Assessing the Effectiveness of Recently Implemented Technologies within the Worcester Regional Transit Authority (WRTA)

An Interactive Qualifying Project submitted to

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Abstract

In 2009, The Worcester Regional Transit Authority (WRTA) purchased a suite of Intelligent Transportation Systems to improve fixed-route bus service. This project quantitatively and qualitatively analyzed the impacts of these technologies and established benchmarks that the WRTA could use to perform future evaluations. Based on this analysis, we drew preliminary conclusions and made recommendations to the WRTA to more effectively use and evaluate these technologies.

Executive Summary

Overview

This report provides an evaluation and benchmarking of the performance of the new technologies installed by the WRTA, specifically; Automatic Vehicle Monitoring (AVM), Automatic Vehicle Location (AVL), Automatic Passenger Counter (APC), as well as their combined effectiveness in providing information to Real Time Information Systems (RTIS). Methods of analysis vary between qualitative and quantitative including statistical analysis of systems and use of proprietary analysis software to name a few. All of the calculations used or proposed can be found in the appendices. Results of this report are largely inconclusive. As noted, the WRTA recently implemented these technologies and, as such, have had little time to develop and utilize these technologies at their optimal productivity level. Due to this, the findings of this report lay out benchmarks for future analyses and pilot tests of the system for measuring the returns rather than a determination of the returns.

Benefits of ITS

Intelligent Transportation Systems (ITS) can provide access to information on ridership and system performance that is far more detailed than data previously available, all at a lower annual cost. The data gathered from these systems can be used to monitor multiple aspects of a transit system's services including the number of riders that board vehicles at a given stop, the location of each vehicle in real time, and the number of riders that use electronic information sources to access transit information. Data from ITS can be used to evaluate the performance of individual route segments, particular service offerings, or the system as a whole. This allows transit providers to make more informed decisions regarding service changes, allocating resources, or creating new routes (M. Blunt, J. Church, Y. Graxirena, Personal Communication, 2012).

Objectives

Because the WRTA chose to employ multiple technologies simultaneously, there were unique challenges to quantitatively analyze individual components due to potential overlap. Rather than focusing on individual components and their relative impacts, we chose instead to investigate comprehensive, aggregate impacts on the system as a whole.

The objectives of this project are laid out below.

- Determine and evaluate how the long term and short term goals of the WRTA align with the capabilities of each of the implemented technologies.

- Identify metrics to measure effectiveness of public transit systems and use these metrics to analyze the WRTA bus system prior to the arrival of the new technologies. This analysis will set a baseline for later comparison.
- Perform a study on initial impact of the new technologies on the WRTA bus system by comparing data gathered after their implementation to the baseline established from data prior to the integration of ITS technology.
- Develop suggestions for the WRTA as to methods of evaluating the cost benefits of their newly implemented technologies over time. These suggestions will allow the agency to monitor and analyze the data that these technologies collect and, as a result, have the ability to make effective business decisions.

Identifying Metrics

Per the request of the WRTA we focused on APC, AVL, AVM, and RTIS. Each of these four systems affected multiple aspects of the WRTA. The areas we determined could show significant change due to ITS are: ridership, technology adoption, customer satisfaction, ease of use for riders, performance of proactive maintenance, inventory and fuel savings, and overall safety. We then developed a specific list of metrics that mapped to the objectives of the WRTA. The figure below lists the 7 objectives of the WRTA and their corresponding metrics.

Ease of Customer Use
- Ridership by Stop
- Technology Adoption
- Annual Breakdowns

Customer Satisfaction
- Ridership by Route
- On-time Performance
- Mean Distance Between Accidents

System Efficiency and Route Optimization
- Ridership by Stop
- On Time Performance
- Preventative Maintenance

Proactive Maintenance
- Work Orders
- Inventory Levels
- Number of Breakdowns

Increased Ridership
- Ridership by Route
- Ridership by Stop

Inventory and Fuel Savings
- Fuel Consumption per Revenue and Operating Mile
- Number of Breakdowns/Work Orders
- Inventory Levels

Increased Safety
- Number of Breakdowns
- Number of Accidents
- Mean Distance between Accidents/Breakdowns

Establishing Baselines for Analysis

For each metric, we separated the relevant data into pre- and post- implementation of ITS. The pre-implementation data was gathered using non-ITS methods, while the post-implementation data was collected through each respective ITS. In some cases, the date that separates the old and new data was not clear due to soft launches of systems and adjustment periods. In these cases we qualified our findings. For all cases we were able to analyze the available data and establish a baseline for future analysis. We outline the use of these baselines for future evaluation in the Recommendations chapter.

Ridership

To isolate local and national socioeconomic factors affecting ridership, we identified twenty agencies similar to the WRTA based on annual ridership and area of service in square miles. Ten of the agencies are geographically close to the WRTA, while the remaining ten are spread across the nation. We then compared changes in ridership of the local and transnational agencies to the WRTA from 2006 to 2011.

This report finds that the newly implemented technologies have a high potential for meeting the goals set by the WRTA, though they are not there yet. Suggestions that we believe would allow the technologies to be utilized to their fullest are listed in the recommendations chapter.

There were, however, some problems that we faced during the completion of this report. Individual limitations of the report can be found in the methodology chapter. However, some of the limitations of this report include but are not limited to: no data collected to properly analyze certain areas at this time, assumptions made about key indicators to expedite the process, along with old data being widely inaccurate. While these problems surfaced throughout the project, we feel as though this project was completed to the best of our ability given the time allotted.

Authorship

As a whole, our team worked together to complete the writing portion of our project. We collaborated with both ourselves and our project advisors as to how our report would be formatted in total. Once the format was agreed upon, we separated and began drafting our respective sections. After initial drafts, we edited each other's work to create a comprehensive and unified report. Sam Johnston drafted the initial Introduction and Background Chapters. Shawn Moes drafted the beginnings of the Methodology. The Findings Chapter was initially drafted by Andrew Nersessian. Each member contributed his own work to the Recommendations Chapter which was then edited by the team as a whole. The remaining parts of the report were drafted as a team as the project was being completed.

As for the statistical analyses that were completed, the following list summarizes which project partner completed which individual analysis:

Sam Johnston

- Technology Adoption
- Survey on Demographics

Shawn Moes

- Ridership Analysis

Andrew Nersessian

- On Time Performance
- Breakdowns and Road Calls

Throughout the project's completion, each individual team member alternated in terms of leading the group and making sure we were heading in the right direction. The beginning of the project, from late August through mid-October 2012, was when Sam Johnston led the group. The middle was taken by Shawn Moes from mid-October through December. The final stage of the report was led by Andrew Nersessian from January through the beginning of March 2013. During these times, each member remained active in meetings and kept their own respective notes which were later compiled for meeting minutes.

Overall, while there were individual sections that were delegated to certain team members, we sought to remain a single unit as best we could during the completion of the report. As a result, we feel as though this report reflects the full efforts of each member working together as a unit rather than the compiling of individual results.

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1. Introduction

Private and public transit agencies are under increasing pressure from local, state, and federal bodies, as well as the public, to optimize their services in order to provide more safe and reliable service at a lower cost. These goals are to be achieved while expanding ridership and thusly service revenue. In order to effectively optimize their services, transit providers must first evaluate the current performance and identify areas where change is needed. Traditionally, transit agencies have used ridership surveys, passenger counting via observers combined with fare box data, and system performance information gathered from observers to evaluate their performance (S. O'Neil, Personal Communication, 2012). These methods are labor intensive and therefore typically costly. As such, these methods are done infrequently in most transit systems resulting in less than desirable data (M. Blunt, J. Church, Y. Graxirena, Personal Communication, 2012).

Intelligent Transportation Systems (ITS) provides access to information on ridership, as well as route and maintenance performance which is far more detailed than data which is conventionally available or realistically/financially executable, at a lower recurring or 'operational' cost. The goal of an ITS environment is to gather and relay data from the field back to a central location for real-time monitoring in addition to further analysis through data-mining. ITS data can also be used to inform the public immediately about key service changes, vehicle arrival times, and other important information via electronic sources. The data gathered from these systems can be used to monitor multiple aspects of a transit system's services, including the number of riders that board vehicles at a given stop, the location of each vehicle in real time, and the number of riders that use electronic information sources to access transit information. Data from ITS can be used to evaluate the performance of individual route segments, particular service offerings, or the system as a whole. This allows transit providers to make more informed decisions when making service changes, allocating resources, or creating new routes (M. Blunt, J. Church, Y. Graxirena, Personal Communication, 2012). By improving services and providing more up to date information to riders, transit agencies make public transit more appealing by improving key services and reliability, with the ultimate aim to increase overall ridership over time.

The existing literature on the use of these technologies is fairly dense and includes comprehensive studies conducted by the Transit Co-operative Research Program (TCRP), Transit Research Board (TRB), as well as various government agencies such as the Federal Transit Administration (FTA) and the National Transit Database (NTD), (Nakanishi et al., 2003). These studies cover material from basic theories of how these technologies function, to the ways in which they can be implemented and perfected in a transit system through practice and rigorous self-evaluation. These studies are generally written for use by transit agencies as guidelines to follow when integrating new technologies into their own systems. In order to be applicable to most types of transit systems, studies of automated systems tend to focus on individual modules or types of modules. The industry is also experiencing a dramatic shift from "product-focused"[1] corporate behavior to a new mindset. "System of Systems"[2] & "Prime Integrator"[3] business models are now being adopted which makes comprehensive studies more complex. While the potential benefits of ITS systems are well laid out in many of the studies that will be highlighted in the literature review, we were unable to find a single study that quantified the benefits, cost savings, or cost avoidances found during and after implementation.

In 2009, the Worcester Regional Transit Authority (WRTA) received $12.4 million in a federal grant through the American Relief and Recovery Act. Of this grant, $3.9 million was invested into a suite of technologies including Automatic Passenger Counting (APC), Automatic Vehicle Location (AVL), Automatic Vehicle Monitoring (AVM), and Real-Time Information System (RTIS) among others (O'Neil). The WRTA anticipates that, by implementing these technologies, they will lower maintenance costs, improve timeliness of service, increase passenger awareness, and more effectively allocate their buses and service offerings more efficiently and effectively.

The goal of this project was to perform a cost benefit analysis on the new technologies recently implemented by the WRTA. We focused on four main components of these technologies: Real Time Information Systems, Automatic Passenger Counting, Automatic Vehicle Location, and Automatic Vehicle Monitoring. Through quantitative and qualitative analysis, we determined metrics for measuring the direct impact that each one of these systems holds and how these impacts improve the WRTA as a whole. The methods we employed are applicable for other transit agencies wishing to evaluate the impacts of their own ITS systems.

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[1] Developing a product with no current market rather than finding a hole in the market and developing a product to fill that hole

[2] Collaboration between departments within a company for increased cohesion and production instead of isolation amongst departments

[3] A person or team hired by a company who works similar to a contractor in construction. A prime integrator takes on the responsibility of a task and completes it through delegation to departments. However, they are still held responsible for the completion of the task.

Because the WRTA chose to employ multiple technologies simultaneously, there were unique challenges to quantitatively analyze individual components due to potential overlap. Rather than focusing on individual components and their relative impacts, we chose instead to investigate comprehensive, aggregate impacts on the system as a whole.

The objectives of this project are laid out below.

1. Determine and evaluate how the long term and short term goals of the WRTA align with the capabilities of each of the implemented technologies.
2. Identify metrics to measure effectiveness of public transit systems and use these metrics to analyze the WRTA bus system prior to the arrival of the new technologies. This analysis will set a baseline for later comparison.
3. Perform a study on initial impact of the new technologies on the WRTA bus system by comparing data gathered after their implementation to the baseline established from data prior to the integration of ITS technology.
4. Develop suggestions for the WRTA as to methods of evaluating the cost benefits of their newly implemented technologies over time. These suggestions will allow the agency to monitor and analyze the data that these technologies collect and, as a result, have the ability to make effective business decisions.

2. Background

In this chapter we present research related to the use of recently developed technologies to improve public transit service. The goal of this chapter is to provide a context for our project, and present case studies of transit systems that have evaluated their own technology for its worth. We will discuss the metrics and analysis tools that these other systems have developed, and their relevance to the WRTA.

2.1 Use of Technology to Enhance Public Transit – Goals, Trends, and Strategies

Intelligent transportation systems (ITS) technology is used to monitor the performance of a transit system in areas that are expensive or difficult to measure using conventional methods. There are many different modules, systems, and analysis tools available to transit providers that offer access to more detailed, accurate, and up to date information on system performance. As varied as the individual components may be, their uses may be divided into one of three categories: real-time monitoring, evaluation of system performance, and market research.

2.1.1 Real-Time Monitoring

One of the simpler uses of ITS technology is real-time monitoring. Data is relayed from modules on-board active buses back to a central location, providing operations staff with real-time information on the status of each individual bus. Some commonly used systems for real time monitoring are Automated Vehicle Location (AVL) and Automated Vehicle Monitoring (AVM).

Uses of ITS technology related to real-time monitoring:

- AVL – GPS or other location data gathered from the bus module is relayed back to a central control center. There it can be referenced against scheduled time points or stops and sent out to the public through real time information systems (RTIS) via display boards and webpages; it can also be stored for later trend studies in on time performance and traffic pattern studies. Knowing the location of each bus in real time allows staff to dispatch more effectively, re-route buses to avoid traffic, and respond to incidents more quickly (Nakanishi et al., 2003).
- AVM – Information on the mechanical, electrical, and communications health and status of the bus is gathered by various modules and relayed back to a central control center. Staff can monitor the current condition of the bus, and can address potential issues as they arise, preventing costly road calls, and reducing maintenance labor and parts costs (K. Shore, Personal Communication, 2012).

2.1.2 Evaluation of System Performance

One of the key reasons for using ITS technologies is to evaluate a system's performance. All of the technologies being reviewed for this project help a given transit provider determine how effective their system is, along with potential areas of growth or improvement. All three of the on-board technology systems contribute to the overall evaluation of a transit system's performance.

- APC – By being able to count riders boarding and exiting vehicles in real-time, transit agencies are able to see when and where people are using the service. This provides valuable information to the agency about areas where services may need to be either increased or decreased. This information, coupled with demographic information about the area of service, also allow agencies to ensure that they are abiding by federal law in terms of equality in service (M. Blunt, J. Church, Y. Graxirena, Personal Communication, 2012).
- AVL – Knowing the location of all vehicles at all times enable transit agencies to see if their system can improve based upon how the system in running in real time. Using these locations and cross-referencing them with the scheduled time-points allow them to know the on-time performance of the fleet as a whole along with buses individually. Additionally, knowing traffic patterns along with the location of buses allow for the potential to re-route buses to avoid potential stoppages and keep the fleet performing at its highest level (Furth, Hemily, Muller, & Strathman, 2006).
- AVM – While it may not be as useful as APCs or AVLs in evaluating the system's performance in relation to ridership, vehicle monitoring allows for an agency to know the current status of every AVM equipped vehicle. An AVM system is a networked set of sensors installed on a vehicle that monitor various aspects of the vehicle during operation. By using this data, an agency can determine if a bus is operating at an acceptable level in terms of fuel consumption, operating temperature, fluid levels, mechanical components and more. Any vehicle not performing within acceptable levels can be identified before failure and serviced appropriately. This ensures that the fleet is operating at peak efficiency (Clever Devices Ltd).

2.1.3 Market Research

As a public service, transit has a social obligation to be as accessible to everyone as feasibly possible. The Civil Rights Act of 1964 requires transit providers to create and maintain a plan to ensure equal access to their services amongst a wide variety of demographics. This has been expanded upon by the

Age Discrimination Act of 1975 and the American Disabilities Act of 1990 to encompass all demographics and ethnicities rather than simply focusing on racial characteristics, which was done in the original Civil Rights Act (United States Office for Civil Rights). The Federal Highway Administration (FHWA), to ensure that these laws are enforced, requires each public transit agency to both have an approved Title VI/Nondiscrimination policy (which parallels the laws laid out in the Civil Rights Act, Age Discrimination Act, and American Disabilities Act) and submit annual reports on the demographics of their ridership, to ensure that services are not inaccessible to any specific group (Title VI of the Civil Rights Act of 1964).

ITS technologies complement, or in some cases replace, traditional data collection methods such as ridership surveys, field observations, and focus groups. Traditional market research methods require a high level of resources compared to actually running the buses, and as such are typically conducted periodically rather than continuously over time (C. Hamman, Personal Communication, 2012). The Transit Cooperative Research Panel (TCRP), sponsored by the Federal Transit Administration, observed that “traditionally, analysis [of passenger trends] required manual data collection, which was a time consuming, costly, and, at best, periodic process” (TCRP 126, p.1). With proper analysis, ITS data can provide more detailed and accurate information about transit ridership and trends, allowing transit providers to make better informed decisions specific to their market. Some commonly used systems for ITS-based market research are Automatic Passenger Counting (APC), Automatic Vehicle Location (AVL), and Real Time Information Systems (RTIS).

