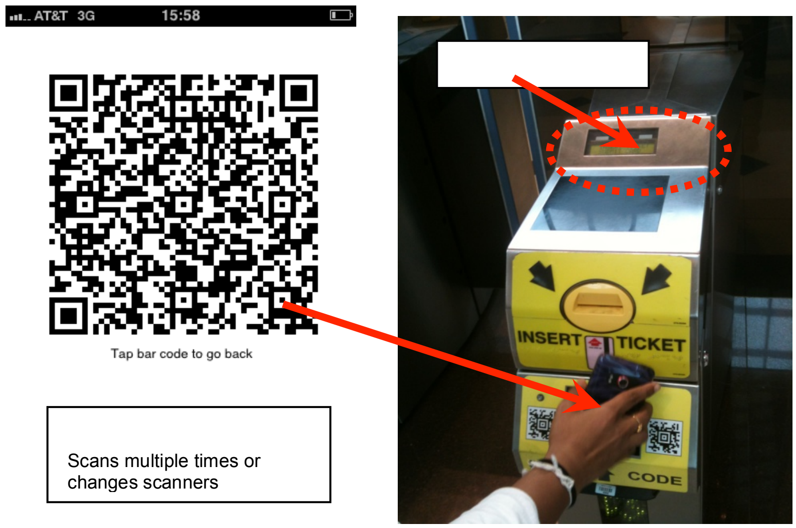


Figure 34. Scanning barcode at the gate

Table 14 shows the scanning issues by phone model and network provider. The user who used the HTC EVO 4G Sprint service experienced this issue 12 times. The same issue was experienced five times by the iPhone4 user. Note that these results should not be generalized since there is only one data point for each phone model in the field tests. To better examine the performance of different phones, more users from each group should be tested.

Table 14. Observed scanning issues by phone model and network provider

Phone Model	Carrier	Issues (Total Scans)
HTC EVO 4G	Sprint	12 (13)
iPhone 4	AT&T	5 (18)
iPhone 5	Verizon	4 (4)
iPhone 3GS	AT&T	2 (10)
iPhone 5	AT&T	2 (20)
Sony TL30AT	AT&T	2 (8)
Samsung Galaxy Exhibit 4G	T-Mobile	1 (4)

Issue 2 - Ticket Activation

The second issue arose when users attempted to activate their purchased tickets. Figure 35 shows the activation error on a phone screen. During multiple tests, this error occurred whenever the user attempted to activate a new ticket while there were still five active tickets. This might have been caused by a software system design that protects users from activating too many tickets by accident. However, in case a user plans to buy tickets for a group with more than 5 passengers, she/he can only activate five tickets within two hours. Therefore, the tickets for the remaining passengers cannot be displayed at that time.

