Chattanooga SmartBus Project: Phase III Evaluation Report

December 2009

Submitted to:
United States Department of Transportation
Intelligent Transportation Systems Joint Program Office
Federal Transit Administration

Submitted by:
Science Applications International Corporation

NOTICE

The U.S. Department of Transportation provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. USDOT periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvements.

This report is in draft format. Comments on this report should be provided to SAIC, via email or fax, to:

Robert Haas
Science Applications International Corporation
Phone: 865-481-2982
haasr@saic.com

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **Chattanooga SmartBus Project: Phase III Evaluation Report**		**5. Report Date** December 2009
		6. Performing Organization Code
7. Authors R. Haas (SAIC), E. Perry (SAIC), J. Rephlo (SAIC)		**8. Performing Organization Report No.**
9. Performing Organization Name and Address Science Applications International Corporation (SAIC) Mailstop E-12-3 8301 Greensboro Drive McLean, VA 22102		**10. Work Unit No. (TRAIS)**
		11. Contract or Grant No. DTFH61-02-C-00061; Task 61025
12. Sponsoring Agency Name and Address United States Department of Transportation ITS Joint Program Office Research and Innovative Technology Administration (RITA) 1200 New Jersey Avenue, SE Washington, DC 20590		**13. Type of Report and Period Covered**
		14. Sponsoring Agency Code HOIT-1

15. Supplementary Notes

Mr. Steve Mortensen, COTM (FTA), Mr. James Pol, COTR (ITS JPO), Ms. Marcia Pincus (ITS JPO)

16. Abstract

This report presents the results of Phase III of the national evaluation of the Chattanooga Area Regional Transportation Authority's (CARTA) SmartBus Project. The SmartBus Project is a comprehensive transit ITS program for the city of Chattanooga, Tennessee. It involves deployment of a wide array of transit ITS technologies including: data warehousing and reporting software; new operations management software to support fixed-route scheduling and demand response scheduling and dispatch; ticket vending machines for the Incline Railway; a remote diagnostics maintenance system; various on-board systems (mobile data computers, computer-aided dispatch / automated vehicle location software, a covert alarm, automated passenger counters, and a next stop automated announcement system); and new fareboxes, a revenue management system, and a multi-modal transit/parking SmartCard electronic fare payment system.

The goal of the evaluation is to determine the impacts of these technologies in performing daily functions such as operations, scheduling, service planning, and maintenance, and to gather and document any lessons learned by the project team throughout the process of the deployment and operation of the technologies. This report discusses impacts of the technologies that have been deployed. The evaluation involved interviews with CARTA staff, review of operations data, a survey of website users, and a review of systems engineering practices. The results of the evaluation indicate that CARTA has seen many benefits from the deployments. However, the fact that the deployment of one of the key technologies, CAD / AVL integration, is not complete has limited the observed benefits.

17. Key Words	18. Distribution Statement
Evaluation, Intelligent Transportation Systems (ITS), Computer-Aided Dispatch / Automated Vehicle Location (CAD/AVL), Mobile Data Terminals (MDT), Automated Announcement System (AAS), Scheduling Software, Paratransit, Transit, Ticket Vending Machines (TVM), Remote Diagnostic Maintenance System (RDMS)	No restrictions.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No of Pages	22. Price
Unclassified	Unclassified	75	N/A

TABLE OF CONTENTS

EXECUTIVE SUMMARY VII

1 INTRODUCTION 1

2 BACKGROUND ON CARTA AND THE SMARTBUS PROJECT 2

2.1 Overview of CARTA Operations 2

2.2 Overview of CARTA ITS Deployments 2

2.2.1 Data Warehousing and Reporting Software 3
2.2.2 Vehicle Fuel Usage System 4
2.2.3 Ticket Vending Machines 4
2.2.4 Maintenance Monitoring System 4
2.2.5 Operations Software 4
2.2.6 Network Connectivity for CARTA Vehicles 5
2.2.7 Fareboxes and Revenue Management System 5
2.2.8 Next Stop Automated Announcement System 5
2.2.9 Bus Arrival Time System 5
2.2.10 Remote Diagnostic Maintenance System 5
2.2.11 Automatic Passenger Counter 6
2.2.12 CAD/AVL 6
2.2.13 Future Plans 6

2.3 Overview of This Evaluation 6

2.3.1 Evaluation Phases 6
2.3.2 Evaluation Approach 7

3 OVERVIEW OF EVALUATION RESULTS 10

3.1 CARTA Data Warehouse and Reporting Software 10

3.2 Vehicle Fuel Usage System 11

3.3 Ticket Vending Machines 12

3.4 Operations Software 12

3.5 Network Connectivity for CARTA Vehicles 14

3.6 Fareboxes and Revenue Management System 15

3.7 Next Stop Automated Announcement System 17

3.8 Bus Arrival Time System 17

3.9 Remote Diagnostic Maintenance System 23

3.10 Automatic Passenger Counter 23

3.11 CAD/AVL 25

4 THE REMOTE DIAGNOSTICS MAINTENANCE SYSTEM 27

4.1 Background 27

4.2 Impacts/Summary 31

5 REVIEW OF THE CARTA SYSTEMS ENGINEERING PROCESS 32

5.1 Overview of the CARTA Systems Engineering Process 32

5.2 The CAD/AVL and Onboard Systems Deployment 33

5.3 Transitioning After the Departure of the Manager of Technology 34
5.4 Summary of Lessons Learned 35
6 SUMMARY AND CONCLUSIONS 37

LIST OF TABLES

Table 1. CARTA ITS Deployments. 3
Table 2. Status of Key Hypotheses 7
Table 3. Status of Secondary Hypotheses 8
Table 4. Status of Additional Hypotheses 9