The uses of each ITS technology that are related to market research include:

- APC and AVL – Boarding data from APC modules can be analyzed for a variety of metrics, including comparisons of ridership, bus capacity based on route or time, ridership based on season, time of day, and day of the week, among others. AVL data from GPS or other location devices onboard of active buses can be correlated with APC data to determine the highest and lowest trafficked stops and route segments. The results of these analyses can then be used to improve operating efficiency by rerouting buses, eliminating seldom used route segments or stops, changing the frequency of buses to match demand, as well as prioritize passenger amenities at various stops (TCRP Report 126).
- RTIS – RTIS technology relays data gathered from the AVL to a central system which then determines an estimated arrival time which is available to both the transit provider and the public ridership. Most RTIS packages track access for a given service, which allows transit

providers to evaluate their marketing strategies, user friendliness of access points, and calculate the approximate number of users. By monitoring where RTIS data is accessed from and then looking at demographic distributions in those specific areas, transit providers are able to identify regions or specific demographics that are not being serviced fully. Transit providers can then modify services in order to improve accessibility to underserved demographics. Further, use of such technology reduces passenger anxiety while waiting on the bus, which allows the passenger to develop trust and faith in the bus system.

2.2 Case Studies of Bus Systems using ITS Technology

In this section, we describe case studies of similar ITS technology. The case studies are broken down by which ITS technology they reference (APC, AVL, or AVM) and their relevance to this project.

2.2.1 Automatic Passenger Counter Case Studies

Case studies to troubleshoot the operation of APC systems were performed by the TCRP and were outlined in their Synthesis 77: Passenger Counting Systems. Among the six transportation systems studied, there were two that stood out due to their relevance to the ITS technologies being studied: the OC Transpo (Ottawa–Carleton Regional Transit Commission) of Ottawa, Ontario, Canada and the Regional Transportation District of Denver, Colorado. These two agencies have over 25 years and 8 years of APC experience respectively. The information that can be provided from both of these agencies can be useful to the WRTA’s future with APCs.

OC Transpo: Ottawa-Carleton Regional Transit Commission of Ottawa, Ontario, Canada

The OC Transpo agency, containing 950 buses and servicing more than 89 million passengers annually, began using APC technologies over 25 years ago (TCRP Synthesis 77). They started out with sign-post APC systems, which tracked buses as they passed certain location markers, and have since been moving towards GPS-based systems. This allows them to instead track buses in real time, including when off route due to either detours or non-standard routes. The agency now needs to staff 3.5 people (3 full time workers and 1 part time) to manage the APC systems which save a considerable amount money in wages alone from the traditional tedious methods of data-gathering. Overall, there were a few key points to take from this study when it comes to implementing and analyzing APC systems. The OTC found that full implementation of APC systems would take time to mature and develop citing that is was approximately three years before their own in-house management was comfortable with utilizing the new technologies to their fullest. They noted that after familiarizing their staff with ITS technology, there was less confusion between departments (TCRP Synthesis 77).

Regional Transportation District (RTD) of Denver, Colorado

The RTD of Denver was a second agency that became a focus of the TCRP study. Because the APC systems in Denver were implemented in 2004 (much more recently than the ones in Ottawa), they have similar functionality to those in the WRTA. Additionally, both the RTD and the WRTA chose to use RideCheck Plus as a data analysis tool for the APC data. One of the conclusions drawn from the RTD study, similar to OC Transpo, is that the integration of these systems takes time (TCRP Synthesis 77). Successful integration and adaptation can take years to fully develop. Since they are utilizing the newest and most up to date software and devices much like the WRTA, this conclusion drawn by the RTD is specifically relevant to the WRTA.

2.2.2 Automatic Vehicle Monitoring Case Studies

Kirk Shore from ITS systems vendor Clever Devices Ltd stated that few studies exist on AVM due to how recently it has been developed. The studies that do exist are simple comparisons of maintenance costs from before and after their implementation. Shore also noted that since transit is subsidized by government funds, some transit providers are worried that if they report large scale savings and avoidances they would lose some of their funding (K. Shore, Personal Communication, 2012). Shore believes these concerns make it difficult to find related studies on return on investments for AVM technologies because of the repercussions transit authorities could receive if they conducted and published these studies this has been expressed to us via many other sources as well. However, several transit agencies such as the Metropolitan Transit Authority (MTA) and the Chicago Transit Authority (CTA) have implemented the technologies in the past and are currently seeing ‘large’ returns. The exact numbers however have either not been calculated as of yet or are unavailable to our study as they may be for internal use only (C. Cipriano, S. Nair, Personal Communication, 2012).

2.2.3 Automatic Vehicle Location Case Study at Valley Metro in Phoenix, AZ

The Phoenix Public Transit Department was an early adopter of AVL systems, implementing rudimentary AVL units on fixed route buses in 1996. Valley Metro, also known as the Regional Public Transit Authority (RPTA), implemented modern AVL units between 2002 and 2005 on over 770 fixed route buses, in addition to paratransit and support vehicles. The RPTA found that AVL was most useful in performance monitoring, safety, customer service, and passenger information. The RPTA needed to hire additional staff to utilize the system more fully. The RPTA believes that there are more uses for the data gathered from AVL that have not been explored yet. They are looking at developing more sophisticated real-time monitoring methods that also log variations in route times without the need for separate analysis. (TCRP Synthesis 73, p.54)

2.3 Technology Investments by the WRTA

The new technologies now used by the WRTA came from an investment via the American Relief and Recovery Act (ARRA) of 2009 (S. O'Neil, Personal Communication, 2012). The WRTA received $12.4 million from the ARRA, $3.9 million of which was the capital cost invested into a suite of new technologies from Clever Devices Ltd, modernizing many aspects of their bus system. Part of the suite consisted of modern versions of traditional technology, but a larger part consisted of cutting edge ITS units. The WRTA equipped 22 Gillig Buses and 23 Nova RTS buses with Automatic Vehicle Locators (AVLs), Automatic Vehicle Monitors (AVMs), Automatic Passenger Counters (APCs), and cellular internet connectivity (WRTA ITS Inventory). The systems that require additional operating costs included Real Time Information System (RTIS), APCs, AVMs, and Intelligent Vehicle Networks (IVNs). Our project focused on the RTIS, APC, and AVM per request of the WRTA. Steve O'Neil, WRTA Administrator, and Chris Hamman, WRTA Consultant, felt that these were the three systems that would have the biggest impact on the WRTA and wanted our focus to be solely on these systems. With all of these pieces in place, the next step was to determine if these moves were justified. A proper analysis of the previously used systems and data-gathering methods, compared to the newly purchased systems, was to be conducted in order to justify not only the purchasing of these ITS technologies, but also to justify their continued use.

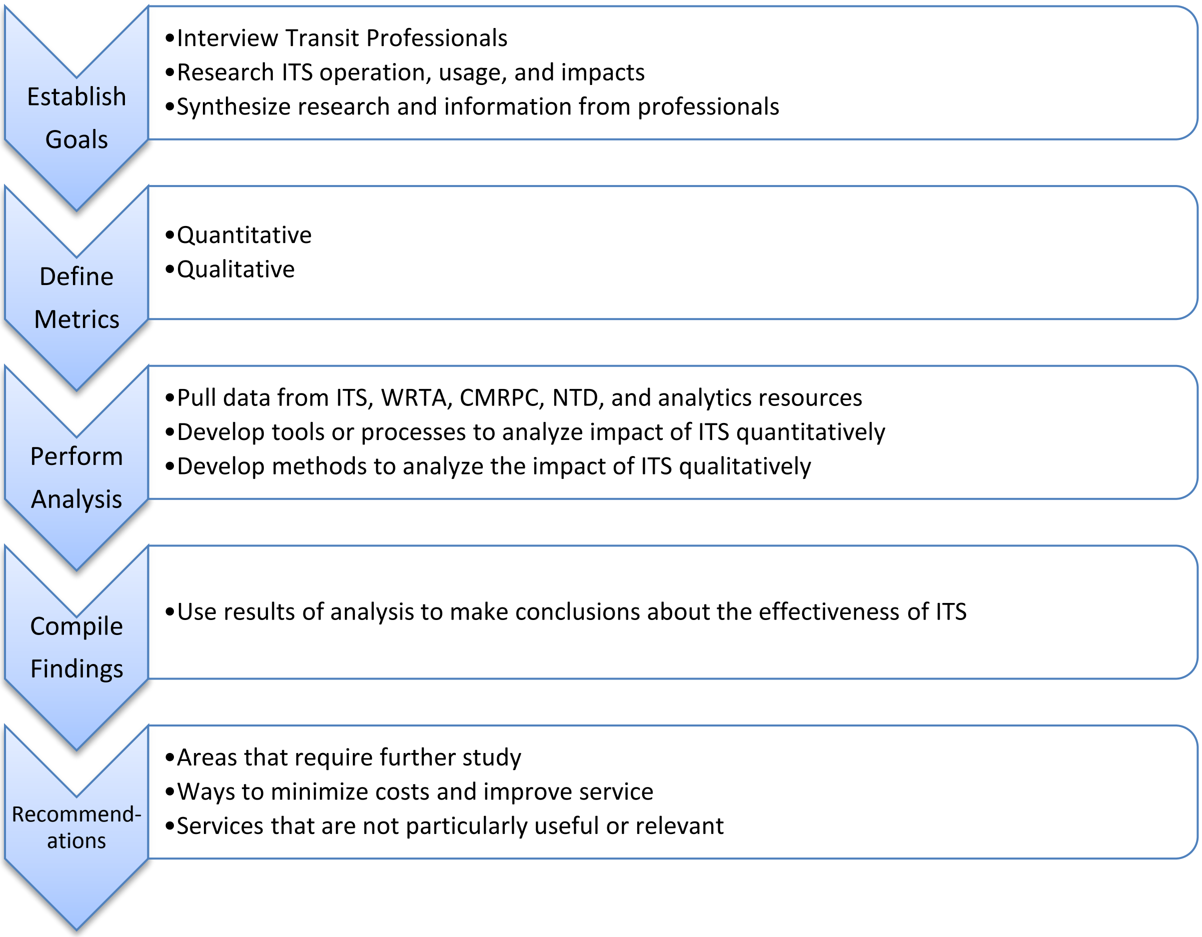
3 Methodology

The goal of this project was to perform a cost benefit analysis (CBA) on new technologies recently implemented by the WRTA. There are three main components of these new technologies: a Real Time Information System with data gathered from Automatic Vehicle Location (AVL), Automatic Passenger Counters (APC), and Automatic Vehicle Monitoring (AVM). Specifically, we studied the ways in which these systems work and the data that can be extracted from them. Through this process, we were able to analyze the direct impact that each one of these systems held for the WRTA. To help us complete the analysis, we developed the following list of objectives:

1. *Through previous studies, explained in the Background chapter, along with using the goals of the WRTA, determine the appropriate metrics to evaluate how the new technologies can impact the WRTA in both quantitative and qualitative measures. We used both established metrics already in use by the WRTA for evaluating performance as well as new metrics we developed for areas that did not have established metrics.*
2. *Use determined metrics to analyze performance of the WRTA fixed route bus operations prior to the implementation of the new technologies. This established a baseline for analysis.*
3. *Perform a study on the initial impact of new technologies and potential changes to WRTA from analysis of WRTA systems prior to technological changes.*
4. *Develop recommendations for a system that the WRTA can use, both now and in the future, to analyze and monitor these new technologies over time.*

This methodology chapter describes our detailed approach. A flow chart of our project methodology can be seen below in Figure 3.1:

Figure 3.1



3.1 Establishing Goals and Metrics

In order to complete our study, we first looked at the goals of the WRTA, as well as other transit agencies in general, and established how these new technologies aligned with them. We then identified specific metrics with which we could evaluate performance towards those goals. The following sections depict our process of identifying the goals, objectives, and metrics we chose for our study.

3.1.1 Determining overall goals and objectives

To begin our process in determining the overall goals and objectives of the WRTA, we developed a list of research questions to guide us. These research questions included:

1. *What are the long and short term goals of the WRTA?*
2. *How did these goals lead to the purchasing of the new technologies?*
    a. *What aspects of the technologies would benefit the WRTA and their goals?*

We began the process of determining the WRTA's goals and objectives by speaking with Steve O'Neil, WRTA Administrator, and Chris Hamman who was hired by the WRTA as an IT consultant. Through these meetings we developed a list of general short- and long-term goals for the WRTA.

After developing this initial list of goals, we then combined this list with a document provided to us by Carol Schweiger and Santosh Mishra of TranSystems, one of the leading US transit consultation firms. This document was written when the WRTA was applying for grant money to install these new technologies. It detailed exactly what the WRTA was hoping to accomplish with each of these new systems. Once these goals were provided to us, we then merged them with our initial list of goals which resulted in a finalized list of long- and short-term goals.

We then moved on to analyzing how the Automatic Passenger Counting (APC), Automatic Vehicle Location (AVL), Automatic Vehicle Monitoring (AVM), and Real Time Information Systems (RTIS), would impact the specific WRTA goals. Each of these systems has individual aspects that provide potential cost reductions to the WRTA. The questions that were laid before for our team were, 'What are these aspects?' and 'How do we measure the impact due to each system?'. To find the answers to these questions, we analyzed the systems individually, learning the physical components of each system so we were fully educated on how they function. In doing this we were able to establish theoretical individual and combined benefits from these systems, as well as areas where we could expect to see measurable performance increases. We then consulted with Steve O'Neil and Chris Hamman as well as various other experts at the WRTA. We also met with Jonathan Church, Mary Ellen Blunt, and Yahaira Graxirena of the Central Massachusetts Regional Planning Commission (CMRPC), which oversees the operation and performance of the WRTA. After these meetings, we finalized a list of areas we would focus on to find measurable increases in performance.

The areas we determined would show significant change due to ITS were ridership, technology adoption, customer satisfaction, ease of use for riders, performance of proactive maintenance, inventory and fuel, and overall safety.

3.1.2 Identifying Metrics of Performance for Analysis Purposes

Our next goal was to establish metrics to evaluate the increases in performance in the areas we identified in Section 3.1.1. To aid us in our process, we developed the following list of research questions:

1. *How is a transit system measured for performance?*

    a. *How do other systems evaluate their performance?*
2. *What data needs to be collected to perform these analyses?*

We first looked at industry publications on the use and evaluation of ITS technologies, noting which metrics could be relevant to our study. We then looked at other transit systems that had already adopted comparable ITS technology and studied their ITS evaluation techniques. By taking this approach, we were able to identify industry standards on how to measure success and cost savings in areas that these new technologies would affect. After consulting with Carol Schweiger and Santosh Mishra of TranSystems we began to gain a picture of how to draft and complete generalized cost benefit analyses. After combining these industry standards and our project objectives with Carol and Santosh's experience, we had a preliminary approach to conducting our project. We then further analyzed the generalized metrics identified from industry practices and, utilizing the WRTA's service standards manual, chose measures of performance that tailored specifically to their goals and objectives.

3.2 Creating a Baseline

In order to study the effects of these new technologies in multiple areas, including ridership, we first established a baseline that could be used for future comparisons. We began this portion of study with the following research questions in mind:

1. *How do we isolate the changes from the technology from other socioeconomic factors (i.e. the economy, weather changes, etc.)?*
2. *How was the WRTA performing prior to the implementation of these technologies?*
3. *How does the data collection in the past compare/contrast to the current methods?*

In order to isolate the changes that are attributable to the technology from other socioeconomic factors, we identified sister agencies which shared enough in common with the WRTA that we could expect to see similar changes in the identified metrics due to outside factors such as the economy and social trends. We looked for data that was both available and applicable. This would allow us to isolate effects due to ITS, and allow the WRTA, in future self-evaluations, to see how they were doing despite changes in social and economic climates. Since their previous performance had happened amidst a varying economy, and as the nation was undergoing a social change, we determined that this would provide a more objective view of how these systems specifically impacted the WRTA.

In order to establish this baseline for analysis, we took a two-step approach. We first analyzed transit agencies that are comparable to the WRTA, and then focused on industry standards as a whole.

We took this approach to set a baseline for how agencies similar to the WRTA were performing, along with what was common in the industry. To accomplish our first task, we compiled a list of comparable transit agencies along with the data that we had available for those agencies. We narrowed our collection down to 20 outside agencies. Ten of these agencies are spread amongst the nation. They were chosen for their similarity in terms of ridership, along with area of service (in square miles). Along with these 10 transnational agencies were 10 agencies in relative closeness to Worcester, MA geographically. Again, we attempted to choose agencies that were as similar to the WRTA as possible. By choosing these two groups, we attempted to isolate the changes that the technology provided to Worcester. Of course, there are numerous variables that affect a transit agency on a daily, monthly, and annual basis. Among these variables include the weather, economy, etc. By analyzing the 10 national and 10 local agencies, we hoped to address the fluctuations in social variables locally along with economic variables nationally. This allowed us to isolate the impacts of the technologies to the best of our ability. The list of comparable transit agencies can be found in Appendix E.