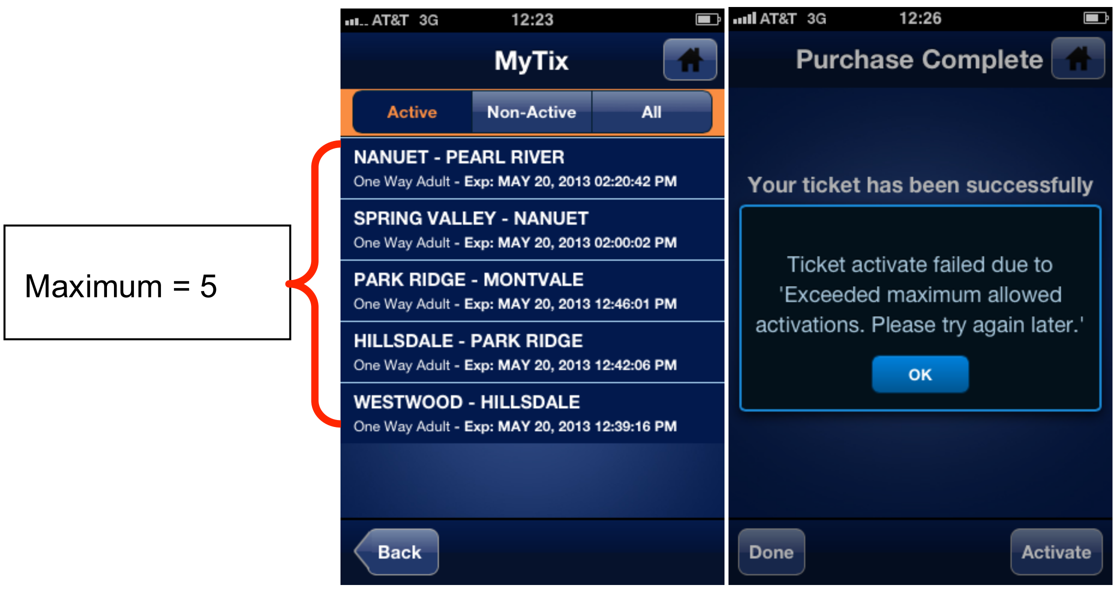


Figure 35. Problem with activating a purchased ticket

Issue 3 - Network Access

Test results show that in 8 of the 247 tests, users experienced problems with accessing their cellular network. This problem occurred most frequently at the Secaucus Junction Station (4 times) and the New York Penn Station (3 times). There was only one time this problem occurred at the Wood-Ridge station. Figure 36 shows the occurrences of this cellular network connection issue.

In regard to phone model and network provider, four of the network issues were reported by the users of HTC EVO 4G with Sprint service; two were from iPhone 3GS users with AT&T service. Users of the iPhone 5 with AT&T service and the Samsung Galaxy Exhibit 4G with T-Mobile service both experienced this network issue only once.