LIST OF FIGURES

Figure 1. System Map of CARTA's Fixed Routes 2
Figure 2. Patron using Incline Ticket Vending Machines 12
Figure 3. CARTA Free WiFi Advertising 14
Figure 4. Number of Respondents that Use CARTA's Free Wireless Internet (N=37) 15
Figure 5. CARTA's Previous and New Fareboxes 16
Figure 6. CARTA SmartCards 16
Figure 7. A CARTA Bus Arrival Time Sign and a Bus Arrival Time Webpage 18
Figure 8. CARTA Bus Tracker Webpage 19
Figure 9. Number of Weekly CARTA Bus Tracker Website Visitors, Jan 2009-Sept 2009 19
Figure 10. Frequency of Use of the Bus Arrival Time System (N=37) 20
Figure 11. Frequency of Use of the Bus Arrival Time System for Frequent and Infrequent Bus Riders (N=37) 20
Figure 12. Reasons for Using the Bus Arrival Time System (N=29) 21
Figure 13. Actions Taking After Consulting the Bus Arrival Time System (N=29) 21
Figure 14. Respondents Agreement that the Bus Arrival Time System Saved Them Time (N=29) 22
Figure 15. Respondents Agreement That the Bus Arrival Time System Made Them More Satisfied With Transit (N=29) 22
Figure 16. Respondents Agreement That the Bus Arrival Time System Caused Them to Use Transit More Often (N=29) 23
Figure 17. An Installed APC Device 23
Figure 18. CARTA Supervisor Using the Fixed-route CAD/AVL System 25
Figure 19. The Fixed-route CAD/AVL Map Display Screen 25
Figure 20. CARTA Vehicle Being Repaired 27
Figure 21. CARTA Mechanic at RDMS Terminal 27
Figure 22. CARTA Staff Reviewing RDMS Report 28
Figure 23. Month-by-Month Comparison of Minor Road Calls, 2008 vs 2009 29
Figure 24. Month-by-Month Comparison of Major Road Calls, 2008 vs 2009 29
Figure 25. The CARTA ITS System Overview Diagram 32

Photo Credits:
Cover photos and Figures 2, 3, 5, 6, 7 (left), 17, 18, 19, 20, 21 and 22: Science Applications International Corporation (SAIC) under contract to the U.S. Department of Transportation
Figures 1, 7 (right), 8 and Appendix A: Chattanooga Region Transportation Authority (CARTA)

GLOSSARY OF ACRONYMS

AAS	Automated Announcement System
APC	Automatic Passenger Counter
AVL	Automatic Vehicle Location
CAD	Computer-Aided Dispatch
CARTA	Chattanooga Area Regional Transportation Authority
DMS	Dynamic Message Sign
EVDO	Evolution-Data Optimized
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GPS	Global Positioning System
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
MAC-ITS	Multi-Agency Coordinated ITS Initiative
MDC	Mobile Data Computer
MOE	Measure of Effectiveness
RDMS	Remote Diagnostic Maintenance System
TSP	Transit Signal Priority
TVM	Ticket Vending Machine
USDOT	United States Department of Transportation
UTC	University of Tennessee at Chattanooga
WLAN	Wireless Local Area Networks

EXECUTIVE SUMMARY

The purpose of this document is to present the Phase III results from the national evaluation of the Chattanooga Area Regional Transportation Authority's (CARTA's) SmartBus Project, a project that is being implemented in part with fiscal year (FY03) ITS Integration Program earmark funding and being evaluated by the US Department of Transportation (USDOT) Intelligent Transportation Systems Joint Program Office (ITS JPO) and the Federal Transit Administration (FTA). In a typical national ITS evaluation, the Phase II results report on "before" data analysis for the new ITS technologies planned for deployment. Because several of these new technologies were already deployed at the start of Phase II of the evaluation, the Chattanooga SmartBus Project Final Phase II Evaluation Report presented information not only on the baseline or "before" conditions for the project elements that were not yet in place, but also on the "before" and "after" findings from analysis of the technologies that were already in place This report will highlight the findings presented in the Phase II report as well as report on the findings of the evaluation of the remaining systems that were deployed since publication of the Phase II report.

BACKGROUND ON CARTA AND THE SMARTBUS PROJECT

Chattanooga, Tennessee is a city of about 170,000 people (about 500,000 in the metropolitan area) located near the Tennessee-Georgia border. CARTA serves this community by providing fixed-route bus service (16 routes), curb-to-curb transit for people with disabilities (Care-A-Van), a free electric shuttle in the downtown area, an incline railway up historic Lookout Mountain, several parking garages, and management for much of the on-street parking in the downtown area. It is a moderate-sized transit organization in a moderate-sized community.

The CARTA SmartBus project is a comprehensive transit ITS program for the city of Chattanooga, Tennessee. It involves deployment of a wide array of transit ITS technologies deployed over a long period of time, including:

- Data warehousing and reporting software to accumulate data from different CARTA applications and provide reports to support CARTA operations (completed in 2004).
- New operations management software to support fixed-route scheduling and demand response scheduling and dispatch (completed in 2006).
- Ticket vending machines for the Incline Railway (completed in 2006).
- New fareboxes, a revenue management system, and a multi-modal transit/parking SmartCard electronic fare payment system (completed in 2008).
- A diagnostics maintenance system that collects vehicle diagnostic data (completed in 2006) and systems to deliver the data in real-time to CARTA maintenance personnel (scheduled for fall 2009).
- Various on-board systems (mobile data computers, computer-aided dispatch / automated vehicle location software, a covert alarm, automated passenger counters, and a next stop automated announcement system) (scheduled for fall 2009).

Other ITS activities are planned beyond 2009 as part of the SmartBus project, but are outside the scope of this evaluation.

CARTA has from the outset desired that this project serve as a foundation for a regional collaborative approach to transit ITS, where CARTA and other transit agencies operating in the immediately adjacent parts of the region can benefit by leveraging a common technology framework and enabling more coordinated services. As the CARTA ITS program

is becoming more fully deployed, CARTA has initiated discussions with other agencies about joint participation in a regional Multi-Agency Coordinated ITS initiative (MAC-ITS).

BACKGROUND ON THE EVALUATION

The goal of the evaluation is to determine the impacts of these various technologies in performing daily functions such as operations, scheduling, service planning, and maintenance and to gather and document any lessons learned by the project team throughout the process of the deployment and evaluation. This report discusses impacts to date of the technologies that have been in place as of October 2009. It is important to note that the full impacts of many of the technologies are not expected to be realized at this time. Some impacts are not expected to occur until the onboard systems are in place and fully integrated with the existing technologies. Other impacts will not occur until CARTA practices evolve to take full advantage of the capabilities of the new systems.