After identifying the sister agencies we created a Microsoft Excel spreadsheet which pulled out various data points that we measured with the WRTA. We then began deriving equations to average each of these metrics individually so that we could later compare them to the WRTA's trends to isolate changes due solely to ITS. After determining individual metrics through the comparison of similar agencies, we continued by focusing on the transit industry's standards as a whole. To do this, we looked at multiple sources on both a local and national scale. Nationally, we looked at data from the Transit Cooperative Research Program (TCRP), National Transit Database (NTD), and Federal Transit Administration (FTA). Another valuable resource, particularly in the area of AVM, was the AVM Conference in New York City, NY which was attended by group member Shawn Moes along with WRTA Consultant Chris Hamman. These four resources provided an extensive list of metrics that we could use or adapt to analyze the impacts of ITS in relation to the goals of the WRTA.

At this point, we turned to the Central Massachusetts Regional Planning Commission (CMRPC). The CMRPC is the agency that oversees the WRTA and their services to central Massachusetts. Considering that they already had standards on which they analyze the WRTA, it was apparent that this was a good place to start. Of the CMRPC, we met with Jonathan Church, Mary Ellen Blunt, and Yahaira Graxirena of CMRPC multiple times. With their aid, we determined specific metrics that mapped to the short and long term goals of the WRTA.

3.3 Analyzing the Current Impacts of ITS

After determining which metrics to focus on, we began our analysis of the WRTA. Because the WRTA began implementing these new technologies in 2009 and have been installing new technologies and familiarizing themselves with them on a rolling basis, via gradual integrations, soft launches, etc., we chose to focus our analysis after the end of calendar year 2012. This was the time that Steve O'Neil, WRTA Administrator, felt the systems were fully implemented and functional. To begin the analysis, we sought to answer the following questions:

1. *How has the performance of the WRTA compared to the performance of the industry as a whole over the past 5 years?*
    a. *How do we account for these changes when analyzing the data that comes from the new technologies?*
2. *How are the goals of the WRTA affected by the new technologies?*

To answer this first question, we averaged out the performances of the 10 national and 10 local agencies in terms of their ridership over the past 5 years. The data for these averages came through the National Transit Database (NTD) who receives the reports of transit agencies on an annual basis. We then determined how the WRTA's ridership data compared to these averages over the same time period. This comparison was also broken down into how the WRTA compared in times of economic downturns along with economic rises. These figures can be used for future comparisons, via data from the new technologies, to see if the WRTA is maintaining/improving in comparison to industry standards, during both times of economic growth or decline. An issue that arises here, though, is determining if any changes in this data can be directly attributed to the technologies. However, seeing if the agency is improving on an overall basis, or even maintaining their current status, is valuable to know after the implementation of the technologies.

In addition, our work in these areas is a beta test for analyzing a transit agency in the manners we determined. These methods can be used by other transit agencies that wish to complete a similar analysis via the NTD database.

After completing this analysis, we then moved on to specifying how the short- and long-term goals of the WRTA are affected by the new technologies. The goals and the impacts made on them are provided in the subsequent sections.

3.3.1 Ridership

Our first area of study was ridership. We chose to begin here because this was the area which the most data was available both internally and through National Transit Database (NTD) reports. Completing ridership first allowed us to get a feel for actually performing an analysis in “familiar territory” before we began studying data that was more unfamiliar to us.

In order to understand the impact of these new technologies, we first needed to determine when exactly when the primary new source of ridership data, APC, went online. While it was initially installed in 2011, the WRTA was still working out software problems until Jan 2012, when it began collecting data reliably with Automatic Counters (Hamman).

The data that we analyzed came from the WRTA system prior to the change in technology. Since the company had not employed any new technologies prior to 2011, the data was gathered once annually, instead of continuously, as it is now. This means that the data is not as detailed as the data provided for the post-2011 change but it is still able to provide trends in ridership that could be potentially impacted by the new technologies.

In order to assess changes in ridership we first calculated the changes between yearly reports, to do this we used the equation:

$$\frac{(Passengers\ per\ rev\ mile\ year\ 2) - (Passengers\ per\ rev\ mile\ year\ 1)}{Passengers\ per\ rev\ mile\ year\ 1}$$

This allowed us to see a percentage rate of change between each reporting year.

Next we needed to create a baseline for comparison, while the WRTA was reporting varied growths through the years, there was no way to be sure what was causing these changes. This ridership baseline is outlined in Section 3.2.

3.3.2 Technology Adoption

Our second area of study was technology adoption. We looked initially at data gathered from TextMarks as well as Google Analytics, two programs that track a wide variety of data points of the users who connect to these various sources, to see the current adoption rates. Seeing that the results only showed us current users, and gave us no indication as to how many people were still using paper schedules, or how many people were still unaware of these new tools and as such had not adopted them, we decided to develop survey questions that the CMRPC and WRTA could include on their next ridership survey.

Analyzing TextMarks was fairly easy; the data provided was easily broken down into number of users and how many times per day, week, month etc. that they were using this feature. TextMarks also specifies unique users versus number of uses allowing us to identify the frequency with which people use this feature. This allowed us to determine if we had a large number of people trying it once and not liking it or a number of return users, allowing us to gauge roughly if this form of RTIS was being adopted.

Google Analytics provided a wealth of useful information as to adoption rates ranging from how many unique users visit the site to the total views per month with many other key statistics also available. This is primarily used to track the number of people redirected to the schedules and the arrival times by scanning the QR codes posted at the stops. It is also used to track users manually going to the WRTAs website. This data allows us to see trends in users to view the progress of adoption, however it still has many limitations, the primary limitation is that it only collects data on those who use these tools, any relevant information regarding riders who do not know about these technologies or choose to not use them is not available.

As stated above, we identified the limitations of these tools and began developing survey questions to complement our quantitative analysis. Specifically, these questions were meant to gather information on who knew and did not know about the new RTIS updates, who had the capabilities to utilize these new RTIS technologies, and some demographic information such as age, education, and employment status.

Due to unforeseen complications we were unable to conduct the survey during our project, as such we simply provided the WRTA with our survey to be conducted at a later time. This will allow for the full analysis to be completed at a later date. The recommended survey along with its methodology can be found in Appendices A and B.

3.3.3 Ease of Use for Riders

The next area we focused on for our study was how the new technologies improved the ease of use for the average rider. This was mainly directed at RTIS and how knowing the current bus schedule as it changes based on traffic and emergency patterns allowed the passengers to more easily use the services of the WRTA. Since this goal was mostly qualitative, the only way we felt we would be able to analyze this effectively was through a survey.

We developed both general questions on overall ease of use as well as questions specific to each technology, allowing us to see individual and aggregate results.

We theorized that a study could be done, as well, to assess time saved by the average passenger, which would give quantitative data to report on. This study would incorporate on time performance and approximate the time saved waiting at stops by looking at how often a bus was going to be 5 or more minutes late. This, in theory, would allow passengers to catch a bus that they otherwise would not be able to by leaving slightly earlier, or by leaving later and spending less time waiting outside at the stop. We decided to not move further with this idea because the study into this would not have provided much useful data for the overall project and any results would have been influenced by environmental variables out of our control. We also brainstormed methods to address the time it took to find a stop time on a paper schedule versus simply scanning a QR code or submitting a query to TextMarks, however we decided that the results would not be particularly significant to our project and did not pursue these methods.

3.3.4 Customer Satisfaction

The next overall goal we looked at was customer satisfaction. This goal, again, was primarily qualitative, and as such was addressed using additional survey questions to provide us with quantitative data to analyze. Unlike technology adoption or ease of customer use, the CMRPC had done a survey in spring of 2011 that included a question on customer satisfaction. This gave us a starting point for our own survey questions.

We began developing our questions by reading through the questions previously asked by the CMRPC in their customer satisfaction surveys. We then tailored our questions to more aptly reflect customer satisfaction with the service provided by the new technologies. The target of this portion of the survey was mainly to gauge customer satisfaction of the RTIS systems. We decided to use brief questions with set responses to gauge how the general user base thought the WRTA had been doing with improving performance and services overall.

After speaking with the Metropolitan Transit Authority (MTA) of New York City, New York, we were shown two new metrics which would allow us to obtain hard numbers on customer satisfaction. The MTA tracks complaints per 5000 passengers as well as positive responses through a variety of media sources (e-mail, Facebook and Twitter being the three primary sources). They look at the trends of these negative and positive responses to address how the community views the recent changes they have made to routes and schedules. While it was impossible to establish a baseline due to the lack of previous data in these areas, we decided that these metrics could be useful to the WRTA. The WRTA already has e-mail, Facebook, and Twitter accounts that are available to the general public. Therefore, we recommended that the WRTA use these metrics after the hard launch of their RTIS systems.

3.3.5 Improving Safety

We next studied the effects of the new technologies on improving overall safety. Our main metric for determining if the WTRA had improved safety with these new technologies was breakdowns and work orders. We analyzed the number of work orders before the technologies had been implemented and established an overall baseline. We could not make any calculations as to if the new technologies had improved safety to date however because the primary technology that would lead to an increase, AVM, had only been fully installed in early 2013.

3.3.6 Proactive Maintenance

Next we moved into working on the goal of proactive maintenance. After the meeting with the MTA we initially established that to move into proactive maintenance was a multi-step process. It first involved optimizing the breakdown repair system by fixing system critical buses first. Over time the agency would then move to a scheduled maintenance program repairing buses and subsystems on a scheduled timeframe. The scheduled maintenance program would then finally evolve into the desired proactive maintenance as buses were inspected and tuned up directly before they, statistically speaking, would break down.

While at the AVM conference in New York, we networked with several of the Clever Devices marketing team. They informed us that they had begun developing an ROI calculator for their product. Working with Michael Elgarten, we acquired this tool and began altering it to fit the WRTA's measured metrics as well as adjusting it to be a realistic return tool instead of a marketing tool which said how much you could potentially save by purchasing their product. Their initial work however gave us insight into industry standard metrics that we had previously overlooked.

The maintenance department at the WRTA, led by Ahmad Yasin, has been working extensively on a proactive maintenance policy. We decided that, through this project, we would attempt to complement and add to the already existing policy using the new technologies. We decided to use two main metrics for this policy. Firstly, operating costs per revenue mile. We had to break this down into fuel costs and maintenance costs, this was particularly difficult because the WRTA only analyzes and reports these costs once per year. Since gas prices can fluctuate on a daily or weekly basis we had to take an average of gas prices rolled up into yearly benchmarks over the past five years and calculate the average cost per revenue mile in fuel based on miles of operation and the fuel efficiency of their fleet. Next, we broke down exactly where the maintenance side of the operation costs were going, separating out parts from labor. Once that was completed, we had our benchmark price for future analyses.

The second metric we were using was number of road calls. This would be the key metric to see if proactive maintenance was effective. We began by establishing how many road calls the WRTA had done in previous years, establishing the benchmark. Now in the future we can compare the number of road calls on two separate measurements. Firstly based on the expert opinion of the foreman, we estimated the savings due to avoided road calls. This is based off of road calls that did not happen because a repair had been made. Since this, however, is speculative, we then compared that total number to changes in road calls before and after AVM was implemented to see how well the data correlates. This allowed us to establish a meaningful baseline, and potentially identify parts or entire buses which should be avoided due to high risk of failure. The savings from this could one day be calculated using the AVM ROI tool provided.

We also looked into adding a new metric to this portion of our study, mean distance between breakdowns. This metric is essentially provided with the basics of AVM so it is rather easy to track and requires no additional technology. This is a metric that allows a shift towards proactive maintenance due to its ability to provide data for preventative maintenance.

3.3.7 Inventory and Fuel

Finally we studied the effects of AVM and its abilities to reduce an agency's parts inventory along with vehicle idle times which would lead to savings in fuel. We were directed towards this goal by Chris Hamman as this is one of AVMs selling points. We wanted to look at how well Clever Devices were portraying their product. We knew right away that neither of these could be assessed for savings immediately as both of them would require a great deal of time to show any meaningful savings. Considering AVM has only been fully installed since December 2012 and has not yet been fully adopted by the WRTA, it would be unreasonable to expect to see a change immediately.

Instead we decided to make a benchmark point and lay the framework for future analyses. Since the overall goal had already laid out the metrics we quickly began working on the data. First we cataloged the parts in the inventory prior to the implementation of AVM to the inventory after. By catching problems early, and making repairs to current components instead of needing to fully replace them, the WRTA would be able to save money by reducing inventory over time. We then researched the prices of these individual parts and were able to set up a sheet to estimate inventory savings over time. This entire process will later be evaluated by the WRTA simply by comparing post AVM inventory numbers to the benchmark we laid down.

3.4 Measuring Success in the Future

One of our project's overall goals was to not only conduct a cost-benefit analysis on the current state of the WRTA in regards to these new technologies but to establish a plan for future analyses to be conducted in the future. This section describes how we established a step by step manual for the WRTA to follow to evaluate themselves in the future.

4. Findings

In this chapter, we present our findings related to WRTA's newly employed technological systems. These findings will also act as a basis for our recommendations to the WRTA. The findings are organized according to the WRTA's seven short- and long-term objectives, and include the following:

- Metrics for Measuring Effectiveness of Public Transport
- Metric-Based Analysis of the WRTA
- Estimation of the Cost Benefits

4.1 Metrics for Measuring Effectiveness of Public Transport

We developed a specific list of metrics that would be used to measure the effectiveness of public transportation. We arrived at this list of metrics by first looking at the short- and long-term objectives as identified by the WRTA Service Standards (citation). Below are the 7 objectives of the WRTA along with the metrics that were developed by reviewing each objective.

1. Ease of Customer Use

Having a product that is easily usable by your customers can increase customer interest in your product and additionally lead to increased customer satisfaction. Being able to decrease the difficulty of using the transit system and making it easier riders will reduce the number of people who do not ride due to any difficulties in the system. For this reason, ease of customer use is a primary goal of the WRTA on an annual basis. The specific metrics that are available to track efficiently via the new technologies that will show any impacts in ease of customer use are:

- Ridership by Stop
  - Ridership by stop is just how it sounds. It is the total ridership for the system which is then broken down by the stop at which the riders board and exit a vehicle
  - Ridership by stop can be measured using APC and AVL data. The APC will count, in real time, where riders are boarding and exiting. This data can be cross-referenced with AVL data to specify where these changes occur
- Technology Adoption
  - Technology adoption is a metric that tracks how many riders are using the technology available to them to update themselves with the system in real time.
  - This is tracked via Google Analytics, Facebook, Twitter, and TextMarks.
- Number of Breakdowns

    - The number of breakdowns metric is measured by the frequency with which vehicles within the agency breakdown over a set period of time
    - This metric can be measured by looking at the breakdown and work order data that is compiled and tracked with the WRTA's Turley system in the maintenance department

2. *Customer Satisfaction*

Like private businesses, the WRTA has identified customer satisfaction as a primary goal because customer satisfaction also drives the success of publicly funded agencies. To maintain customer satisfaction, we recommend that the WRTA should monitor the following metrics using the newly adopted technologies:

- Ridership by Route
    - Ridership by route is similar to ridership by stop. However, rather than the data being broken down by individual stop, it is compiled by routes as a whole.
    - The data for this metric is tracked by totaling the APC data for each vehicle for each route.
- On-time Performance
    - On time performance is the metric that tracks when buses arrive at their given stop and if the time of arrival is within an acceptable period to be considered "on time". This period usually includes falling in the range of 1 minute early to 5 minutes late.
    - This data is tracked by compiling AVL data. By tracking the precise location of a bus and cross-referencing the location with the predetermined stop times, the agency can see if a given bus is early, late, or on time at any given stop.
- Mean Distance Between Accidents
    - Mean distance between accidents tracks the number of accidents for a given vehicle per revenue mile. Using this metric, agencies can begin to predict when an accident may occur via revenue mile data
    - This metric can be tracked AVM data. The number of accidents can be tracked and then divided by the total revenue miles to obtain this metric for a determined period of time.

3. *System Efficiency and Route Optimization*

System efficiency is a way for a company to truly see the success and productivity of their product. This is at the top of most transit agencies' lists of goals. The WRTA also lists this as an important aspect to monitor in their system. Route optimization falls into the category of system efficiency. Optimizing routes allows for maximum productivity and increased business success. To see how efficient their system is, the WRTA can track the following metrics:

- Ridership by Stop
- On Time Performance
- Preventative Maintenance
    - Preventative maintenance is a metric that can be tracked using AVM data. By using AVM data to identify any trends in vehicle maintenance, the predictability of the maintenance can be increased by seeing that certain issues may arise with certain regularity.

4. *Proactive Maintenance*

Proactive maintenance is an important way for public transit agencies to avoid costly repairs and, therefore, save capital in the long run. By staying proactive about their fleet, agencies can reduce their necessary inventory levels by having greater knowledge about anticipated and expected problems. This reduced inventory ultimately saves money for the agency as a whole. Proactivity also reduces maintenance times. This reduces the wages paid to mechanics along with maximizing the profitability of the fleet by keeping a full fleet on the roads at all times. There are a few ways in which the newly implemented technologies can lead to more proactive maintenance. Among these include:

- Work Orders
    - Work orders are tracked using an internal system in the WRTA maintenance department. By seeing trends in work orders, the maintenance department can be more proactive in their operations and have the ability to prevent more serious problems before they occur.
- Inventory Levels
    - Being able to reduce inventory levels decreases the value of parts that the WRTA needs to have on hand at a given time.
    - The ability to reduce inventory levels can come via the AVM systems and preventative and predictive maintenance plans.