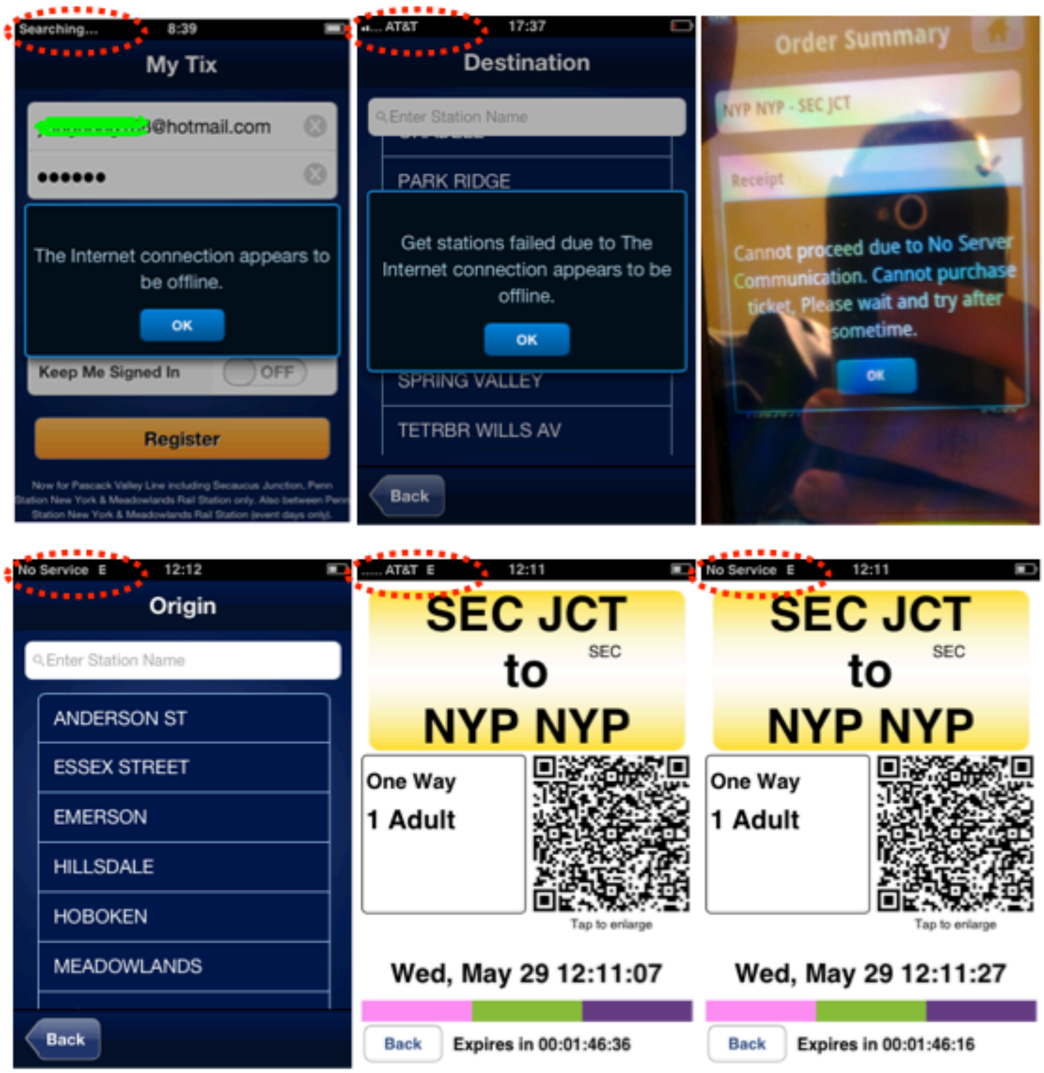


Figure 36. Examples of network access failure at different stages of purchasing ticket

<u>Issue 4 - MyTix Register and Login</u>

Sometimes test users felt it was difficult to quickly login to the MyTix app. As shown in Figure 37a and b, the requests to login to the App sometimes timed out. This may be related to the phone network and/or phone configuration. A more rigorous investigation should take place to determine the actual reasons for these errors.

As noted in Figure 37c, a phone could not be registered for other users once the phone was already registered to someone else.