CONCLUSIONS OF THE EVALUATION

Based on the results of this evaluation to date, a summary of the conclusions are presented below:

- While the technologies deployed at CARTA have had many direct impacts, the biggest change observed during this period is that CARTA is beginning to make better use of its data archives to support operational decisionmaking. Prior to SmartBus, key performance data was maintained in a variety of paper logs, electronic spreadsheets, and proprietary software applications. After implementation of the data warehouse, multiple systems could be deployed and incorporated into the data warehouse to start collecting data on the new systems to help various CARTA departments (IT, accounting, maintenance, operations, planning, grants, and procurement) perform their duties more efficiently. Overall, CARTA believes that it has seen a return on investment from the data warehousing and scheduling software in just 1.39 years.
- In January 2006, CARTA installed five ticket vending machines (TVM) to support ticket sales for the Incline Railway. Prior to the TVMs, employees sold tickets to patrons from a ticket counter in the gift shops located at the base and top of the Incline. Since employees' responsibilities have shifted rather than decreased, it is important to note that the number of employees required to operate the Incline Railway has not changed as a result of the TVMs. However, the most important benefit of the TVMs is that they provide CARTA access to a wealth of information not previously available. A secondary benefit is having a better quality control over revenue stream and ridership data.
- The deployment of new operations software for CARTA's fixed route and paratransit operations was the first step in a deployment that would become part of an integrated suite of systems that provide CARTA with many new capabilities. (The deployment of new operations software to support flex-route operations was delayed until CAD/AVL capabilities were available.) For the fixed route operations, the software significantly decreased the time required to perform run-cutting. The paratransit operations did improve some parts of the scheduling process; however, the software did not accommodate all of CARTA's business practices and policies and made booking a trip take longer than the previous system.
- CARTA required network connectivity for its vehicles to support a number of the technologies deployed; therefore, CARTA contracted for cellular Evolution-Data Optimized (EVDO) network service and equipped its vehicles with cellular modems. This service has proven to be reliable and effective and has allowed CARTA to add free wireless internet to vehicles with little additional cost.

    - One lesson that CARTA took away from this experience is to be sure that the wireless modem selected by an agency be appropriately robust for use on a transit vehicle. CARTA has realized since deployment of the cellular modems it selected to provide wireless connectivity that they were not designed for the more industrial uses to which they are being put and are therefore more prone to failure.

- In 2008, CARTA replaced its current fareboxes with newer models that support a transactional database (i.e., one where a time-stamped record is created for each fare transaction indicating the amount collected and the fare type) and contactless SmartCard readers. This deployment has allowed CARTA to access more accurate and more detailed fare data with less driver interaction. The one draw back that CARTA has noticed is that passengers are treating the SmartCards as being more disposable than originally intended, resulting in higher than anticipated card resupply costs.
- In 2008, CARTA deployed an onboard audio and visual next stop automated announcement system (AAS) to provide an announcement for each bus stop as the vehicle approaches along with an LED display inside the vehicle that simultaneously displays a corresponding text message. As part of the deployment of this system, CARTA got the stakeholders involved in a preliminary meeting to get their input, which resulted in buy-in and high praise for the project.
    - For this deployment, CARTA identified two lessons that other agencies should keep in mind: 1) consider performing a comprehensive test of the AAS before releasing it for fleet-wide use and 2) consider the impact of closely-spaced stops in the design of the system.
- As part of the deployment of the various technologies, CARTA took steps to inform riders about bus arrival. These steps included the deployment of a bus tracking system that allowed CARTA to display messages to riders on when buses will arrive at their stops. The messages are conveyed through dynamic message signs at various bus stops and through CARTA's website, where the agency posts current bus locations and schedule adherence. This allows riders to check whether buses are on time and when the next bus will arrive at a certain location.
    - One lesson learned was that accuracy of the pre-existing bus schedule information may not be sufficient to support a bus arrival time system – CARTA tuned and recalibrated its bus schedule information in order to help produce accurate arrival time estimates.
- Another onboard technology that CARTA deployed was the remote diagnostics maintenance system. This system monitors vehicle performance and provides feedback to CARTA maintenance staff on problems associated with the vehicles. Eventually this system will be available in real-time to allow CARTA staff to make decisions about potential vehicle problems and how best to address these problems. In the short term, this is leading to more minor road calls and reducing major road calls; however, CARTA expects the system will reduce on-the-road failures. This reduction is expected to be enhanced when the real-time information starts streaming to the maintenance staff after the CAD/AVL is fully integrated. This information will allow maintenance staff to actively manage bus alerts to reach the Head of Maintenance's goal of zero road calls.
- Automatic Passenger Counters (APC) were deployed on fixed- and flex-route buses in 2009. The APC hardware was deployed on the buses and integrated with the already deployed MDCs, which stored the data temporarily until it was uploaded via the WLAN to APC central management software. This software created the permanent archive of the passenger count data and provided CARTA with tools to report on passenger counts.

However, problems detected during testing prevented CARTA from using the system while the vendor corrected the APC software. CARTA expects to begin using the system in 2010.

- AVL features were deployed in 2008 as part of the systems supporting AAS and bus arrival time estimation. The deployment of a CAD system for fixed-route vehicles and its integration with these AVL features was nearing completion in October 2009. Integrating CAD/AVL features into flex-route and paratransit operations software is expected to occur in 2010.

1 INTRODUCTION

The United States Department of Transportation (USDOT) Intelligent Transportation Systems Joint Program Office (ITS JPO) has established a National ITS Evaluation Program to determine the impacts of federally funded ITS deployments across the country. The objective of this evaluation program is to document findings from ITS deployments that can be useful to a wide variety of external audiences including planners, engineers, and managers. The results of these evaluations are intended to assist agencies in the planning and implementation of future ITS projects by providing information about lessons learned from systems that are already implemented.

This document presents the Phase III results from the national evaluation of the Chattanooga Area Regional Transportation Authority's (CARTA's) SmartBus Project, a project that is being implemented in part with fiscal year 2003 (FY03) ITS Integration Program earmark funding and is being evaluated by the ITS Joint Program Office and the Federal Transit Administration (FTA). The project, termed the "SmartBus Project," was chosen for national evaluation as it provides an opportunity to evaluate the impacts of the use of extensive data warehousing and reporting software, as well as to document the benefits of applying a systems engineering approach when designing a comprehensive transit ITS program with a suite of integrated technologies.

As with traditional Phase III evaluation reports, this document presents a summary of the "before and after" analysis to determine benefits based on technologies that are deployed and fully integrated. However, in this evaluation some of the technologies were deployed prior to the Phase II report and, as a result, findings were presented in the Phase II report.[1] This report summarizes those findings and completes the evaluation by presenting findings for the technologies that were deployed after publication of the Phase II report.