- Number of Breakdowns
- Mean time between breakdowns

5. *Increased Ridership*

A primary goal for any transit agency is to always increase ridership. Increases in ridership lead to more revenue and a higher quality of service on all fronts. The goal of the WRTA, as determined by Administrator Steve O'Neil, is for ridership to increase 3% each year for the next 5 years. Ridership numbers reaching this goal would reflect a success in this newly implemented technology and be a telling sign that this was a profitable decision. To see the impacts of ridership, the WRTA need not look further than the following metrics:

- Ridership by Route
- Ridership by Stop

6. *Inventory and Fuel Savings*

Inventory and fuel savings have also been identified as a key demographic to analyze the success of the new technology within the WRTA. For the WRTA, having a reduced inventory, along with savings in fuel, can lead to significant savings on an annual basis. There are a few metrics that can be tracked through the new technologies that can lead to achieving these goals.

- Fuel Consumption per Revenue and Operating Mile
    - An easy way to analyze fuel savings is to look at total fuel consumption per operating and revenue mile. Seeing downward trends in fuel consumption would show that these technologies have been impactful in these areas.
- Number of Breakdowns/Work Orders
- Inventory Levels

7. *Increased Safety*

Increased safety is an area that every transit agency or public service provider should be aware of and take very seriously. This is always something to monitor and should be increased and improved at any presented opportunity. The recently employed technology is an example of one of those opportunities. Via the new technologies, the WRTA can track the following metrics to analyze customer safety:

- Number of Breakdowns
- Number of Accidents
- Mean Distance between Accidents/Breakdowns

Overall, these new technologies have a lot to offer to the WRTA. They have many capabilities and features that directly provide benefits to the goals and objectives of the agency as a whole. While only 7 long and short terms goals are outlined here, the deliverables of these new technologies are many. They provide invaluable information to the WRTA which leads to savings in all areas. The collection of WRTA goals along with their applicable metrics are outlined below.

WRTA Goal	Applicable Metric(s)
Customer Satisfaction	• Ridership by Route • On Time Performance • Mean Distance Between Accidents
Ease of Customer Use	• Ridership by Stop • Technology Adaptation • Number of Breakdowns
System Efficiency/Route Optimization	• Ridership by Stop • On Time Performance • Preventative Maintenance
Proactive Maintenance	• Work Orders • Inventory Levels • Number of Breakdowns
Increased Ridership	• Ridership by Route and Stop
Inventory and Fuel Savings	• Fuel Consumption per Revenue and Operating Mile • Number of Breakdowns/Work

	Orders • Inventory Levels
Increased Safety	• Number of Breakdowns • Number of Accidents • Mean Distance between Accidents/Breakdowns

The criteria that we used above serve as key indicators for the success of the WRTA as a whole. If these factors are operating successfully, then we can confidently assume that the operation in total is operating successfully. This saves us time from analyzing every piece of datum available to the agency which can prove time consuming and tedious.

4.2 Analysis of the WRTA Based on Determined Metrics

After determining the list of metrics to use to measure the effectiveness of the WRTA, we began analyzing just how effective the WRTA is based on their performance towards these metrics. For each of the given metrics, we sought to break down the data available to us through pre- and post-implementation dates. The pre-implementation data came from the WRTA's older methods of gathering and were given to us through the data stored within the WRTA. The post-implementation data came from the data that has already been collected by the respective technologies. In many cases, however, it is difficult to establish when the pre-implementation data end and the post-implementation data begins. This is due to soft launches of the systems and adjustment periods rather than having no technologies one day and having them the next. Because of this, there are many cases where our analyses will serve as baselines for future comparisons to be completed by the WRTA. These specifications will be outlined in the Recommendations Chapter.

The specifics metrics that were analyzed for this project are as follows:

- Total Ridership by Route & Stop
- On Time Performance
- Technology Adoption
- Number of Breakdowns/Road Calls
    - This analysis also included the information for Work Orders
- Parts Inventory Levels

4.2.1 Total Ridership

After determining the 20 sister agencies and performing the analysis outlined in the methodology chapter, we began to see the trends of ridership in the WRTA's data. Our primary finding is the trends in the growth and decline of the WRTA's riders. We noted that in national periods of growth, before the technologies were implemented, the WRTA grows 2% faster than the national average. Similarly in periods of decline pre RTIS, the WRTA retains 4% more of its riders than the national average. It is also notable that while the WRTA's growth is higher than the national average, this is potentially due to a change in the social climate in Massachusetts. This theory is backed by the high growth rates in the local sister agencies which are both better than the national average as well as the WRTA.

When continuing forward with future analysis this benchmark allows the WRTA to compare their post RTIS changes in ridership to these identified sister agencies. Periods of national growth that show the WRTA growing at more than 2% over the national average, or periods of decline that show the WRTA retaining over 4% more than the national average will be attributable to the new technologies. This only holds true when correlated with the local sister agency data to identify if the WRTA has begun to approach their growth and decline rates, otherwise the increase can simply be counted as a continued increase in the social climate resulting in more riders.

The charts that reflect this data can be found in Appendix F.

4.2.2 On Time Performance

We analyzed the on time performance metric by using the data collected by the WRTA over the last 3 years (data provided by Dave Trabucco of the WRTA). This data was collected by hand. Individual inspectors would go to different bus stop locations throughout the system and manually time drivers as they pulled in and out of their respective stops. The inspectors would then annotate onto their turn in sheet the appropriate data and the data is totaled monthly. This data is also broken down by the location where the data was taken.

Overall, the on time performance of the WRTA has stayed relatively consistent since the beginning of 2012. In 2010, the WRTA had a total on time performance percentage of 83.5%. In 2011, this number rose to 86.0% and then fell to 82.8% in 2012. However, these numbers have stayed in the range of mid-70s to high-80s consistently. The data, and representative graphs, can be found in Appendix C.

On the other hand, the data that has been collected by the Automatic Vehicle Location devices, when cross-referenced with specific schedules and time-points, does not have the same level of on time percentage. The data extracted from the AVL systems has begun starting in 2012 and has shown initial trends of on time performance to remain in the low-70s in terms of percentage.

As a result, this data does not serve as a reliable baseline for the new data coming in from the AVL devices. The hand-timed the data compared to the computer tracked data essentially does not correlate with any statistical significance. Therefore, we recommend using the new data that is coming in to serve as its own baseline. After gathering a significant amount of data from AVL (perhaps collecting until the end of 2013), use future on time performance data (2014 and on) to compare to that initial sample.

4.2.3 Technology Adoption

4.2.3.1 Lijit Demographics

Description

Lijit Demographics analyzes web traffic using cached data in order to determine the approximate demographics of the users.

Limitations

Makes assumptions based on browsing history, does not account for multiple users on a single device, and only stores from previous 30 days.

Findings

Figure 1 - September 5, 2012

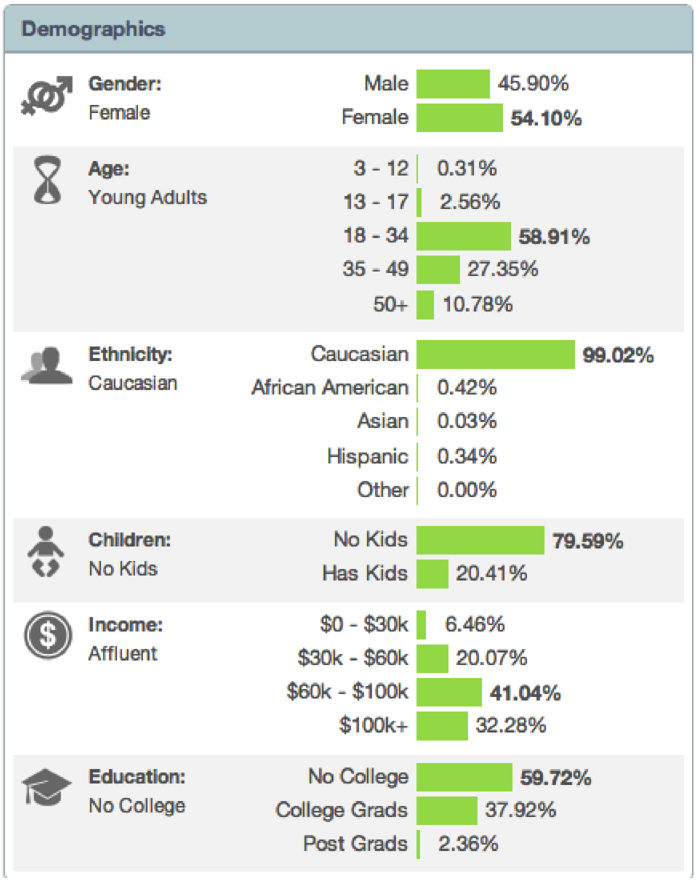
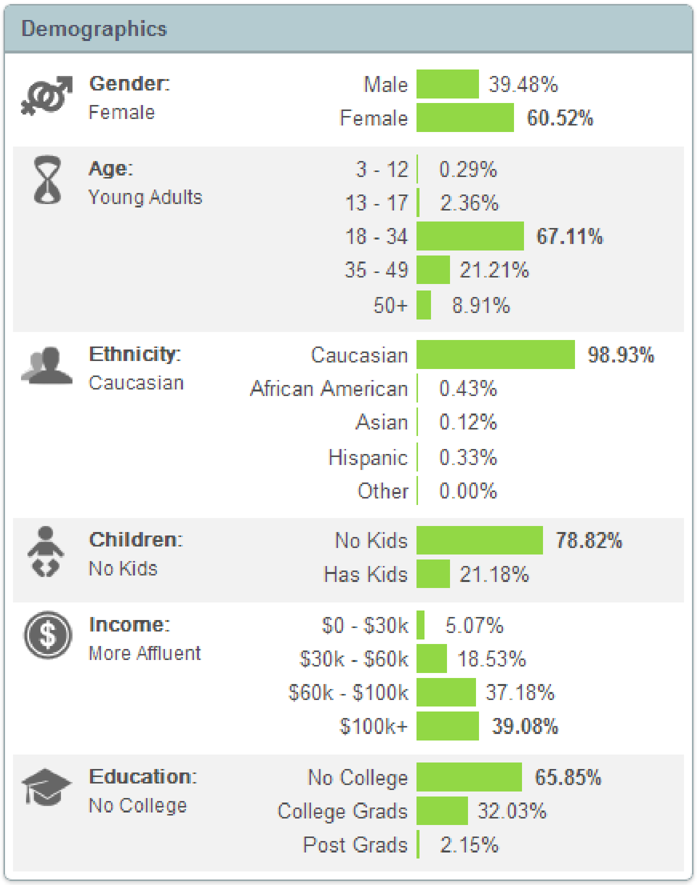


Figure 2 - December 8th, 2012



Analysis

Statistics from Lijit seem to have remained relatively constant. However, there are a few notable changes.

Gender: since September 5^{th} there has been a shift of approximately 5% towards more female users, from 54.1% to 60.52%.

Age: While users under 18 have remained unchanged, there has been an increase in users 18-34 years old, from 58.91% in September to 67.11% in December. Also, the number of users above 35 has decreased from 38.13% to 30.12%.

Ethnicity: Ethnicity has remained unchanged, with approximately 99% of users identified as Caucasian. However, this could be inaccurate due to the assumptions used by Lijit when analyzing browsing history.

Income: There has been a growth in more affluent users.

Education: There has been a growth of approximately 6% in users that have No College education.

Recommendations

While interesting, the data gathered from Lijit Demographics is limited both by how it is collected, and how it is presented. Because each category only lists a percentage, there is no way of knowing whether the number of actual users that fall under that category has grown or decreased. We recommend that the WRTA checks the statistics quarterly, and uses the data gathered to influence potential marketing rather than decisions that affect services.

4.2.3.2 Google Analytics

Description

Google Analytics tracks the number of times web content is accessed in order to track trends in usage over time. The WRTA uses Google Analytics to track when WRTA web content is accessed via QR Codes, Web, and Mobile Web. Google Analytics also identifies unique versus return users, calculates average visit duration, and analyzes how users navigate between content.

Limitations

Google Analytics treats each new device as a new user. For QR Code analytics this is not an issue because only mobile devices can scan in, but for web sites there could be multiple devices per user registering as unique visitors.

QR Codes

Description – QR Codes are unique images linked to mobile content. Users scan the image on a camera-equipped mobile device using a specialized application, which redirects to content on the mobile web. The WRTA has QR codes posted at bus stops that, when scanned, provide the user with the estimated arrival time of the next bus generated using AVL data.

Findings

Figure 3 - Overall Visits

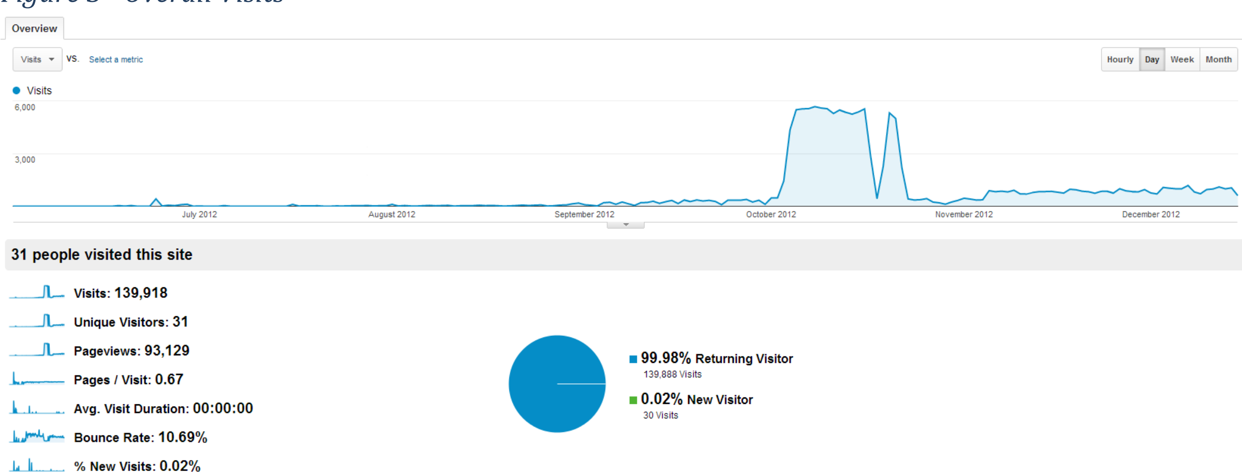
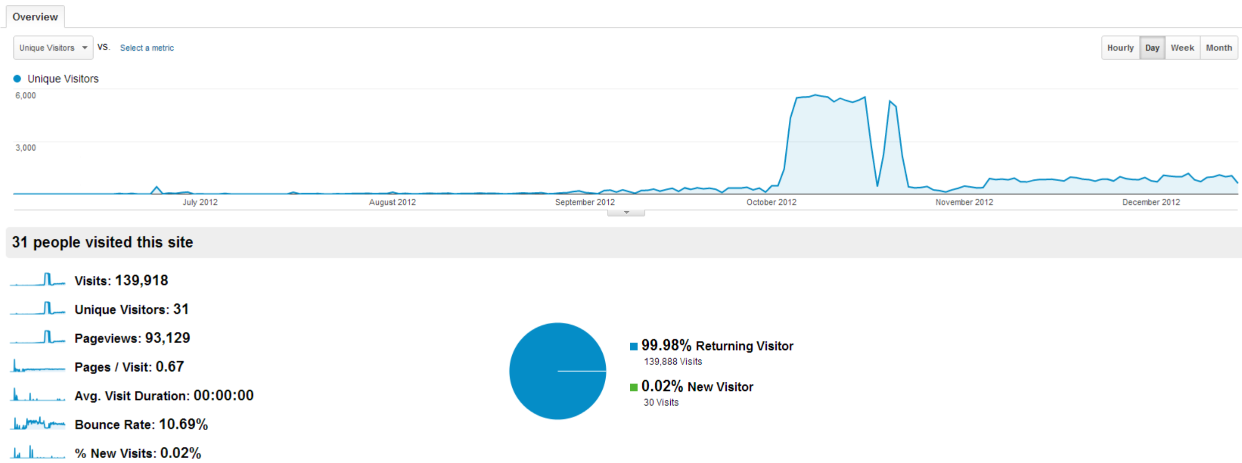


Figure 4 - Unique Visits



QR Code use has risen steadily since June 2012, with a surprisingly large bump in October. Christopher Hamman indicated that this bump could be due to testing of the system, so we discounted it from our analysis.

Analysis

Adoption of the QR codes is increasing. Though nearly 100% of visitors are returning, the steady increase in unique visitors indicates that once a user learns how to use the QR codes, they tend to do so again. This means that there is a high retention rate for users of the WRTA QR Codes, and it can be safely assumed that the service is useful to riders.

The steady increase in QR code use and high retention rate of users show that the service is working effectively. However, we believe that once the WRTA begins advertising the service they will see a much faster rate of adoption.