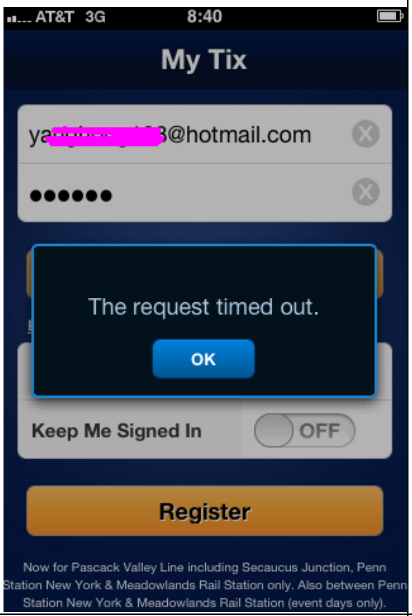
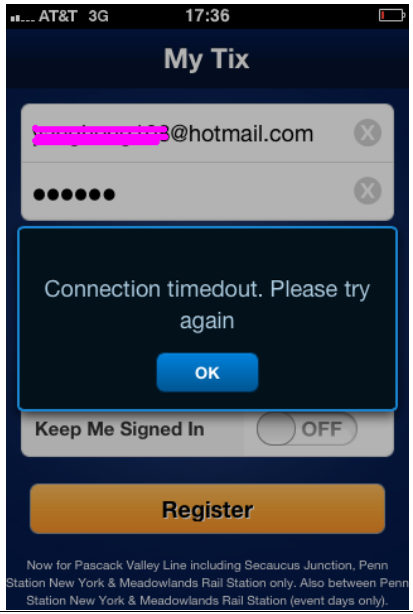
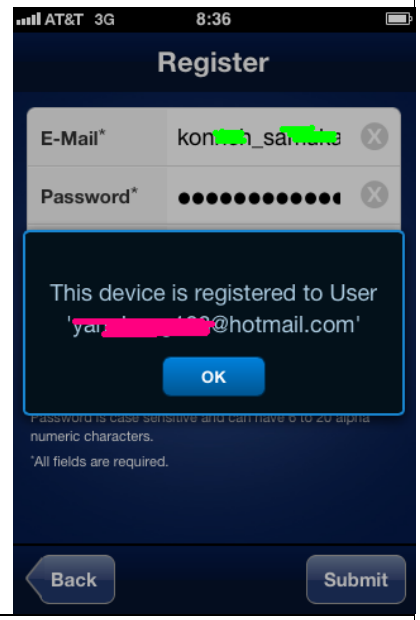
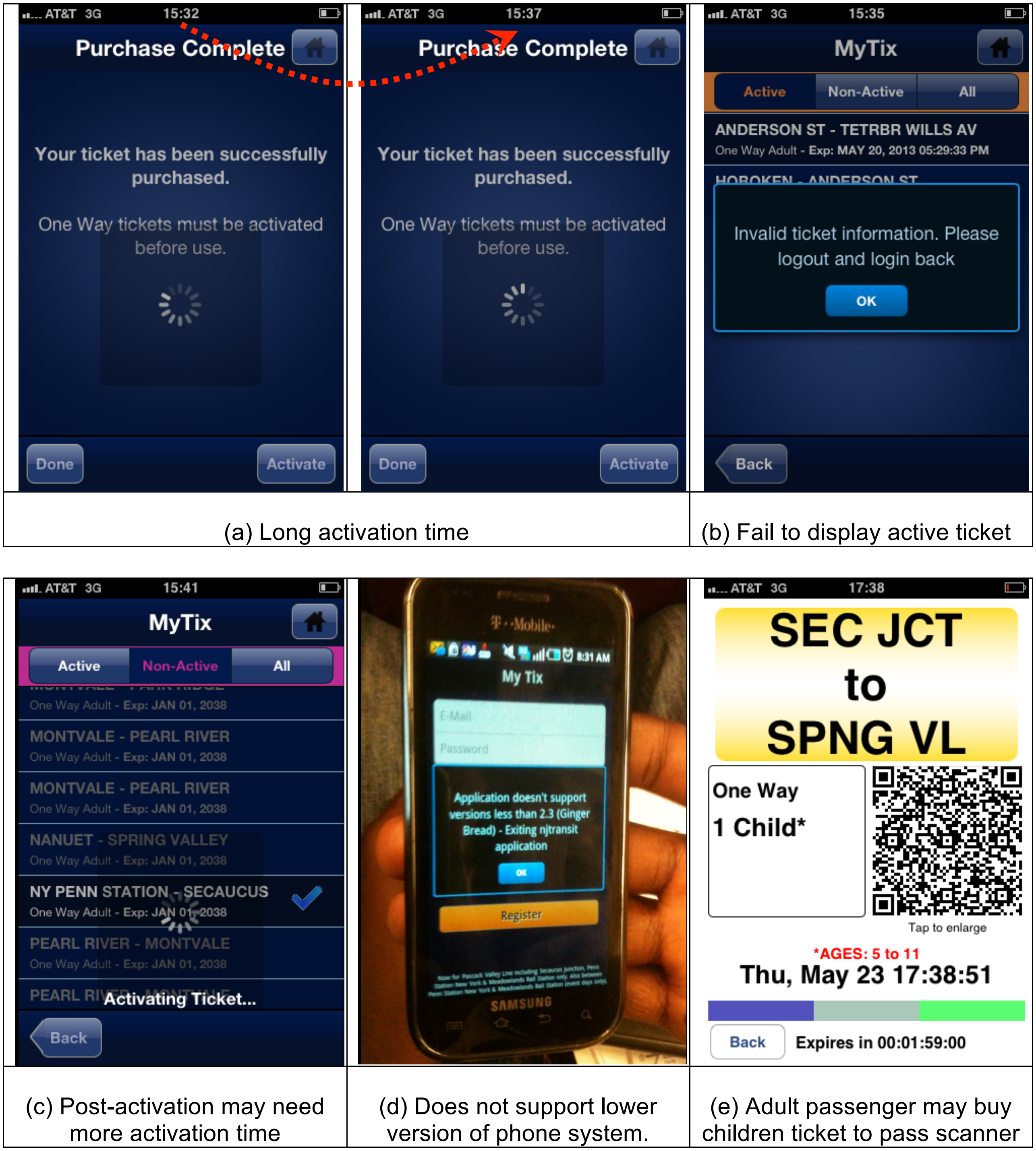
		
(a) Fail to login - type 1	(b) Fail to login - type 2	(c) The registered phone cannot register an account for other users.

Figure 37. Examples of register and login issues

Issue 5 - Other

Other than the aforementioned issues, a number of minor issues were observed when using the MyTix app. The first issue was the time-consuming process of activating the purchased tickets as shown in Figure 38 a and b. It may also occur during the post-activation of a non-active ticket, as shown in Figure 38c.

In addition, it was found that some smartphones could not run the App because of the earlier operating system versions (see Figure 38d).