The remainder of this document is organized as follows:

- **Section 2 – Background on CARTA and the SmartBus Deployment.** This section provides background information on CARTA, on the project being evaluated, and on the overall evaluation approach for the national evaluation.
- **Section 3 – Updates on Phase II Activities.** This section provides information about each of the technologies that were deployed prior to the Phase II report and that were examined in the Phase II report. In addition, this section reviews any additional data that became available after the Phase II report and provides updates on the deployed technologies.
- **Section 4 – Post Phase II Activities.** This section provides background information about CARTA deployments that took place after the Phase II report, which include onboard WiFi, an automated announcement system (AAS), real-time transit information, a remote diagnostic maintenance system (RDMS), automated passenger counters (APC), CAD/AVL, and security systems as well as information about the impacts of the technologies deployed.
- **Section 5 – Systems Engineering Process.** This section provides an overview of CARTA's system engineering process and discusses the transition from the deployment phase to the maintenance phase.
- **Section 6 – Summary and Conclusions.** This section provides a summary of the report and highlights the key lessons learned during this evaluation.

[1] Chattanooga SmartBus Project: Final Phase II Evaluation Report, June 10, 2008.

2 BACKGROUND ON CARTA AND THE SMARTBUS PROJECT

2.1 OVERVIEW OF CARTA OPERATIONS

CARTA provides transit services for the City of Chattanooga in southeastern Tennessee and portions of nearby counties. Transit services include: fixed route service within the City of Chattanooga and Hamilton County; complementary demand-response paratransit service for citizens with disabilities within the City of Chattanooga and the Town of Signal Mountain; a downtown shuttle and parking system; and the Lookout Mountain Incline Railway (the Incline). CARTA operates 13 main line fixed routes, 3 neighborhood flex routes, the Care-A-Van demand responsive service, parking facilities in downtown Chattanooga, and a free shuttle service in downtown Chattanooga. Figure 1 shows a system map of CARTA's main line and neighborhood fixed routes.

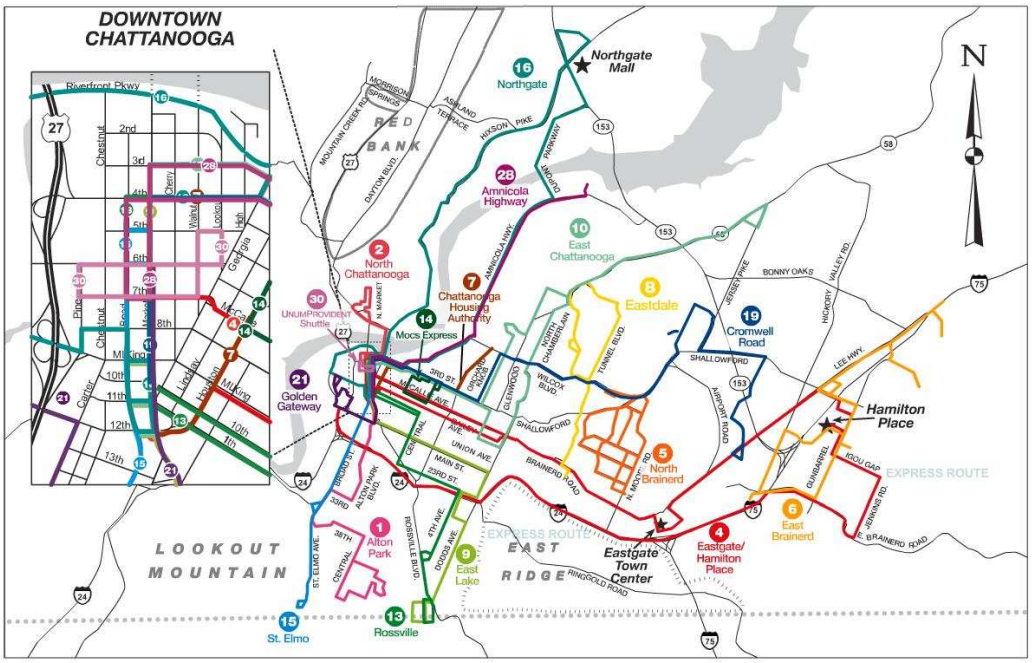


Figure 1. System Map of CARTA's Fixed Routes

CARTA's fixed and flex route services operate 7 days per week using a mix of conventional diesel buses and electric shuttle buses. Buses on the fixed route service make stops on a fixed route at fixed times. Buses on the flex route service make stops at a shopping mall every 30 minutes, driving through nearby neighborhoods to pick up and drop off passengers in the intervening periods. Passengers can call in to schedule a pick up at any location in the neighborhood serviced by the bus. The CARTA Care-A-Van demand response service also operates 7 days per week.

2.2 OVERVIEW OF CARTA ITS DEPLOYMENTS

CARTA's experience with technology deployments dates back to 1996, when it began using maintenance planning and tracking software for vehicles and facilities. In 1998, it began using GIS network software to support ADA paratransit operations. In 2001, it deployed a parking garage security system, established a system-wide network for CARTA fixed facilities, and integrated the CARTA network with the City IT network. The agency's experience with technology took an important step forward in 2003, when it applied for and was awarded an ITS Deployment Program earmark. With long-term funding for ITS

technologies secured, CARTA began deploying a series of technologies that would integrate technologies across its operations.

Table 1 summarizes these deployments, and each of the technologies deployed is summarized in the following sections.

Table 1. CARTA ITS Deployments.

Year	Activity
2004	Deployed data warehousing and reporting software.
2005	Deployed handheld system ("tricoder") for recording vehicle fuel, oil, and other liquid usage.
2005	Deployed TVMs for the Incline Railway.
2006	Began requiring multiplex system on all new bus purchases so as to support the planned remote diagnostics maintenance system.
2006	Deployed new fixed-route scheduling software and new scheduling and dispatch management software for demand-response service.
2007	Provided network connectivity to CARTA vehicles via cellular Evolution-Data Optimized (EVDO) network to enable real-time data collection from vehicles for the upcoming next arrival predictions and CAD/AVL systems. CARTA also began offering wireless public Internet access on CARTA buses.
2008	Deployed a new revenue management system and new electronic registering fareboxes in fixed route vehicles. This included introducing the use of SmartCards for fare payment.
2008	Deployed onboard audio and visual next stop automated announcement system (AAS) as well as a headsigns interface (to automatically change the headsign as the vehicle approaches the end of a trip).
2008	Deployed a Web-based bus arrival time system and bus arrival time signs at eight bus stops.
2009	Implemented daily upload via WLAN of bus diagnostic information collected onboard to the RDMS server, making this data available to maintenance staff.
2009	Deployed APCs on fixed- and flex-route vehicles, with APC data uploaded daily via the WLAN, and the APC central management software to manage and analyze the collected APC data.
2009	Will complete deployment of the CAD/AVL dispatcher software initially for operations management on the fixed-route fleet. This will include integration with the onboard systems to enable real-time fleet status data and new communications tools. It will also enable sending critical RDMS alerts to dispatchers over the mobile data communications system.
2010	CAD/AVL deployment will be extended to the flex-route and demand-response fleets, including the deployment of flexible-route scheduling and dispatch management software and integration with the demand-reponse scheduling and dispatch management software.
2010	The SmartCard fare collection system will be extended to support stored value as an additional alternative to cash payment and web-based SmartCard revaluing.
2010	Fareboxes will be interfaced with the onboard systems for CAD/AVL to enable a single point login, additional data for the fare transactions database, and real-time access to farebox alarms data.