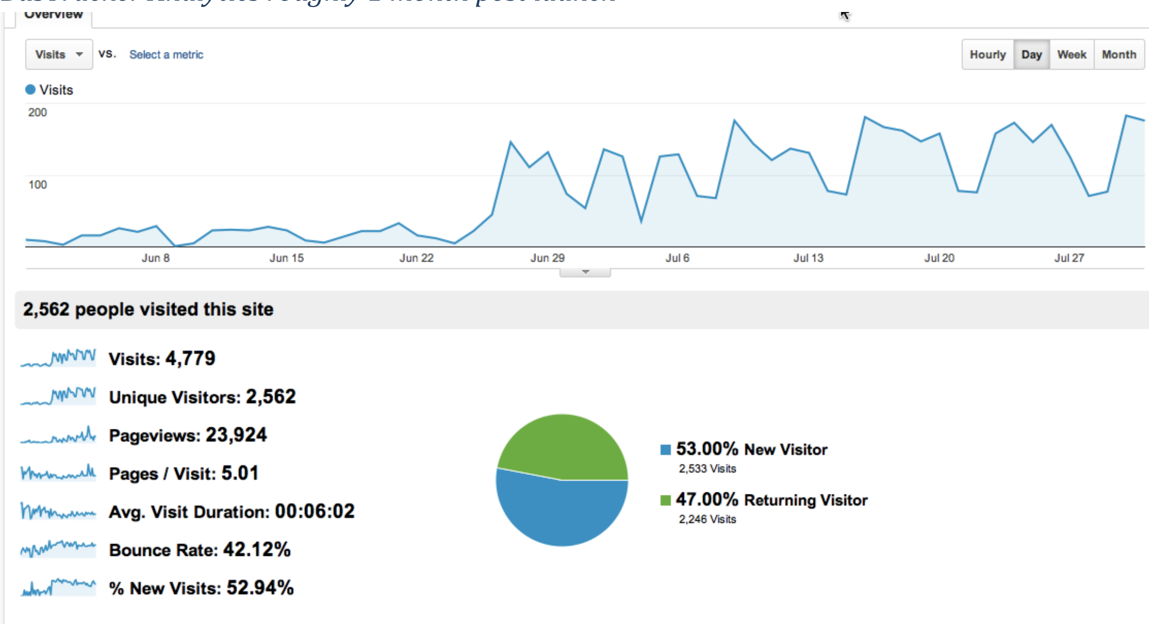
4.2.3.3 BusTracker

Description

The BusTracker page on the WRTA website (www.therta.com) allows users to find estimated arrival times for all buses on their computer or mobile device. The WRTA tracks the number of hits on the site using Google Analytics.

Findings

BusTracker Analytics roughly 1 month post launch



BusTracker Analytics roughly 8 months post launch

The graphs representing this data can be found in Appendix D.

Analysis

Overall usage has more than doubled, with visits increasing from less than 200 per day to consistently over 500 during the week.

There is a clear trend of decreased visits during the weekend. We can therefore infer that most of the web traffic during the week is from riders commuting to and from work.

Despite being live for more than 6 months Google Analytics reports that ~30% of the hits on the BusTracker page are new users. This is impressive, but could be due to Google Analytics counting every new device as a new user.

Recommendations

Noting the increased midweek traffic, we recommend that the WRTA focuses advertising towards college ridership, because students typically have fewer commitments on the weekends.

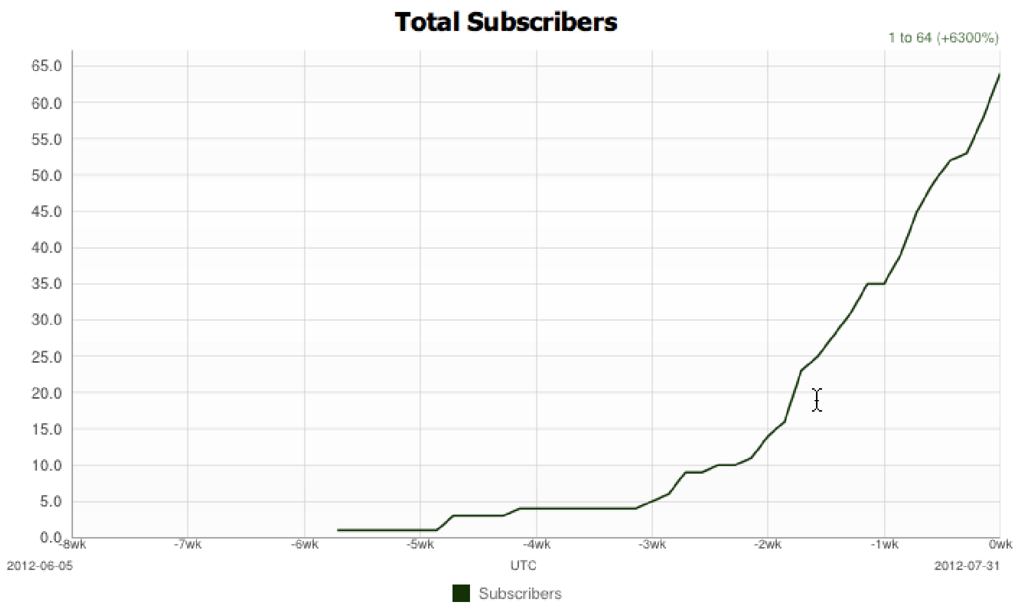
4.2.3.4 TextMarks

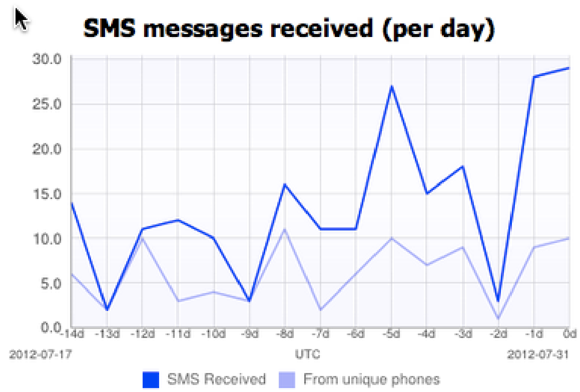
Description

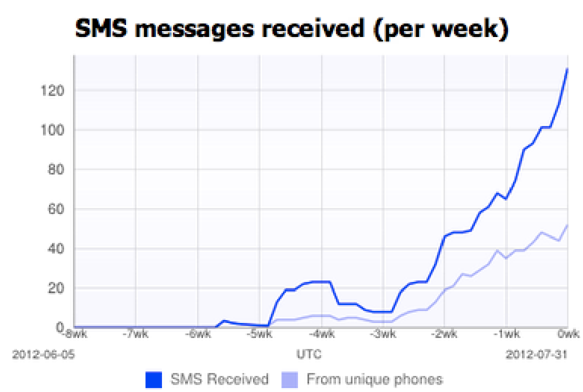
TextMarks is a service to send mass text messages to subscribed users. TextMarks tracks the number of users, as well as the rates of opt-ins and opt-outs. The WRTA uses TextMarks to send out service updates and estimated arrival times.

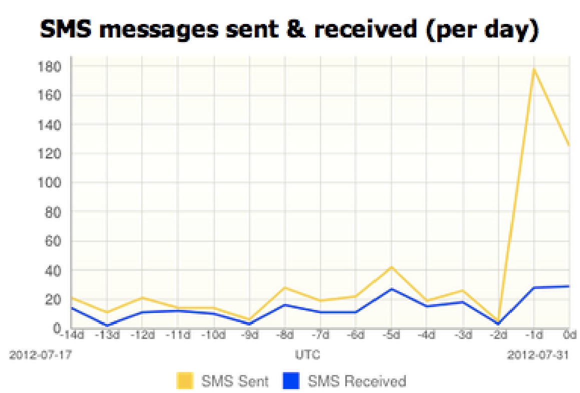
Findings

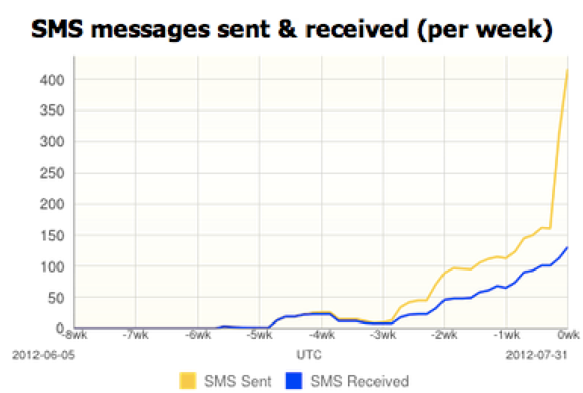
Text Message Usage roughly 1 month post launch



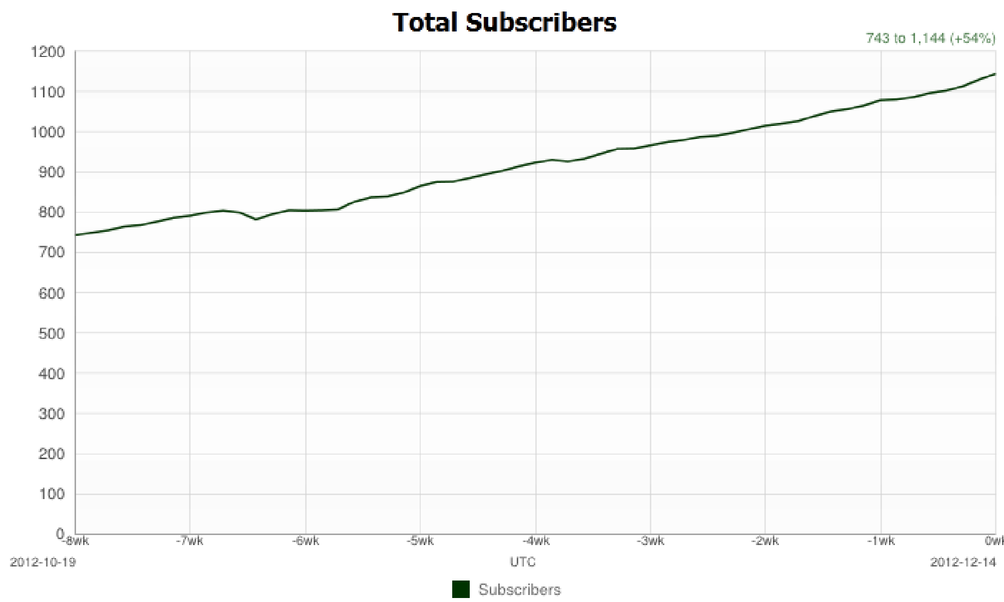


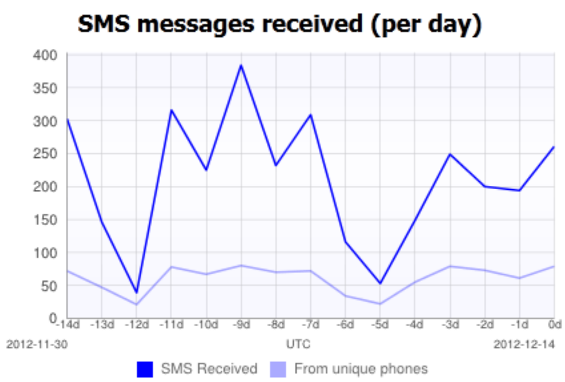


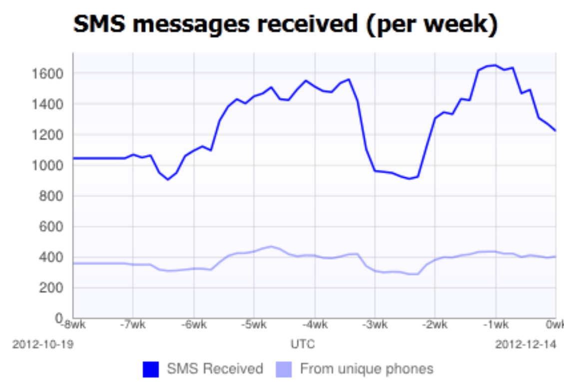


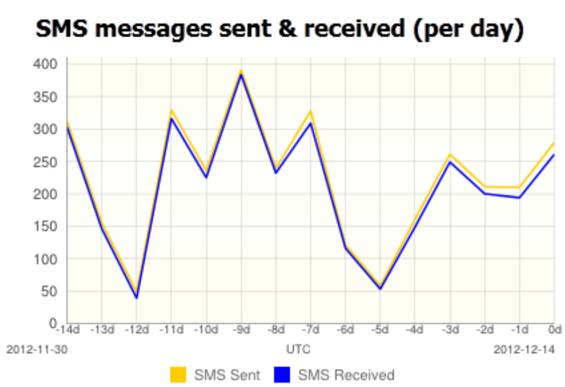


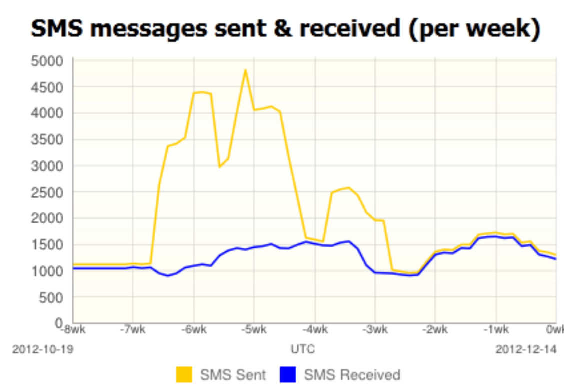
Text Message Usage roughly 7 months post launch











Analysis

We can see that over this 5 month period there has been a dramatic increase in the usage of text message alerts. As of 3/1/2012, there were over 1,500 users registered for the service, despite intentional lack of advertising, and not including opt-outs. As word spreads about the service and more people see the signs and recognize how to use the text messaging services, we expect this number to continue growing.

Sending too many alerts will cause opt outs. At both analysis points there is a strong correlation between number of messages sent and the number of subscribers who opt out.

Recommendations

We recommend that the WRTA limit the number of alerts they send out via TextMarks in order to retain more subscribers.

4.2.4 Number of Breakdowns/Road Calls

An analysis that we determined would be useful to see the effectiveness of the Automatic Vehicle Monitoring (AVM) systems would be to look at the number of Breakdowns/Road Calls along with the work orders for the WRTA. By doing so, we would be able to see if the AVM components are detecting problems in the engines and getting them fixed before they get worse. This would decrease the money spent on both parts and mechanic wages within the agency. The data for this analysis came from Ahmad Yasin, Maintenance Manager of the WRTA.

We began with looking at the Road Call failure records on a monthly basis beginning with January 2003. The failures are further broken down into the system that failed (A/C, Air System, etc.) along with separating the mechanical vs. non-mechanical failures (e.g. A/C is mechanical, Dirty Bus is not). The following chart summarizes that data:

Total Road Calls By Problem

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	TOTAL
MECHANICAL											
A/C	49	15	51	35	70	77	57	80	105	56	595 / sum(TOTAL)
Air System	68	30	60	50	61	52	62	27	27	36	473
Body	47	22	37	44	39	35	63	57	55	34	433
Brakes	37	30	47	36	30	43	49	29	29	27	357

Wheelchair Lift	77	61	82	68	74	207	133	88	61	39	890
Doors	74	46	70	46	39	34	67	42	46	21	485
Electrical	58	38	64	60	39	59	41	62	58	63	542
Engine	136	86	142	136	126	187	160	144	208	140	1465
Fluid Leak	23	12	12	28	17	18	23	29	34	17	213
Heating	30	15	20	8	17	17	22	18	16	6	169
Kneeler	3	2	6	8	8	7	8	8	0	2	52
Lights	58	43	51	52	75	50	47	78	82	37	573
Steering	14	17	16	12	9	15	11	9	20	6	129
Transmission	90	58	79	75	88	108	109	68	57	50	782
Windshield wiper	19	14	14	14	21	14	21	12	19	8	156
TOTAL	783	489	751	672	713	923	873	751	817	542	7314
	NON-MECHANICAL										
Nothing Found	22	25	30	32	27	26	35	27	26	42	292
Accidents	16	6	13	5	7	6	11	13	22	15	114
Fare box	176	135	150	266	543	459	259	285	280	674	3227
Radio	48	79	19	19	7	56	21	13	20	21	303
Tires	27	9	16	16	15	13	15	5	8	13	137
Dirty Bus	1	0	4	2	3	0	3	0	6	0	19
Transportation	20	13	52	50	67	70	111	72	61	52	568
TOTAL	310	267	284	390	669	630	455	415	423	817	4660
TOTALS	1093	756	1035	1062	1382	1553	1328	1166	1240	1359	11974

After summarizing the data in such a way, we then determined 10 key metrics to analyze even further that would represent the data as a whole. The 10 key indicators that we chose are the 10 that are highlighted in yellow in the previous table. Taking these 10 indicators, we then moved on to analyzing how much the WRTA spends when these problems occur.

We returned to Ahmad Yasin to gather more data from the WRTA's internal Turley -system which catalogues the work order data for the WRTA. We extracted all of the work order data dating back to 2003 and totaled the amount spent on wages, parts, and their total. This data can be found in Appendix G.