(a) Long activation time

(b) Fail to display active ticket

(c) Post-activation may need more activation time

(d) Does not support lower version of phone system.

(e) Adult passenger may buy children ticket to pass scanner

Figure 38. Examples of other issues occurred when using the MyTix

Field Test of Main/Bergen Line for NJ TRANSIT MyTix App

Overview

A group of Rutgers University students (6 participants) tested the application for the Main/Bergen line on October 28, 2013 (Monday). Table 15 shows the stations and how many times each station was used by the test group for the Main/Bergen line. Field test couldn't be conducted at the Port Jervis Line Stations due to maintenance operations.

Table 15. Field trip summary for Main/Bergen Line Stations

ID	Line	Test Station	Number of Test
1		Hoboken	12
2		New York	16
3		Secaucus	39
4	Bergen	Rutherford	5
5	Bergen	Garfield	4
6	Bergen	Plauderville	5
7	Bergen	Broadway (Fairlawn)	5
8	Bergen	Radburn (Fairlawn)	5
9	Bergen	Glen Rock (Boro Hall)	4
10	Main	Kingsland	4
11	Main	Lyndhurst	11
12	Main	Delawanna	5
13	Main	Passaic	6
14	Main	Clifton	7
15	Main	Paterson	9
16	Main	Hawthorne	6
17	Main	Glenrock (Main Line)	9
18	Main/Bergen	Ridgewood	12
19	Main/Bergen	Ho-Ho-Kus	5
20	Main/Bergen	Waldwick	4
21	Main/Bergen	Allendale	5
22	Main/Bergen	Ramsey	6
23	Main/Bergen	Ramsey Route 17	4
24	Main/Bergen	Mahwah	3
25	Main/Bergen	Suffern	10
26	Port Jervis	Sloatsburg (NY)	*Maintenance*
27	Port Jervis	Tuxedo (NY)	*Maintenance*
28	Port Jervis	Harriman (NY)	*Maintenance*
29	Port Jervis	Salisbury Mills (NY)	*Maintenance*
30	Port Jervis	Campbell Hall (NY)	*Maintenance*
31	Port Jervis	Middletown (NY)	*Maintenance*
32	Port Jervis	Otisville (NY)	*Maintenance*
33	Port Jervis	Port Jervis (NY)	*Maintenance*
Total			201

Summary of the six participant's carrier and phone models are shown in Table 16. Different from previous field trips, each participant recorded signal bar and internet coverage for each station.

Table 16. Participants' devices and carriers

Participant ID	Phone	Carrier
1	Google Nexus 4	Family Mobile
2	HTC One	Sprint
3	Samsung Galaxy Exhibit	T-Mobile
4	Iphone 4S	T-Mobile
5	Iphone 5	AT&T
6	Samsung Galaxy S4	AT&T

App Performance

Trip tickets for 18 stations of the Main/Bergen line were purchased for each origin destination as planned by each participant. The average purchase time was approximately a minute for buying and activating tickets. Issues faced during the trips were recorded in a field trip form. These issues are summarized and shown in Table 17.

NJ TRANSIT increased the activation time from 2 hours to 2 hours and 45 minutes. This increase caused trouble for the test group since there is a limit of 5 activated tickets at the same time. To overcome this problem, each participant followed their plan to buy tickets without activation, to determine if the app could be used at the Main/Bergen line stations. Tickets were only activated for beginning and end stations and shown to the conductor for verification. This problem would not be an issue for normal commuters.

Unlike the previous field trip (PVL), no scanning issues were observed during scanning at the Secaucus Junction fare gates. This shows that NJ TRANSIT officials resolved the issue. All participants passed through the entry and exit fare gates at Secaucus Junction on their first try.

Based on the data recorded by the participants, 8.5 percent of the trips had performance issues. The participants observed the following issues during their Main/Bergen field trip.