2.2.1 Data Warehousing and Reporting Software

CARTA understood that many of the activities needed to support its operations relied on information managed by different software applications. For example, reports needed to support tire lease payments relied on combining data from mileage logs with maintenance data that identified the tires mounted on each bus. Assessments of the cost-effectiveness of alternative fuels required a combination of fuel usage and maintenance cost data. CARTA also noted that some of its existing applications were not capable of producing necessary reports. For example, the maintenance system could not produce the annual parts inventory audit reports needed for end-of-year accounting.

Recognizing these needs, CARTA decided to deploy data warehousing and reporting software. This data warehouse combined data from all CARTA software applications and was the central repository that supported key CARTA operational reporting. Making the CARTA data warehouse the first ITS application deployed enabled CARTA to include integration with the data warehouse as a requirement for future ITS deployments at CARTA.

2.2.2 Vehicle Fuel Usage System

One type of data CARTA wished to include in the data warehouse was information on vehicle fuel and oil usage. At the time when the data warehouse was deployed, fuel and oil usage and miles traveled information was recorded manually each night and transcribed into an Excel® spreadsheet the next morning by CARTA staff. Spreadsheet-driven processes were used to combine this data with other information (e.g., vehicle miles traveled for each bus) to produce reports for CARTA management. This overall process was labor intensive and error prone.

CARTA recognized that pushing this data into the data warehouse could simplify and improve this process. Rather than simply develop a tool to allow staff to transcribe this data into the data warehouse, CARTA reviewed the entire process and recognized that electronically recording the data while servicing each bus would eliminate the time-consuming and error-prone transcription process. To aid in this process, CARTA deployed a handheld device that allowed maintenance staff to enter this information as the bus was being processed each night.

This system was seen as an early success related to the CARTA ITS program. The system saved CARTA time by automating a previously manual process. It also took advantage of the data warehouse reporting capabilities to automate and improve on the existing reporting methods.

2.2.3 Ticket Vending Machines

In the spring of 2005, CARTA deployed five TVMs along with a central TVM management server application to support the Incline Railway operation. The TVMs accept both cash and credit cards. The use of TVMs allowed CARTA to migrate from its former paper-based system for tracking Incline Railway ticket sales to an automated system that integrated with its data warehouse.

2.2.4 Maintenance Monitoring System

Beginning in 2006, CARTA required the inclusion of a maintenance monitoring system on all buses purchased. This system included a master controller connected through a J1939 data bus to various slave devices that monitored key bus operating parameters (e.g., high engine oil temperature, low oil pressure, high transmission oil temperature). The master controller collected data and logged the data for later retrieval. The main purpose of this system was for integration with other planned in-vehicle equipment to eventually provide CARTA with a full remote diagnostics maintenance system, which began operation in 2009.

2.2.5 Operations Software

In April 2006, CARTA completed the deployment of new fixed route scheduling software and new scheduling and dispatch management software for demand-response operations. Although the new software provided some immediate benefit, the full benefit for demand-response operations will not be achieved until the various onboard technologies are installed and integrated with the computer-aided dispatch/automated vehicle location (CAD/AVL) system and with the mobile data computers. The fixed-route scheduling software immediately supported more efficient development of the blocks, runs, and rosters for fixed-route schedules and allowed the user to explore various alternative scenarios. The

paratransit scheduling and dispatch management software supports paratransit booking, scheduling, manifest generation, and completed trip validation, invoicing, and reporting. Once integrated with the CAD/AVL system and the demand-response fleet MDTs, this paratransit software will be better able to support same day scheduling adjustments and implement an electronic manifest and the real-time collection of data for completed trips.

CARTA had intended to use the same software to support the operation of the flexible neighborhood routes using real-time scheduling and manifest updating in response to telephone requests from passengers. However, it discovered that, without real-time location information from CAD/AVL, the software was not effective for this type of operation. For this reason, CARTA decided to delay this part of the software deployment.

2.2.6 Network Connectivity for CARTA Vehicles

In 2007, CARTA provided network connectivity for its vehicles via cellular EVDO network. The primary purpose was to support real-time data collection that would be necessary to support planned deployments of CAD/AVL and real-time remote diagnostics systems. CARTA also took advantage of the EVDO network to provide free wireless Internet access on CARTA buses.

2.2.7 Fareboxes and Revenue Management System

CARTA's fareboxes were replaced with newer models that support a transactional database (i.e., with a time-stamped record created for each fare transaction indicating the amount collected and the fare type) and contactless SmartCard readers. As part of this deployment, new revenue management software was also deployed. This software included support for the initial role of SmartCard in the system as both monthly and day passes. When a monthly or day pass expires, passengers can revalue the SmartCard by purchasing another month or day pass onboard.

2.2.8 Next Stop Automated Announcement System

In 2008, CARTA deployed an onboard audio and visual next stop automated announcement system (AAS) for its fixed route buses. This involved deploying global positioning system (GPS) receivers to track vehicle locations, mobile data computers (MDC) to provide onboard processing to support AAS, and interior LED signs to display the next stop information, as well as integration with the existing public address (PA) system for stop announcements. (The system also integrated with the existing headsigns to automatically update the signs (e.g., at the end of each route). A wireless local area network (WLAN) was also deployed at both vehicle storage facilities to support bulk data transfer of route information to support AAS. This data was downloaded from the fixed-route operations software.

2.2.9 Bus Arrival Time System

CARTA deployed a bus arrival time system that leveraged the onboard infrastructure already in place (e.g., location tracking, network connectivity). CARTA configured the MDC to transmit arrival time information at each stop to a bus arrival time server, which used this information to estimate the arrival time at future stops. CARTA deployed bus arrival time signs at eight stops and developed a public website to display bus arrival time information. (This website also displayed real-time bus location information.)

2.2.10 Remote Diagnostic Maintenance System

In early 2009, CARTA deployed RDMS. The MDCs were integrated with the onboard maintenance monitoring system to collect information about bus operating parameters. (For buses without a maintenance monitoring system, a less comprehensive set of parameters was collected from existing onboard systems.) An RDMS server was deployed at the CARTA

maintenance garage, and data was automatically downloaded from the bus to the RDMS server via the WLAN whenever the bus was in range of that network. The RDMS server created a permanent archive of the bus monitoring data and provided reporting tools that maintenance staff could use to support maintenance operations.