However, there are many issues with this data. The first of which comes from the data that was extracted from the Turley system. As can be seen in the charts, there are multiple years where there are zeros for the number of work orders for a particular system. This is obviously not feasible as maintenance is done on all systems on a regular basis within the WRTA. In addition, the data laid out above only comes from buses that are currently part of the active fleet. For example, if there was a bus that ran for the WRTA from 2003-2010 and was sold in 2010, then the data for that bus from 2003-2010 is not included since it is not a part of the active fleet. Therefore, the data is skewed toward the more recent years.

Additionally, we wanted to break down the data in terms of what component failed on each system. For example, the component of the A/C that failed (belts, motors, etc.) so that we know what is failing more often than others. However, after discussion with Ahmad Yasin, this type of analysis is not feasible. Not only are the work orders that are filled out not as accurate as they could be, not all of the buses are the same within the fleet. With multiple different kinds of buses, including biodiesel and hybrid buses, not all of the components are the same on each bus. Therefore, an analysis of any kind would be an apples to oranges comparison and would not hold statistical significance.

4.2.5 Parts Inventory Levels

After looking into breakdowns and road calls, we then began to analyze the parts inventory of the WRTA on its own. We did this to track how much the WRTA stores in parts regularly and if this amount is decreasing. If not, can the new technologies help to decrease inventory? Decreasing inventory means that the AVM systems have provided information on predictive maintenance along with helping to reduce to number of repairs needed over time.

To do this, we sat down with Troy Senosk, WRTA Parts and Environmental Coordinator. Troy has been working for the WRTA for the last 5 years working with the maintenance inventory. According to Troy, ever since he began working with the WRTA, he has been working to reduce inventory levels over time. He has been doing this without the aid of AVM technologies. He also added that his systems would not use the aid of AVMs until approximately the fall of 2013.

Due to the fact that inventory levels have been steadily reducing without the help of AVM, this data analysis did not seem very useful to analyzing the effects of the AVM systems. However, tracking inventory levels as they begin to adopt the AVM technologies will remain a recommendation stemming from this project due to the preventative costs that it could provide. However, statistical analysis was not completed beyond the conversation held with Troy.

4.3 Cost Benefit Estimation

At this point in the project, we planned on estimating the up-to-date cost benefits that the system has already provided the WRTA. There were a few issues leading up to this point that led to flaws with this plan. After completing the background research and our methodology to this point, we had realized that the full implementation and use of these systems were not completely in effect until around the end of the calendar year 2012. As such, the amount of data that has been collected after that point is rather slim. It has only been a few months since that point and any savings in system costs are minute and cannot be directly attributed to the new technologies with a high level of statistical confidence.

As such, we were not able to conduct a significant calculation that can provide the current savings to this point. Therefore, the calculations to be performed in the future (once a significant amount of data has been collected) will be included in the recommendations for the WRTA.

5 Recommendations

5.1 Introduction

At the beginning of the project we were not only tasked with assessing the current return on investment and cost benefit analysis but also laying down a plan for future studies. We were also asked that we take our knowledge and expertise on these new technologies and make any suggestions as to their uses and the implementation there in. This chapter lays out our suggested plan for monitoring ROI and CBA in coming years as well as how, through our studies, we have identified that these technologies can be utilized to their fullest.

5.2 New Metrics

In determining our metrics for analysis we based this off of several key metrics already tracked, however as we investigated further, we noted better ways to track how well the technologies were affecting the WRTAs goals and objectives. The following suggestions are metrics that we believe should be tracked in order to provide the WRTA with a more comprehensive and accurate assessment of these technologies impacts.

- Track Customer satisfaction and Technology adoption rates via surveys in addition to traditional methods (complaints per 5,000 riders, compliments per 5,000 riders etc.) to more efficiently track these metrics
    - This will allow the WRTA to in time by following our equations and plans, figure out how these technologies have improved their service in the eyes of the riders this will allow them to better decide if and when they add more new technologies as well as how to modify what they are doing to retain and even possibly grow in ridership numbers.
- Track Breakdowns Prevented
    - This will be generated via expert opinion if a problem would have led to a breakdown had it not been corrected. This will only apply if the correction was made due to AVM warnings and would have had a reasonable chance of not being caught otherwise.
        - This will allow the WRTA to assess a monetary value in the money saved in both labor time and reduced number of expensive road calls. As well as be a clear indicator as to how well they are progressing along the improved maintenance plan.
- Track Mean Distance Between Breakdowns

- While work orders are being reduced or reallocated more effectively, there is still little in the way of tracked metrics to see how the WRTA is doing on evolving into preventative maintenance. This would allow the WRTA to track if they are extending the mileage they get on buses between breakdowns (both for a specific bus and also an average) and to see if this is growing to indicate that they are getting better at using AVM.

5.3 Low Priority Metrics

While working on the project we assessed various metrics as options for evaluating performance, some of these metrics that were being tracked we determined were superfluous in that they weren't functioning as intended and in our opinion have no real need to be tracked.

- Lijit Demographics
    - While interesting, the data gathered from Lijit Demographics is limited both by how it is collected, and how it is presented. Because each category only lists a percentage, there is no way of knowing whether the number of actual users that fall under that category has grown or decreased. We recommend that the WRTA checks the statistics quarterly, and uses the data gathered to influence potential marketing rather than decisions that affect services.

5.4 New policies to implement/Better ways to use ITS

Finally, we have our suggestions and recommendations to the WRTA regarding policy and procedure specifically.

- Following our methodology every 6 months to replicate our findings and track the benefits in future years.
    - This will allow the WRTA to see the trends over time of their return on investment and continue to make changes as the data becomes available or more refined as the cases may be. Allowing them to fine tune how they are utilizing RTIS
- Implement the Repair > Scheduled > Preventative Maintenance plan laid out
    - It is too demanding and unrealistic to expect that AVM will allow mechanics unfamiliar with its intricacies to utilize it to its fullest, instead follow the suggested plan we laid out to in X Months be using it to its maximum potential.

- The first step into fully utilizing AVM is recognizing where the WRTA is currently at; utilizing a similar method to the work order analysis performed in this project we recommend that the WRTA first assesses how many part failures it replaces on a monthly basis.
- The next step is to figure out what parts are failing most frequently, whether they cause a road call or not. The afore mentioned list is well detailed in the work order analysis performed in this study and it is our recommendation that the WRTA utilizes the ten key indicators outlined there in. Taking this a step further it is important to analyze the time between failures of these parts on a bus by bus basis, both in mileage and time between failures.
- Using the data gathered from step two, then average the mileage and time between failures and implement a plan that performs a full check up on these specific parts and subsystems at some percentage of time (we recommend 5-10%) before the failures typically occur, allowing them to be serviced (on average) before they become a problem rather than afterwards.
- After the plan from step 3 has been implemented for a period of time (suggested 3-6 months or more), use the work order analysis once again to analyze the number of failures per month in order to benchmark the current progress.
- At this point there are two steps to take simultaneously, First repeat steps 2 and 3 again (or simply up the percentage of time) to further refine the scheduled maintenance program. At the same time, scour through the still occurring breakdowns and identify specific AVM warnings or combinations of warnings that are flagged prior to these individual breakdowns if they exist.
- While sticking to the scheduled maintenance plan, begin to service buses earlier as the findings from step 5 indicate a breakdown is likely to occur earlier, continue analyzing data as in step 5 to continually improve the preventative maintenance.
- Notes: Scouring through the data on a day by day basis and analyzing which buses are throwing the proper combination of codes to warrant repairs is a daunting task. It is in our opinion that using some of the money saved through the implementation of the scheduled maintenance program should be applied

towards training and incentivizing the mechanics, this will help with the adoption of the new technology and thereby decrease the time required to move into the preventative maintenance plan, ultimately saving more money while also improving worker morale.

- Augmenting the current login for Bustracker Web
  - A unique login could benefit users. Most people have an automatic login and this would be a faster way to navigate to their specific routes than going through the entire website every time (a customizable homepage with their routes/stops they have chosen to appear there), improving RTIS usage and rider satisfaction due to the increased simplicity. This would also provide the WRTA with useful data on unique users and allow questions such as "which routes do you ride most frequently" to be eliminated as we could see that solely based on routes they have chosen to be displayed on their own personal homepage.
  - This would also allow the WRTA to track users specifically and send out surveys through to each individual profile so that unique users weren't bombarded with requests every time they logged in, annoying them less while at the same time giving the WRTA more useful and accurate data due to less repeat responses.
    - Potential profile page that would allow for repeat survey questions (such as male/female, age, income level, etc.) to be prefilled out expediting survey times and making it more likely that they would be willing to take the survey due to the fact that surveys would be shorter and less repetitive.

- Increase service and advertisement to colleges and schools in the surrounding area.
  - Our background has indicated that the highest adoption rates of these new technologies, specifically RTIS, lay in the younger demographic. Now that these technologies have been fully implemented, it is our recommendation that the WRTA begin increasing service and advertisement to this demographic. Our research leads us to believe that this will allow the WRTA to attain a significant portion of these students as riders.

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APPENDIX A: Proposed Survey

Description: This survey is meant to gather information about how many people know about and use WRTA service updates via electronic sources, as well as some demographic information. This information will not be used to identify you, and is being collected by the WRTA in order to improve route and service update methods. All questions presented in this survey are optional, answer as many or as few questions as you see fit.

Background

Do you own a smartphone?

Yes	No

If not do you own a cellphone with text messaging capabilities?

Do you own or regularly use a computer?

Yes	No

To what degree do you have experience using the internet?

No Experience	I use the internet occasionally	I use the internet about once a day	I use the internet a few times a day	I frequently go online

Updates from the WRTA

Which of these services offered by the WRTA are you aware of? Check all that apply.

BusTracker on www.therta.com/	BusTracker Mobile Web Site	Text-Messaging Updates
Scan-able QR Code at bus stops	Email Updates	None of the above

Which of these services offered by the WRTA do you use? Check all that apply.

BusTracker on www.therta.com/	BusTracker Mobile Web Site	Text-Messaging Updates
Scan-able QR Code at bus stops	Email Updates	None of the above

Please indicate approximately how many times you use each service to receive route or bus information in a typical week.

BusTracker on www.therta.com/	Do not use	5 or Less	6-15	15-30	30+
BusTracker Mobile Web Site	Do not use	5 or Less	6-15	15-30	30+
Text-Messaging Updates	Do not use	5 or Less	6-15	15-30	30+
Scan-able QR Code at bus stops	Do not use	5 or Less	6-15	15-30	30+
Email Updates	Do not use	5 or Less	6-15	15-30	30+

For the services you do use, how satisfied are you with the service provided?

BusTracker on www.therta.com/	Do not use	Very Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Very Satisfied
BusTracker Mobile Web Site	Do not use	Very Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Very Satisfied
Text-Messaging Updates	Do not use	Very Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Very Satisfied
Scan-able QR Code at bus stops	Do not use	Very Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Very Satisfied
Email Updates	Do not use	Very Dissatisfied	Somewhat Dissatisfied	Neutral	Somewhat Satisfied	Very Satisfied

Comments:

Demographics

What is your gender?

Male
Female

What age range below best describes you?

Under 18	18-24	25-34	35-44	45-54	55+

What is your marital status?

Now married	Widowed	Divorced	Separated	Never married

Please select the response below that best describes your education. If you are currently In school choose the response that describes the education you have already received.

No High School	Some High School	High School Graduate	Vocational School	Some College	College Degree	Graduate degree (Masters, PHD)

Are you currently...?

Employed for wages	Self-employed	Out of work and looking for work	Out of work but not currently looking for work	A homemaker	A student	Retired	Unable to work

APPENDIX B: Survey Methodology

High Level Goals:

The goal of our proposed survey is to assess awareness of ITS update services among the WRTA's ridership, and gather information on rider satisfaction, ease of use, and demographic information. For use in a wide range of areas specified in the Survey Reasons for Questions document provided.

Survey Design:

When designing the survey, we determined that multiple choice questions were the most effective due to the ease of cataloging answers, and as such employed them as much as possible. We decided that a shorter survey would be more appealing to riders, and limited our survey to 3 pages.

Sample Size:

The Central Massachusetts Regional Planning Commission (CMRPC) recommend 300 surveys for our proposed ITS study. They also provided us with an excel document detailing how they select the sample size for surveys they conduct.

Having a wide range of things covered by our proposed survey, we recommend a survey goal of at least 500 paper responses. We also were asked to pioneer distributing these surveys through different social media and communication services. By using the equation the CMRPC used in their excel calculations in conjunction with the numbers of users of each different media outlet we determined the number of surveys needed for each media source.

For our proposed survey we recommend that the WRTA conduct 584 Paper surveys, 102 Facebook Surveys, 18 Twitter Surveys, 222 Text Surveys, and 1000 Surveys linked from the WRTA website.

Variables:

- Number of surveys per route - to ensure that demographics results are representative of actual ridership, more paper surveys are necessary on busier routes, and less on less busy routes. Therefore, we calculated 15% of the total ridership per route as reported by RideCheck Plus and made that the goal for surveys taken per route.
- Day of the week - in order to isolate the change in ridership per weekday, we recommend the WRTA conduct 20% of the surveys on Saturday, 20% on Sunday, and the remaining 60% taken during weekdays. If a route does not operate on Saturday or Sunday, the additional 20% is added to the weekday surveys.
- Determining who to survey - We determined that for the in person survey it is necessary to control the way potential survey takers are selected in order to maintain a random sample. We determined that for all routes surveyors would need to approach a rider to survey every 5th rider to board a bus. In the case of the 5th rider being a minor, or an adult choosing not to take the survey, the surveyor should ask the next available rider until someone accepts. Then the count to 5 begins again.
- Guaranteeing the consistency of surveyors - because the actual in-person surveying will most likely be done using multiple surveyors, a system to ensure that each was following the same methods needs to be developed.

Breakdown of surveys by route and day of the week:

				Surveys per day of the week (rounded)					
Route	Surveys per Route		Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	19		4	2	2	2	2	2	4
2	32		6	4	4	4	4	4	6
3	24		X	4	4	4	4	4	5
4	18		4	2	2	2	2	2	4
5	33		7	4	4	4	4	4	7
6	19		X	4	4	4	4	4	4
7	37		7	4	4	4	4	4	7
8	0		X	0	0	0	0	0	X
11	37		7	4	4	4	4	4	7
14	11		X	2	2	2	2	2	2
15	21		X	4	4	4	4	4	4
16	20		X	4	4	4	4	4	4
18	0		X	0	0	0	0	0	X
19	35		7	4	4	4	4	4	7
22	14		X	3	3	3	3	3	X
23	32		6	4	4	4	4	4	6
24,34	35		7	4	4	4	4	4	7
25	9		X	2	2	2	2	2	2
26	34		7	6	6	6	6	6	X
27	38		8	5	5	5	5	5	8
29	0		X	0	0	0	0	0	X
30	44		9	8	8	8	8	8	X
31	21		X	4	4	4	4	4	4
33	14		X	3	3	3	3	3	X
42	10		X	2	2	2	2	2	2
	Total:	557			Total Surveys		584		

APPENDIX C: On Time Performance Data

2010

Location	Number of Checks	Number On Time	Percent On Time
JANUARY			
City Hall	137	117	85.4%
End of Line	31	25	80.6%
Billings Sq.	36	28	100.0%
Britton Sq.	26	21	80.8%
Newton Sq.	41	35	85.4%
Umass	19	12	63.2%
Webster Sq.	24	22	91.7%
Clark University	29	27	93.1%
Other	51	45	88.2%
OVERALL	394	332	84.3%
FEBRUARY			
City Hall	83	74	89.2%
End of Line	37	32	86.5%
Billings Sq.	14	13	92.9%
Britton Sq.	12	9	75.0%
Newton Sq.	24	19	79.2%
Umass	28	24	85.7%
Webster Sq.	34	29	85.3%
Clark University	24	20	83.3%
Other	91	73	80.2%
OVERALL	347	293	84.4%
MARCH			
City Hall	101	88	87.1%
End of Line	21	12	57.1%
Billings Sq.	6	6	100.0%
Britton Sq.	65	54	83.1%
Newton Sq.	37	33	89.2%
Umass	35	30	85.7%
Webster Sq.	10	8	80.0%
Clark University	35	28	80.0%
Other	148	131	88.5%
OVERALL	458	390	85.2%
APRIL			
City Hall	77	59	76.6%
End of Line	4	4	100.0%
Billings Sq.	22	20	90.9%
Britton Sq.	26	19	73.1%