Table 17. Summary of performance when purchasing and using MyTix

ID	Performance	Frequency
1	No network	13
2	App is nonresponsive or fail to sign in	3
3	Transaction error	1
4	Failed to purchase ticket due to purchase limit	*
5	Failed to activate the purchased ticket due to limit	*
6	Bug found for app (Search station by names)	*
7	App worked smoothly	184
Total Test	-----	201

**Note: Not an issue for normal commuters or does not have an effect on ticket purchases.*

Major Issues

The most frequent issue was a network error. Besides 13 “*no network*” issues, there were 6 reports of a “*network is weak*” error. Of the 13 “*no network*” issues, one was recorded by a Sprint user, four by T-Mobile users;\ and one by an AT&T user. In terms of purchasing tickets, AT&T provided the best network performance among all carriers used in this study. Table 18 shows the signal power recorded by each participant. Based on the network issues, the Secaucus Junction lower level and Hoboken station were found to be the weakest in terms of network signal strength.

Table 18. Network signal for Main/Bergen line stations

ID	Test Station	Network Signal			Network Performance		
		AT&T	T-Mobile	Sprint	AT&T	T-Mobile	Sprint
1	Hoboken	4 Bar,	2 Bar,	3 Bar	Good	1 Fail	1 Fail
2	New York	3 Bar,	3 Bar,	3 Bar	Good	Good	Good
3	Secaucus	3 Bar,	2 Bar,	4 Bar	Good	1 Fail	2 Fail
4	Rutherford	4 Bar, LTE	3 Bar, 4G	3 Bar	Good	1 Fail	Good
5	Garfield	4 Bar,			Good	Good	Good
6	Plauderville	3 Bar,	5 Bar,	4 Bar	Good	Good	Good
7	Broadway	2 Bar,		5 Bar	Good	Good	Good
8	Radburn	5 Bar,		3 Bar	Good	Good	Good
9	Glen Rock (Boro	4 Bar,			Good	Good	Good
10	Kingsland	3 Bar,	3 Bar,		Good	Good	Good
11	Lyndhurst	4 Bar,	4Bar, 4G	3 Bar	Good	Good	Good
12	Delawanna	4 Bar,	4Bar, 4G		Good	Good	Good
13	Passaic	3 Bar,	5Bar, 4G	5 Bar	Good	Good	Good
14	Clifton	5 Bar,	3Bar, 4G		Good	Good	Good
15	Paterson	5 Bar,	3Bar, 4G	5 Bar	Good	Good	Good
16	Hawthorne	4 Bar,	3Bar, 4G		Good	Good	Good
17	Glenrock (Main	3 Bar,	4Bar, 4G	2 Bar	Good	Good	Good
18	Ridgewood	5 Bar,	3 Bar,	3 Bar	Good	Good	1 Fail
19	Ho-Ho-Kus	4 Bar,	3 Bar,	3 Bar	Good	Good	Good
20	Waldwick	4 Bar,	3Bar, 4G		Good	Good	Good
21	Allendale	5 Bar,	1Bar, 4G		Good	Good	Good
22	Ramsey	4 Bar,	4 Bar,	No	Good	Good	1 Fail
23	Ramsey Route	4 Bar,	5 Bar,		Good	Good	Good
24	Mahwah	3 Bar,	1 Bar,		1 Fail	Good	Good
25	Suffern	4 Bar,	3Bar, 4G	5 Bar	Good	Good	Good

App was not responsive or participants could not sign in due to app crash. Figure 39 shows some snapshots of the authentication problems during signing in. These problems were possibly caused by poor network service.