2.2.11 Automatic Passenger Counter

Automatic Passenger Counters (APC) were deployed on fixed- and flex-route buses in 2009. The APC hardware was deployed on the buses and integrated with the already deployed MDCs, which stored the data temporarily until it was uploaded via the WLAN to APC central management software. This software created the permanent archive of the passenger count data and provided CARTA with tools to report on passenger counts.

2.2.12 CAD/AVL

CAD/AVL software was deployed for fixed-route buses. This software integrated with the already deployed onboard systems to provide real-time fleet status monitoring tools to CARTA staff and new communications tools. The CAD software displays real-time bus location information. Critical RDMS alerts are transmitted to dispatchers in real-time, and a covert alarm button is provided that will alert dispatchers if activated by the bus operator. The software also supports text messaging between dispatchers and bus operators. The software also supports other features, such as logging incident reports and review of historical data.

These CAD/AVL capabilities will be extended to flex-route buses and paratransit vehicles in 2010. The CAD/AVL will also be integrated with the paratransit dispatch software, so that trip manifests will be displayed on the MDCs, same-day trips can be scheduled and will take into consideration current vehicle locations, and electronic manifests will be automatically updated when same-day trips are scheduled. For flex-route vehicles, new scheduling software will be deployed that will support both call-in and walk-on trip requests.

2.2.13 Future Plans

CARTA has a number of additional long-range ITS plans that are not currently scheduled. One such plan is to extend the SmartCard system to allow the use of SmartCards as debit cards to pay transit fares. Another is the installation of bus security video that could be activated and transmitted to CARTA headquarters if the covert alarm was active.

2.3 OVERVIEW OF THIS EVALUATION

The following section summarizes the process followed for this evaluation.

2.3.1 Evaluation Phases

USDOT-sponsored ITS evaluations are traditionally divided into two phases. During Phase II, the evaluation team collects data before the technologies are deployed and summarizes the "before" data in a Phase II Report. During Phase III (after approval of the Phase II Report), the evaluation team collects data after the technologies have been deployed and presents the findings of the "before and after" analysis in a Phase III Report.[2] In the case of the SmartBus Project, some of the technologies that are being evaluated were already in place as of submission of the Detailed Test Plan document in September 2007.[3] Therefore, this evaluation was conducted in the following manner, which enabled the timely publication of evaluation results for the technologies that were deployed early on in the process:

[2] Chattanooga SmartBus Project: Final Phase II Evaluation Report, June 10, 2008.

[3] Chattanooga SmartBus Project: Final Detailed Test Plans, September 10, 2007.

- **Phase II:** This phase was initiated immediately following approval of the Detailed Test Plan document. During this phase, a "before and after" analysis was performed for those technologies that are fully deployed and that had been operational for at least one full year. For those technologies that were not yet deployed or not in place for one full year, analysis was performed for only the "before" data (for those measures that are qualitative in nature, the findings reported here were those that resulted from interviews regarding experiences "before" deployment of that particular technology).
- **System Engineering Review:** One of the observations made during Phase II was that CARTA seemed to be applying an effective system engineering process to its ITS deployments. Because of this, a review of the agency's system engineering processes was conducted and documented in a report titled *A Case Study on Applying the Systems Engineering Approach: Best Practices and Lessons Learned from the Chattanooga SmartBus Project*.
- **Phase III:** This phase consists of evaluating the technologies deployed after publication of the Phase II Report, performing an "update analysis" for the some technologies that were already evaluated during Phase II (i.e., for each of the technologies that were already evaluated in Phase II, the team gathered and analyzed additional data for the time period between publication of the Phase II and Phase III reports), and gathering the information for the systems engineering case study.

2.3.2 Evaluation Approach

The hypotheses and measures of effectiveness (MOE) that guided this evaluation were presented in the Detailed Test Plans Document. The hypotheses were developed in consideration of the agency's goals, and many were taken directly from the agency's planning documents, in which specific goals and potential hypotheses were identified. The hypotheses for this evaluation were divided into "key" and "secondary" based on the likelihood of successfully being able to measure the hypothesis and the relevance of the hypothesis to the USDOT goals. Because of the need to publish this report in the 2009 calendar year, some of the hypotheses could not be addressed. Table 2 and Table 3 list these hypotheses along with the status of each including whether the hypothesis was able to be addressed in this report, and if so, where the results can be found.

Table 2. Status of Key Hypotheses

Key Hypothesis	Description	Results
The addition of scheduling software and CAD/AVL will allow dispatchers to improve headway/schedule control among particular "problem" routes in real-time and will allow for tighter scheduling of demand-responsive routes.	CAD/AVL is still being integrated, and achieving this benefit requires a history of data generated from CAD/AVL.	Not Tested
The addition of mobile data computers will improve the efficiency and effectiveness of communication between drivers and dispatchers and will reduce the need for radio communication.	Implementation of these communication features is scheduled for late 2009.	Not Tested
The addition of mobile data computers will provide the capability for non-verbal communication between drivers & dispatchers which will result in increased safety during emergency situations.	Implementation of these communication features is scheduled for late 2009.	Not Tested
The addition of automated passenger counters will result in access to less expensive, more frequent, and more accurate ridership data that will be useful in planning and scheduling.	Problems detected during testing delayed use of the APC system.	Not Tested

Key Hypothesis	Description	Results
The addition of a remote diagnostics maintenance system will result in reduced annual maintenance costs and will reduce the incidence of on-road maintenance-related vehicle failures.	This is addressed in section 4.	Tentatively supported
The addition of CAD/AVL and its integration with the scheduling software will result in an improvement in customer satisfaction among riders.	CARTA has received positive feedback related to some of its new capabilities (e.g., AAS).	Not Tested