Newton Sq.	10	9	90.0%
Umass	39	29	74.4%
Webster Sq.	17	12	70.6%
Clark University	12	10	83.3%
Other	135	117	86.7%
OVERALL	342	279	81.6%
MAY			
City Hall	101	85	84.2%
End of Line	34	28	82.4%
Billings Sq.	21	15	100.0%
Britton Sq.	39	29	74.4%
Newton Sq.	20	16	80.0%
Umass	21	18	85.7%
Webster Sq.	23	21	91.3%
Clark University	23	17	73.9%
Other	141	112	79.4%
OVERALL	423	341	80.6%
JUNE			
City Hall	93	73	78.5%
End of Line	47	35	74.5%
Billings Sq.	19	14	100.0%
Britton Sq.	34	27	79.4%
Newton Sq.	23	17	73.9%
Umass	39	31	79.5%
Webster Sq.	28	23	82.1%
Clark University	21	18	85.7%
Other	83	74	89.2%
OVERALL	387	312	80.6%
JULY			
City Hall	93	80	86.0%
End of Line	27	22	81.5%
Billings Sq.	15	11	73.3%
Britton Sq.	34	30	88.2%
Newton Sq.	15	11	73.3%
Umass	15	12	80.0%
Webster Sq.	16	12	75.0%
Clark University	17	14	82.4%
Other	88	70	79.5%
OVERALL	320	262	81.9%
AUGUST			
City Hall	59	53	89.8%
End of Line	36	29	80.6%

Billings Sq.	21	18	85.7%
Britton Sq.	23	21	91.3%
Newton Sq.	13	10	76.9%
Umass	21	17	81.0%
Webster Sq.	30	24	80.0%
Clark University	6	5	83.3%
Other	111	99	89.2%
OVERALL	320	276	86.3%
SEPTEMBER			
City Hall	76	67	88.2%
End of Line	16	14	87.5%
Billings Sq.	8	8	100.0%
Britton Sq.	30	22	73.3%
Newton Sq.	17	15	88.2%
Umass	33	25	75.8%
Webster Sq.	29	24	82.8%
Clark University	12	8	66.7%
Other	103	86	83.5%
OVERALL	324	269	83.0%
OCTOBER			
City Hall	65	55	84.6%
End of Line	26	18	69.2%
Billings Sq.	8	7	87.5%
Britton Sq.	36	29	80.6%
Newton Sq.	23	23	100.0%
Umass	21	16	76.2%
Webster Sq.	40	33	82.5%
Wal-Mart	41	27	65.9%
Clark University	12	10	83.3%
Other	87	71	81.6%
OVERALL	359	289	80.5%
NOVEMBER			
City Hall	36	31	86.1%
End of Line	17	15	88.2%
Billings Sq.	8	8	100.0%
Britton Sq.	19	12	63.2%
Newton Sq.	54	51	94.4%
Umass	14	12	85.7%
Webster Sq.	31	29	93.5%
Wal-Mart	18	15	83.3%
Clark University	38	34	89.5%
Other	63	49	77.8%

OVERALL	298	256	85.9%
DECEMBER			
City Hall	78	70	89.7%
End of Line	11	10	90.9%
Billings Sq.	3	3	100.0%
Britton Sq.	11	10	90.9%
Newton Sq.	20	17	85.0%
Umass	21	20	95.2%
Webster Sq.	8	6	75.0%
Wal-Mart	8	7	87.5%
Clark University	22	21	95.5%
Other	56	51	91.1%
OVERALL	238	215	90.3%

2010 TOTALS			
	Number of Checks	Number On Time	Percent On Time
January	394	332	84.3%
February	347	293	84.4%
March	458	390	85.2%
April	342	279	81.6%
May	423	341	80.6%
June	387	312	80.6%
July	320	262	81.9%
August	320	276	86.3%
September	324	269	83.0%
October	359	289	80.5%
November	298	256	85.9%
December	238	215	90.3%
TOTAL	**4210**	**3514**	**83.5%**

2011

Location	Number of Checks	Number On Time	Percent On Time
JANUARY			
City Hall	32	29	90.6%
End of Line	14	12	85.7%
Billings Sq.	8	7	87.5%
Britton Sq.	19	16	84.2%
Newton Sq.	6	6	100.0%
Umass	6	5	83.3%

Webster Sq.	23	17	73.9%
Wal-Mart	19	15	78.9%
Clark University	14	13	92.9%
Other	21	20	95.2%
OVERALL	162	140	86.4%
FEBRUARY			
City Hall	71	66	93.0%
End of Line	11	9	81.8%
Billings Sq.	3	2	66.7%
Britton Sq.	21	19	90.5%
Newton Sq.	2	1	50.0%
Umass	3	3	100.0%
Webster Sq.	8	7	87.5%
Wal-Mart	23	19	82.6%
Clark University	1	1	100.0%
Other	4	3	75.0%
OVERALL	147	130	88.4%
MARCH			
City Hall	63	57	90.5%
End of Line	11	10	90.9%
Billings Sq.	3	3	100.0%
Britton Sq.	9	7	77.8%
Newton Sq.	17	16	94.1%
Umass	6	5	83.3%
Webster Sq.	20	17	85.0%
Wal-Mart	25	21	84.0%
Clark University	12	12	100.0%
Other	54	50	92.6%
OVERALL	220	198	90.0%
APRIL			
City Hall	135	123	91.1%
End of Line	3	3	100.0%
UMASS	24	21	87.5%
Britton Sq.	41	34	82.9%
Newton Sq.	20	19	95.0%
Union Station	14	12	85.7%
Webster Sq.	27	18	66.7%
Wal-Mart	41	34	82.9%
Clark University	6	3	50.0%
Other	79	64	81.0%
OVERALL	390	331	84.9%
MAY			

City Hall	93	80	86.0%
End of Line	24	21	87.5%
UMASS	33	30	90.9%
Britton Sq.	41	31	75.6%
Newton Sq.	27	27	100.0%
Union Station	3	3	100.0%
Webster Sq.	13	11	84.6%
Wal-Mart	27	24	88.9%
Clark University	5	4	80.0%
Other	92	75	81.5%
OVERALL	358	306	85.5%
JUNE			
City Hall	138	126	91.3%
End of Line	8	6	75.0%
UMASS	25	19	76.0%
Britton Sq.	40	31	77.5%
Newton Sq.	20	17	85.0%
Union Station	7	5	71.4%
Webster Sq.	26	25	96.2%
Wal-Mart	17	14	82.4%
Clark University	4	4	100.0%
Other	52	46	88.5%
OVERALL	337	293	86.9%
JULY			
City Hall	108	101	93.5%
End of Line	56	47	83.9%
UMASS	18	15	83.3%
Britton Sq.	46	40	87.0%
Newton Sq.	6	6	100.0%
Union Station	12	10	83.3%
Webster Sq.	18	17	94.4%
Wal-Mart	22	16	72.7%
Clark University	5	5	100.0%
Other	78	71	91.0%
OVERALL	369	328	88.9%
AUGUST			
City Hall	168	153	91.1%
End of Line	33	26	78.8%
UMASS	34	31	91.2%
Britton Sq.	19	18	94.7%
Newton Sq.	12	11	91.7%
Union Station	6	5	83.3%
Webster Sq.	25	22	88.0%

Wal-Mart	24	20	83.3%
Clark University	12	8	66.7%
Other	75	67	89.3%
OVERALL	408	361	88.5%
SEPTEMBER			
City Hall	64	50	78.1%
End of Line	47	38	80.9%
UMASS	65	54	83.1%
Britton Sq.	48	42	87.5%
Newton Sq.	37	36	97.3%
Union Station	17	15	88.2%
Webster Sq.	42	28	66.7%
Wal-Mart	36	31	86.1%
Clark University	8	7	87.5%
Other	123	109	88.6%
OVERALL	487	410	84.2%
OCTOBER			
City Hall	143	119	83.2%
End of Line	34	26	76.5%
UMASS	32	30	93.8%
Britton Sq.	31	29	93.5%
Newton Sq.	21	21	100.0%
Union Station	12	10	83.3%
Webster Sq.	23	17	73.9%
Wal-Mart	18	15	83.3%
Clark University	20	16	80.0%
Other	95	84	88.4%
OVERALL	429	367	85.5%
NOVEMBER			
City Hall	86	67	77.9%
End of Line	29	23	79.3%
UMASS	37	26	70.3%
Britton Sq.	38	36	94.7%
Newton Sq.	35	32	91.4%
Union Station	17	15	88.2%
Webster Sq.	24	19	79.2%
Wal-Mart	29	25	86.2%
Clark University	19	17	89.5%
Other	67	54	80.6%
OVERALL	381	314	82.4%
DECEMBER			
City Hall	131	104	79.4%

End of Line	18	18	100.0%
UMASS	17	16	94.1%
Britton Sq.	23	21	91.3%
Newton Sq.	12	12	100.0%
Union Station	27	23	85.2%
Webster Sq.	21	17	81.0%
Wal-Mart	28	21	75.0%
Clark University	15	13	86.7%
Other	98	83	84.7%
OVERALL	390	328	84.1%

2011 TOTALS			
	Number of Checks	Number On Time	Percent On Time
January	162	140	86.4%
February	147	130	88.4%
March	220	198	90.0%
April	390	331	84.9%
May	358	306	85.5%
June	337	293	86.9%
July	369	328	88.9%
August	408	361	88.5%
September	487	410	84.2%
October	429	367	85.5%
November	381	314	82.4%
December	390	328	84.1%
TOTAL	**4078**	**3506**	**86.0%**

2012

Location	Number of Checks	Number On Time	Percent On Time
JANUARY			
City Hall	124	96	77.4%
End of Line	15	12	80.0%
UMASS	35	30	85.7%
Britton Sq.	12	11	91.7%
Newton Sq.	17	17	100.0%
Union Station	7	5	71.4%
Webster Sq.	16	15	93.8%
Wal-Mart	31	24	77.4%

Clark University	17	15	88.2%
Other	124	104	83.9%
OVERALL	398	329	82.7%
FEBRUARY			
City Hall	103	91	88.3%
End of Line	37	33	89.2%
UMASS	42	35	83.3%
Britton Sq.	12	11	91.7%
Newton Sq.	17	14	82.4%
Union Station	14	13	92.9%
Webster Sq.	31	24	77.4%
Wal-Mart	23	21	91.3%
Clark University	9	8	88.9%
Other	74	62	83.8%
OVERALL	362	312	86.2%
MARCH			
City Hall	171	147	86.0%
End of Line	7	6	85.7%
UMASS	14	13	92.9%
Britton Sq.	5	5	100.0%
Newton Sq.	12	9	75.0%
Union Station	21	17	81.0%
Webster Sq.	23	19	82.6%
Wal-Mart	12	10	83.3%
Clark University	7	6	85.7%
Other	67	58	86.6%
OVERALL	339	290	85.5%
APRIL			
City Hall	85	67	78.8%
End of Line	37	32	86.5%
UMASS	23	17	73.9%
Britton Sq.	12	12	100.0%
Newton Sq.	19	14	73.7%
Union Station	23	19	82.6%
Webster Sq.	35	31	88.6%
Wal-Mart	25	22	88.0%
Clark University	11	10	90.9%
Other	73	61	83.6%
OVERALL	343	285	83.1%
MAY			
City Hall	83	67	80.7%
End of Line	37	29	78.4%

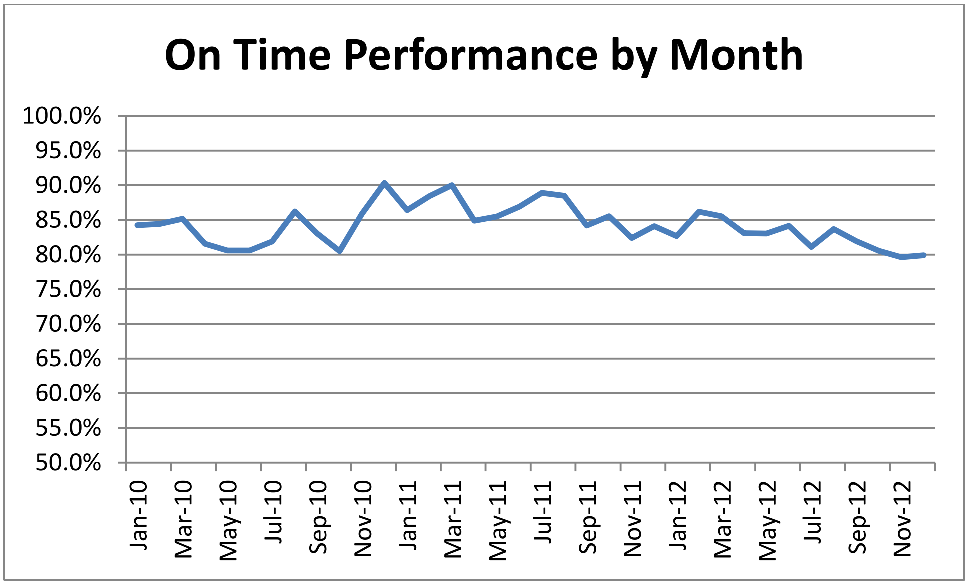
UMASS	17	14	82.4%
Britton Sq.	12	10	83.3%
Newton Sq.	12	9	75.0%
Union Station	17	15	88.2%
Webster Sq.	23	19	82.6%
Wal-Mart	21	19	90.5%
Clark University	14	14	100.0%
Other	71	59	83.1%
OVERALL	307	255	83.1%
JUNE			
City Hall	71	57	80.3%
End of Line	39	34	87.2%
UMASS	23	19	82.6%
Britton Sq.	11	10	90.9%
Newton Sq.	12	12	100.0%
Union Station	21	17	81.0%
Webster Sq.	27	23	85.2%
Wal-Mart	31	26	83.9%
Clark University	10	9	90.0%
Other	83	69	83.1%
OVERALL	328	276	84.1%
JULY			
City Hall	73	59	80.8%
End of Line	45	35	77.8%
UMASS	23	19	82.6%
Britton Sq.	12	11	91.7%
Newton Sq.	14	9	64.3%
Union Station	12	9	75.0%
Webster Sq.	17	14	82.4%
Wal-Mart	21	15	71.4%
Clark University	12	11	91.7%
Other	83	71	85.5%
OVERALL	312	253	81.1%
AUGUST			
City Hall	77	63	81.8%
End of Line	35	29	82.9%
UMASS	16	14	87.5%
Britton Sq.	23	20	87.0%
Newton Sq.	17	17	100.0%
Union Station	14	12	85.7%
Webster Sq.	31	26	83.9%
Wal-Mart	27	23	85.2%
Clark	8	8	100.0%

University			
Other	71	55	77.5%
OVERALL	319	267	83.7%
SEPTEMBER			
City Hall	71	59	83.1%
End of Line	33	27	81.8%
UMASS	23	19	82.6%
Britton Sq.	7	6	85.7%
Newton Sq.	11	9	81.8%
Union Station	17	14	82.4%
Webster Sq.	27	19	70.4%
Wal-Mart	21	17	81.0%
Clark University	12	10	83.3%
Other	55	47	85.5%
OVERALL	277	227	81.9%
OCTOBER			
City Hall	77	63	81.8%
End of Line	59	43	72.9%
UMASS	23	17	73.9%
Britton Sq.	7	7	100.0%
Newton Sq.	12	10	83.3%
Union Station	27	23	85.2%
Webster Sq.	29	23	79.3%
Wal-Mart	14	12	85.7%
Clark University	15	12	80.0%
Other	71	59	83.1%
OVERALL	334	269	80.5%
NOVEMBER			
City Hall	47	38	80.9%
End of Line	51	37	72.5%
UMASS	23	17	73.9%
Britton Sq.	11	9	81.8%
Newton Sq.	14	13	92.9%
Union Station	23	19	82.6%
Webster Sq.	31	24	77.4%
Wal-Mart	27	23	85.2%
Clark University	5	5	100.0%
Other	53	42	79.2%
OVERALL	285	227	79.6%
DECEMBER			
City Hall	71	57	80.3%
End of Line	2	2	100.0%
UMASS	17	13	76.5%

Britton Sq.	12	10	83.3%
Newton Sq.	14	9	64.3%
Union Station	23	17	73.9%
Webster Sq.	11	10	90.9%
Wal-Mart	19	15	78.9%
Clark University	12	9	75.0%
Other	83	69	83.1%
OVERALL	264	211	79.9%