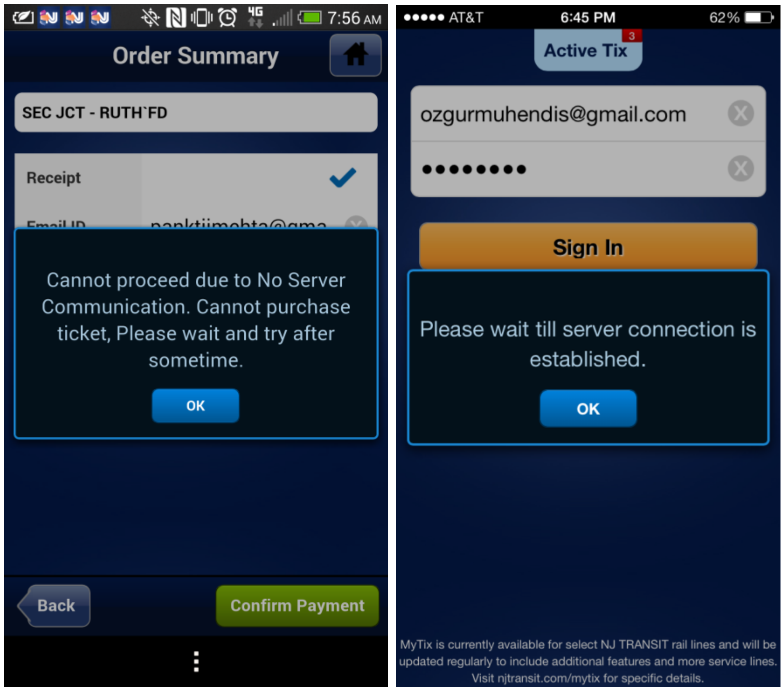
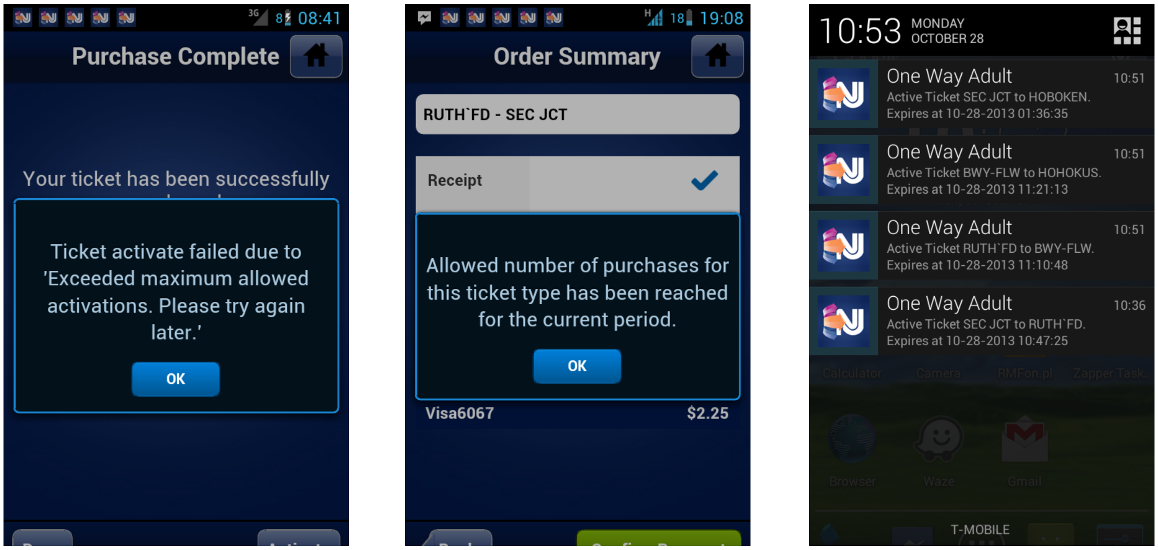


Figure 39. Network issue snapshots

<u>Minor Issues</u>

- One of the participants had a problem during the ticket purchase because of a transaction issue. The screen presented an alert of “transaction error”. After three such errors, the user was able to buy a ticket.
- The “Search stations” function did not work properly. An application bug was found for both iOS and Android versions. When searching a station by entering a name on the search prompt, participants couldn’t select the station. Participants could select the station by using the scroll function.
- The Activation limit was reached during the trip. App allows 5 active tickets at the same time, and activation duration is increased to 2 hour 45 minutes. Figure 40 (a) shows this issue as a snapshot.
- Purchase limit was reached during the trip. There is a limit to the number of purchased tickets. However, just one participant encountered this issue. Figure 40 (b) shows a snapshot of this issue.
- (Android Version) When tickets expire, they disappear from the “active tickets” in the app, but not from the cell phone’s notification bar. In order to remove these tickets, the app needs to be restarted.
- (Android Version) Once a ticket expired, it should be removed from the active tickets lists. Figure 40 (c) shows that the last ticket was expired but still showing in the list of active tickets.



(a) (b) (c)

Figure 40. Snapshots for other issues

In addition to these issues, one of the NJ TRANSIT conductors stated his/her ideas about the new application;

- Cell phones run out of power or network.
- Cell phones are not dependable.
- Easy to falsify (video recording of valid ticket).