Table 3. Status of Secondary Hypotheses

Secondary Hypothesis	Description	Result
The addition of the ticket vending machines will result in a revenue improvement for the Incline Railway service.	This is addressed in section 3.3.	Inconclusive
The addition of data warehousing and reporting software will allow for more rapid preparation of a variety of reports.	This is addressed in section 3.1.	Supported
The addition of data warehousing and reporting software will result in efficiencies in operations; will make it possible to answer complex business decisions quickly.	This is addressed in section 3.1.	Supported
The addition of fixed route scheduling software will allow CARTA to provide the same level of service with lower operating costs.	This is addressed in section 3.4.	Supported
The addition of paratransit scheduling and dispatch management software will increase efficiency in terms of trips per vehicle-hour.	This is addressed in the Phase II report.	Supported
The addition of paratransit scheduling and dispatch management software will reduce the average trip booking time.	This is addressed in the Phase II report.	Not Supported
The addition of paratransit scheduling and dispatch management software will reduce the time required to issue invoices.	This is addressed in the Phase II report.	Supported to a limited extent
The addition of paratransit scheduling and dispatch management software will improve on-time performance.	This is addressed in the Phase II report.	Inconclusive
The addition of flexible route scheduling and dispatch management software will result in increased efficiency in terms of trips per vehicle-hour.	Deployment of the flex-route scheduling software is scheduled for 2010.	Not Tested
The addition of flexible route scheduling and dispatch management software will result in increased customer satisfaction due to improved on-time performance.	Deployment of the flex-route scheduling software is scheduled for 2010.	Not Tested
The addition of a bus stop audio and visual automated announcement system (AAS) on the buses will result in improved customer satisfaction among riders.	This is addressed in section 0.	Supported to a limited extent

Sections 3 through 6 describe the details of the approach that the evaluation team took to gathering data and information for the evaluation and the findings from these activities. The data collection approach and the findings are presented as follows: Section 3 presents the updates since the Phase II report, Section 4 presents the impacts of the RDMS, Section

5 presents the system engineering process that CARTA followed, and Section 6 presents a lessons learned and conclusions on the deployment.

In addition to the key and secondary hypotheses, the team added more hypotheses based on CARTA's change in schedule, in which the additional hypotheses are shown in Table 4.

Table 4. Status of Additional Hypotheses

Additional Hypothesis	Description	Result
The bus next arrival time system will increase customer satisfaction.	This is addressed in section 3.8.	Supported to a limited extent
Free internet for CARTA passengers will increase customer satisfaction	This is addressed in section 3.5.	Supported to a limited extent
The CARTA approach to systems engineering will be effective	This is addressed in section 5.	Supported

3 OVERVIEW OF EVALUATION RESULTS

Unlike many evaluations, where the majority of key observations occur during Phase III of the evaluation, key observations occurred during both Phase II and Phase III of the CARTA evaluation effort. This was because the deployment of several of CARTA's IT systems were already complete when the Phase II report was being researched. The evaluation team took advantage of that opportunity to report observations and lessons learned in the Phase II report and in the systems engineering review report that followed. Additional observations and lessons learned were identified during Phase III activities. This section of the report summarizes these observations and lessons learned and provides references to the report section to which an interested reader could refer to find out more information.

3.1 CARTA DATA WAREHOUSE AND REPORTING SOFTWARE

The data warehouse was a very successful project at CARTA. It succeeded in replacing many different manual reporting processes with automated processes that were both more efficient and more accurate, and it integrated data from previously disparate sources so that CARTA could produce new types of reports that relied on this consolidated data. The data warehouse quickly became the first place CARTA personnel would go when they wanted a report or some data to support their operational decision-making. The impact of the data warehouse on CARTA operations is well summarized by the following remark that was made to the evaluation team:

> ***"When you don't have the data, the business drives you – we want to drive the business."***
>
> **Ron Sweeney, General Manager**

Because the data warehouse was one of the first systems deployed by CARTA, most of the observations related to the data warehouse were documented in the Phase II evaluation report, with some additional observations reported in the systems engineering case study. The following list summarizes the key observations from these reports:

- *The data warehouse saved staff time by automating the process for producing a number of monthly and annual reports*. This allowed CARTA staff to spend more time improving operations rather than generating and manipulating data to fulfill reporting requirements. (See sections 5.2.3 and 5.3 of the Phase II evaluation report.)
- *The data warehouse saved money by allowing CARTA staff to create custom reports, a task previously outsourced to contractors*. Purchasing a data integration and reporting tool simplified these processes, so that CARTA could develop and maintain these items internally. By 2009, CARTA had developed more than 120 data warehouse reports, without the cost of hiring outside help for development. The report generation functionality has already saved CARTA the money in that the agency previously paid an outside entity to develop reports at roughly $600 per report. CARTA now has easy access to reports that would have cost approximately $72,000 to create before the Data Warehouse. (See section 5.3 of the Phase II evaluation report.)
- *The data warehouse helped CARTA make more informed decisions*. By consolidating data from many different sources and providing sophisticated reporting tools, the data warehouse allowed CARTA staff to analyze operations data in new ways in order to provide support to management decision makers. For example, CARTA's purchaser reports a time savings of 2 days for the whole "end of the month" process, which includes gathering the total operating cost of individual vehicles, including both fuel and maintenance costs. This has helped CARTA determine the most cost-effective fuel to use

in vehicles and the least costly buses to operate — an important consideration for future purchases.

- *The data warehouse helped CARTA document the benefits of its services*. In 2008, the University of Tennessee at Chattanooga (UTC) was considering eliminating the program that provided free transit service to UTC students. CARTA responded by developing a data warehouse report that listed daily student ridership. This information helped convince UTC to continue its agreement with CARTA. The data warehouse is now configured to email this report to UTC automatically each day.
- *The existence of a data warehouse simplified development of some IT systems*. CARTA relied on the data warehouse to provide reporting tools, eliminating the need for sophisticated reporting tools in some of CARTA's IT applications. For example, the new revenue management system, when first delivered, did not include six reports that were critical to CARTA operations. CARTA staff was able to develop versions of these missing reports quickly using reporting tools from the data warehouse.
- *The existence of a data warehouse simplified the integration between IT systems at CARTA*. When possible, CARTA integrated IT systems with the data warehouse rather than directly with each other. This was simpler to develop and maintain than integrating each individual IT systems into a whole.

In summary, the data warehouse was a good first choice for CARTA ITS. It provided immediate operational benefits to CARTA while establishing a key tool to facilitate ITS integration for the upcoming deployments. CARTA reports saving roughly $72,000 for producing reports. CARTA's purchaser used some of these reports to save about 2 days of labor per month on monthly reports. The data warehouse provided many other benefits that provided CARTA with better access to its data to support decisionmaking.

3.2 VEHICLE FUEL USAGE SYSTEM

The upgraded vehicle fuel usage system at CARTA built on the success of the data warehouse deployment by automating an important data feed to the data warehouse, the vehicle fuel and oil usage data. This simplified and made less error prone a previously tedious task. It also helped demonstrate the power of the data warehouse by allowing CARTA to automate fuel usage reports. The evaluation team noted several lessons learned related to this system:

Look for opportunities to improve existing systems as part of integrating them with a data warehouse. CARTA could have continued to use its manual methods for gathering fuel usage data and developed tools that allowed staff to enter this data into the data warehouse. This would have satisfied the requirement that the data warehouse include this data. CARTA chose to improve the process rather than just integrate the existing process.