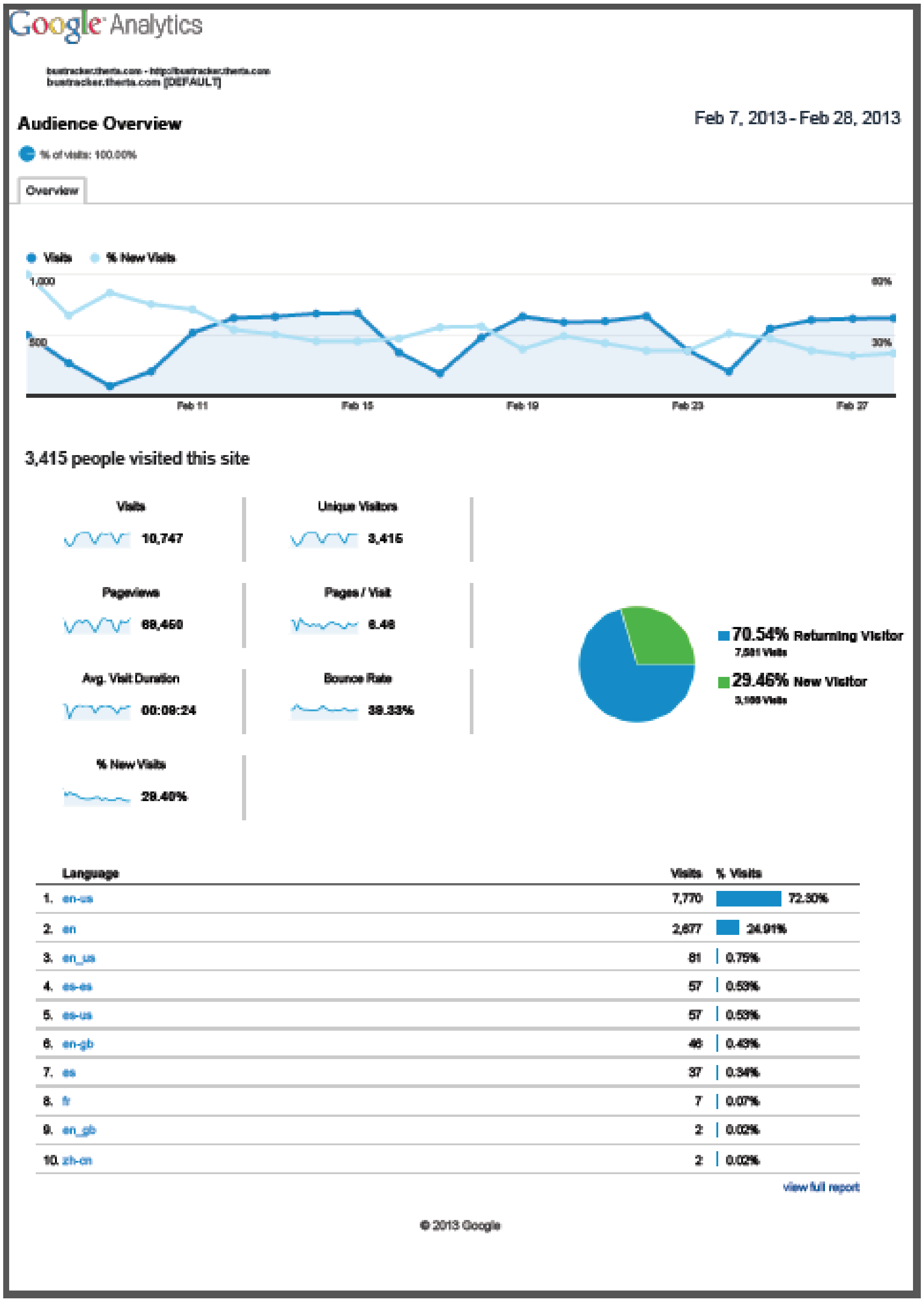
2012 TOTALS			
	Number of Checks	Number On Time	Percent On Time
January	398	329	82.7%
February	362	312	86.2%
March	339	290	85.5%
April	343	285	83.1%
May	307	255	83.1%
June	328	276	84.1%
July	312	253	81.1%
August	319	267	83.7%
September	277	227	81.9%
October	334	269	80.5%
November	285	227	79.6%
December	264	211	79.9%
TOTAL	**3868**	**3201**	**82.8%**

2010-2012



On Time Performance by Month
100.0%
95.0%
90.0%
85.0%
80.0%
75.0%
70.0%
65.0%
60.0%
55.0%
50.0%
Jan-10
Mar-10
May-10
Jul-10
Sep-10
Nov-10
Jan-11
Mar-11
May-11
Jul-11
Sep-11
Nov-11
Jan-12
Mar-12
May-12
Jul-12
Sep-12
Nov-12

Appendix D: Google Analytics



Google Analytics

bustracker.therta.com - http://bustracker.therta.com
bustracker.therta.com [DEFAULT]

Audience Overview

Feb 7, 2013 - Feb 28, 2013

% of visits: 100.00%

Overview

3,415 people visited this site

Visits	10,747
Unique Visitors	3,415
Pageviews	69,460
Pages / Visit	6.46
Avg. Visit Duration	00:09:24
Bounce Rate	39.33%
% New Visits	29.40%

70.54% Returning Visitor
7,581 Visits

29.46% New Visitor
3,166 Visits

	Language	Visits	% Visits
1.	en-us	7,770	72.30%
2.	en	2,677	24.91%
3.	en_us	81	0.75%
4.	es-es	57	0.53%
5.	es-us	57	0.53%
6.	en-gb	46	0.43%
7.	es	37	0.34%
8.	fr	7	0.07%
9.	en_gb	2	0.02%
10.	zh-cn	2	0.02%

view full report

Appendix E: Transit Agencies for Ridership Comparison

The 10 transit agencies that were chosen amongst the nation based on ridership and service area (in square miles) include:

- Central Midlands Regional Transit Authority (SC)
- Charleston Area Regional Transportation Authority (SC)
- Dutchess County Division of Mass Transportation (NY)
- Escambia County Area Transit (FL)
- Interurban Transit Partnership (MI)
- Knoxville Area Transit (TN)
- Lee County Transit (FL)
- Mountain Metropolitan Transit (CO)
- Toledo Area Regional Transit Authority (OH)
- Wichita Transit (KS)

Additionally, the 14 local transit agencies that were chosen for their geographical location to Worcester, along with ridership size, included:

- Berkshire Regional Transit Authority
- Brockton Area Transit Authority
- Cape Ann Transportation Authority
- Cape Cod Regional Transit Authority
- Franklin Regional Transit Authority
- Greater Attleboro Regional Transit Authority
- Lowell Regional Transit Authority
- Vineyard Transit Authority
- Merrimack Valley Regional Transit Agency
- MetroWest Regional Transit Authority
- Montachusett Regional Transit Authority
- Nantucket Regional Transit Authority
- Pioneer Valley Transit Authority
- Southeastern Regional Transit Authority

Appendix F: Ridership Data

Ridership Annual Trends

Company/Year	'06-'07	'07-'08	'08-'09	'09-'10	'10-'11
WRTA	-1.28%	-0.68%	1.85%	0.04%	5.69%
National Transit Agencies	'06-'07	'07-'08	'08-'09	'09-'10	'10-'11
Central Midlands Regional Transit Authority (SC)	-24.80%	19.07%	-21.20%	8.16%	-1.65%
Charleston Area Regional Transportation Authority (SC)	-4.64%	35.26%	15.17%	3.79%	1.79%
Dutchess County Division of Mass Transportation (NY)	-24.36%	7.05%	-20.71%	-20.68%	-7.64%
Escambia County Area Transit (FL)	-12.89%	11.81%	-5.06%	0.19%	17.41%
Interurban Transit Partnership (MI)	9.99%	11.23%	3.40%	4.24%	10.99%
Knoxville Area Transit (TN)	-6.84%	8.60%	-18.19%	-8.89%	25.25%
Lee County Transit (FL)	4.70%	-2.32%	-1.81%	-2.08%	7.61%
Mountain Metropolitan Transit (CO)	10.88%	2.06%	-10.59%	-42.47%	30.76%
Toledo Area Regional Transit Authority (OH)	-5.18%	22.26%	1.33%	-40.08%	-6.71%
Wichita Transit (KS)	-3.73%	7.36%	-1.63%	17.11%	-1.05%
Total National Transit Ridership	-5.69%	12.24%	-5.93%	-8.07%	7.68%
Local Transit Agencies	'06-'07	'07-'08	'08-'09	'09-'10	'10-'11
Berkshire Regional Transit Authority	1.03%	2.65%	9.46%	-12.03%	2.00%
Brockton Area Transit Authority	-0.32%	5.84%	-3.69%	2.16%	-2.94%
Cape Ann Transportation Authority	2.61%	-7.67%	-0.42%	-2.97%	9.14%
Cape Cod Regional Transit Authority	9.93%	3.71%	0.69%	8.40%	14.74%
Pioneer Valley Tansit Authority	4.67%	8.53%	23.54%	-30.58%	-6.79%
Greater Attleboro Regional Transit Authority	5.23%	6.37%	2.01%	-2.61%	12.99%
Lowell Regional Transit Authority	-0.78%	5.05%	5.02%	-4.72%	3.98%
Montachusett Regional Transit Authority	11.35%	-23.36%	29.42%	-5.76%	-4.63%
Merrimack Valley Regional Transit Agency	17.96%	7.43%	16.52%	-20.75%	10.96%
MetroWest Regional Transit Authority	N/A	N/A	-36.05%	69.40%	3.73%
Total Local Transit Ridership	5.17%	0.85%	4.65%	0.05%	4.32%

Total Ridership

Company/Year	2006	2007	2008	2009	2010	2011
WRTA	18,274	18,041	17,918	18,249	18,256	19,294
National Transit Agencies	2006	2007	2008	2009	2010	2011
Central Midlands Regional Transit Authority (SC)	13,931	10,476	12,474	9,830	10,632	10,457
Charleston Area Regional Transportation Authority (SC)	19,006	18,124	24,515	28,234	29,305	29,831
Dutchess County Division of Mass Transportation (NY)	5,062	3,829	4,099	3,250	2,578	2,381
Escambia County Area Transit (FL)	6,658	5,800	6,485	6,157	6,169	7,243
Interurban Transit Partnership (MI)	38,194	42,010	46,729	48,317	50,366	55,902
Knoxville Area Transit (TN)	18,476	17,212	18,692	15,291	13,931	17,449
Lee County Transit (FL)	19,672	20,597	20,119	19,755	19,344	20,817
Mountain Metropolitan Transit (CO)	19,059	21,132	21,568	19,283	11,094	14,506
Toledo Area Regional Transit Authority (OH)	33,348	31,621	38,659	39,175	23,474	21,898
Wichita Transit (KS)	12,673	12,200	13,098	12,884	15,089	14,931
Total National Transit Ridership	186,079	183,001	206,438	202,176	181,982	195,415
Local Transit Agencies	2006	2007	2008	2009	2010	2011
Berkshire Regional Transit Authority	3,098	3,130	3,213	3,517	3,094	3,156
Brockton Area Transit Authority	15,933	15,882	16,809	16,188	16,538	16,052
Cape Ann Transportation Authority	1,996	2,048	1,891	1,883	1,827	1,994
Cape Cod Regional Transit Authority	4,171	4,585	4,755	4,788	5,190	5,955
Pioneer Valley Tansit Authority	57,530	60,217	65,353	80,734	56,048	52,240
Greater Attleboro Regional Transit Authority	4,534	4,771	5,075	5,177	5,042	5,697
Lowell Regional Transit Authority	6,385	6,335	6,655	6,989	6,659	6,924
Montachusett Regional Transit Authority	4,624	5,149	3,946	5,107	4,813	4,590
Merrimack Valley Regional Transit Agency	9,370	11,053	11,874	13,836	10,965	12,167
MetroWest Regional Transit Authority	-	-	2,003	1,281	2,170	2,251
Total Local Transit Ridership	107,641	113,170	121,574	139,500	112,346	111,026

Appendix G: Work Order Data

TOTAL ROAD CALL COSTS											
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	TOTAL
MECHANICAL											
A/C	21,663.81	14,290.05	9,238.93	10,703.70	6,030.71	6,201.82	10,647.97	19,495.03	28,188.41	16,344.11	142,804.54
Parts	10,256.49	6,970.20	2,530.05	5,558.03	2,422.19	3,191.55	4,882.28	9,626.24	13,419.67	8,071.61	66,928.31
Labor	11,407.32	7,319.85	6,708.88	5,145.67	3,608.52	3,010.27	5,765.69	9,868.79	14,768.74	8,272.50	75,876.23
Air System	6,586.48	6,028.00	7,938.86	8,622.18	11,304.29	6,059.25	8,934.39	9,743.02	9,968.57	7,122.30	82,307.34
Parts	3,805.06	3,390.62	3,895.42	5,121.48	7,203.19	3,868.46	5,104.59	5,630.22	6,495.19	3,734.64	48,248.87
Labor	2,781.42	2,637.38	4,043.44	3,500.70	4,101.10	2,190.79	3,829.80	4,112.80	3,473.38	3,387.66	34,058.47
Body	64.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13,141.91	13,206.52
Parts	43.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7,601.30	7,645.14
Labor	20.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5,540.61	5,561.38
Wheelchair Lift	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5,332.76	5,332.76
Parts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4,386.30	4,386.30
Labor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	946.46	946.46
Doors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2,277.07	2,277.07
Parts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,221.80	1,221.80
Labor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,055.27	1,055.27
Electrical	644.60	267.92	180.08	180.74	389.12	454.18	1,492.13	370.13	514.18	4,773.89	9,266.97
Parts	285.89	98.43	70.43	74.24	172.78	198.48	518.34	219.32	143.91	3,161.08	4,942.90
Labor	358.71	169.49	109.65	106.50	216.34	255.70	973.79	150.81	370.27	1,612.81	4,324.07
Engine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22,343.28	22,343.28
Parts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14,349.80	14,349.80
Labor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7,993.48	7,993.48
Transmission	41,474.93	16,781.62	9,435.70	13,488.44	16,852.46	6,922.88	11,058.04	8,628.41	14,003.08	9,332.23	147,977.79
Parts	31,557.53	8,968.30	3,585.09	8,334.44	9,785.18	3,413.53	4,146.35	4,438.47	9,762.19	4,884.80	88,875.88
Labor	9,917.40	7,813.32	5,850.61	5,154.00	7,067.28	3,509.35	6,911.69	4,189.94	4,240.89	4,447.43	59,101.91
NON -MECHANICAL											
Farebox	17,140.90	34,909.29	14,809.60	5,388.96	4,958.48	4,904.69	7,917.61	7,594.17	24,559.70	3,075.16	125,258.56
Parts	14,395.96	32,340.80	13,079.69	4,851.24	4,521.61	4,415.92	7,055.94	6,390.30	22,924.62	2,880.55	112,856.63
Labor	2,744.94	2,568.49	1,729.91	537.72	436.87	488.77	861.67	1,203.87	1,635.08	194.61	12,401.93
TOTAL	116,534.83	92,862.85	58,961.04	57,890.64	57,259.18	37,258.07	61,124.63	75,438.94	115,905.10	155,078.03	828,313.31

TOTAL WORK ORDERS											
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	TOTAL
MECHANICAL											
A/C	147	88	64	45	32	25	38	63	85	57	644
Air System	36	44	63	52	47	29	44	38	40	25	418
Body	1	0	0	0	0	0	0	0	0	56	57
Wheelchair Lift	0	0	0	0	0	0	0	0	0	18	18
Doors	0	0	0	0	0	0	0	0	0	13	13
Electrical	9	7	5	3	7	3	6	7	4	52	103
Engine	0	0	0	0	0	0	0	0	0	74	74
Transmission	84	95	74	66	59	26	41	38	37	34	554
NON - MECHANICAL											

Fare box	53	27	39	17	13	19	26	24	41	7	266
TOTAL	330	261	245	183	158	102	155	170	207	336	2,147

AVERAGE ROAD CALL COSTS											TOTAL
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	AVERAGE
MECHANICAL											
A/C	147.37	162.39	144.36	237.86	188.46	248.07	280.21	309.44	331.63	286.74	221.75
Parts	69.77	79.21	39.53	123.51	75.69	127.66	128.48	152.80	157.88	141.61	103.93
Labor	77.60	83.18	104.83	114.35	112.77	120.41	151.73	156.65	173.75	145.13	117.82
Air System	182.96	137.00	126.01	165.81	240.52	208.94	203.05	256.40	249.21	284.89	196.91
Parts	105.70	77.06	61.83	98.49	153.26	133.40	116.01	148.16	162.38	149.39	115.43
Labor	77.26	59.94	64.18	67.32	87.26	75.54	87.04	108.23	86.83	135.51	81.48
Body	64.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	234.68	231.69
Parts	43.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	135.74	134.13
Labor	20.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	98.94	97.57
Wheelchair Lift	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	296.26	296.26
Parts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	243.68	243.68
Labor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	52.58	52.58
Doors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	175.16	175.16
Parts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	93.98	93.98
Labor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	81.17	81.17
Electrical	71.62	38.27	36.02	60.25	55.59	151.39	248.69	52.88	128.55	91.81	89.97
Parts	31.77	14.06	14.09	24.75	24.68	66.16	86.39	31.33	35.98	60.79	47.99
Labor	39.86	24.21	21.93	35.50	30.91	85.23	162.30	21.54	92.57	31.02	41.98
Engine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	301.94	301.94
Parts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	193.92	193.92
Labor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	108.02	108.02
Transmission	493.75	176.65	127.51	204.37	285.63	266.26	269.71	227.06	378.46	274.48	267.11
Parts	375.68	94.40	48.45	126.28	165.85	131.29	101.13	116.80	263.84	143.67	160.43
Labor	118.06	82.25	79.06	78.09	119.78	134.98	168.58	110.26	114.62	130.81	106.68
NON -MECHANICAL											
Farebox	323.41	1,292.94	379.73	317.00	381.42	258.14	304.52	316.42	599.02	439.31	470.90
Parts	271.62	1,197.81	335.38	285.37	347.82	232.42	271.38	266.26	559.14	411.51	424.27
Labor	51.79	95.13	44.36	31.63	33.61	25.72	33.14	50.16	39.88	27.80	46.62
TOTAL AVERAGE	353.14	355.80	240.66	316.34	362.40	365.28	394.35	443.76	559.93	461.54	385.80