Early in the deployment, look for easy-to-implement opportunities that highlight the benefits of ITS. CARTA recognized that a handheld system for recording fuel usage data would be relatively easy to implement and would simplify an onerous, manual process. It would also take advantage of the data warehouse, calling attention to the power of ITS to improve operations. This early success helped secure support among CARTA staff for future ITS deployments.

CARTA reported that the vehicle fuel usage system saved them about one person-hour per day entering data into the system. The system also ensured higher quality data.

3.3 TICKET VENDING MACHINES

The TVM deployment proved to be another good choice for an early ITS deployment. Like the vehicle fuel usage system, it automated a previously tedious, manual process and took advantage of the data warehouse reporting capabilities. The level of integration with other CARTA systems was also limited, so that the project could be deployed independently of other CARTA ITS projects. (For comparison, consider the deployment of MDCs which have to be integrated with and support many different onboard systems, such as AAS, RDMS, and CAD/AVL.)

Figure 2. Patron using Incline Ticket Vending Machines

The observations related to the TVMs and summarized below were documented in Section 4.2 of the Phase II evaluation report:

- *The TVM system provided better loss prevention than the previous manual system*. The previous manual system provided little accounting of the ticket transactions and also required that workers handle large quantities of cash.
- *The TVM system provided CARTA with much more detailed sales data than was previously available*. With the previous manual system, ticket sales data was limited to the total number of daily ticket sales at each location. With TVMs, the exact time of each ticket sale was recorded and archived.
- *The TVM system and its integration with the data warehouse allowed CARTA to analyze Incline Rail ticket sales data in new ways*. When CARTA was considering reducing Incline Rail hours of operation, the agency queried the TVM data in the data warehouse to generate a report on tickets sales by hour of day in order to estimate the potential impact on ticket sales.
- *The TVM system helps CARTA resolve credit card disputes*. Resolving questions regarding credit card payments previously required manual searches through paper records to find credit card purchase slips. Now, a query of the archived TVM data provides a record of credit card payments for resolving disputes.

In summary, the TVM system provides a more secure ticket sales environment while providing CARTA with more detailed sales information that could be used to better manage Incline Rail operations. CARTA estimated that the TVM system saved one man year of time spent on ticket sales, though CARTA chose not to reduce staff. Instead, they used that time to improve customer service.

3.4 OPERATIONS SOFTWARE

The deployment of new operations software for CARTA's fixed route and paratransit operations was the first step in a deployment that would become part of an integrated suite of systems that provide CARTA with many new capabilities. (The deployment of new operations software to support flex-route operations has been delayed to take place after CAD/AVL capabilities are available.) For example, the fixed route operations software will provide the route data to the AAS tool, and the paratransit operations software will

integrate with the CAD/AVL to better support same-day trip scheduling. This first step supported run-cutting operations for fixed route service and trip scheduling for paratransit operations.

Section 3.1.2.1 of the Phase II evaluation report described the following benefits and lessons learned related to the deployment and use of the fixed route operations software:

- *The software significantly decreased the time required to perform runcutting*. The new software can perform runcutting calculations in about 5 minutes, which allows CARTA staff to run many different scenarios quickly in search of an optimal one. The software also automated production of headway sheets and paddles, eliminating a previously time-consuming, manual activity.
- *The software sometimes found a lower cost solution than was found using more manual methods*. The software considered many different parameters in its calculations, such as hourly rates, overtime rates, overtime policies, and driver break policies. By considering a wider range of variations in these factors, it sometimes found a lower cost solution than was found using more manual methods. The new software produced runcuts requiring about 60 hours less per week of operator time than previously required.
- *The software captured CARTA's runcutting knowledge, making the agency less dependent on the specialized expertise of the runcutting staff*. CARTA reported that the runcutting process has become more fluid as the experience of personnel has increased, particularly in the definition of runcutting parameters.

CARTA staff anticipated seeing even more benefits once the CAD/AVL capabilities are integrated with the fixed-route operations software. Section 3.11 provides more information on the CAD/AVL deployment at CARTA.

The benefits and lessons learned related to the deployment and use of the paratransit operations software were described in Section 3.2.2.1 of the Phase II evaluation report. The following list summarizes these benefits and lessons learned.

- The software did improve some parts of the paratransit scheduling process. CARTA reported the software did speed up the process of mixing together the call-in reservations with the standing orders to develop routes for the day. However, other processes seemed more difficult than before, and CARTA reported that the software did not result in significant time savings.
- CARTA reported that the time required to book a trip is about 50 percent greater than it was using the former system.
- CARTA entered most of its business practices into the paratransit operations software so that the software usually produces schedules that comply with CARTA practices and policies. However, the software did not accommodate all CARTA business practices, so CARTA staff do have to override some recommendations made by the system. This can slow the scheduling process.
    - For example, it is not CARTA's practice to send a driver home after a partial workday if demand can be serviced by fewer vehicles. However, the software schedules trips on as few vehicles as possible. In such circumstances, CARTA schedulers have to work against the software recommendations to distribute the trips across the available drivers.

The benefits CARTA estimated from using the operations software included saving almost two weeks every run cut, which CARTA does twice a year. The run cutting software also reduced the total operator time required by 60 hours per week while still satisfying CARTA fixed route schedule requirements.

The paratransit software required more time to book trips than their previous software; however, CARTA expected this cost to be offset by improved efficiencies when the CAD/AVL and electronic manifest capabilities become available.

CARTA did expect that, with the addition of CAD/AVL capabilities, the additional benefits of the new software would become apparent. CARTA did note that one of the reasons for migrating away from the previous paratransit operations software was that the former software was not compatible with the agency's long-term ITS plans; the previous software did not support CAD/AVL and could not easily be integrated with the data warehouse.

3.5 NETWORK CONNECTIVITY FOR CARTA VEHICLES

CARTA required network connectivity for its vehicles in order to support a number of capabilities, such as CAD/AVL, text communication with drivers, and covert alarms on vehicles and security cameras. To prepare for these systems, CARTA contracted for cellular EVDO network service and equipped its vehicles with cellular modems. By equipping vehicles with cellular modems that included a wireless router and negotiating with the EVDO network supplier, the agency was able to provide free wireless Internet service to passengers.

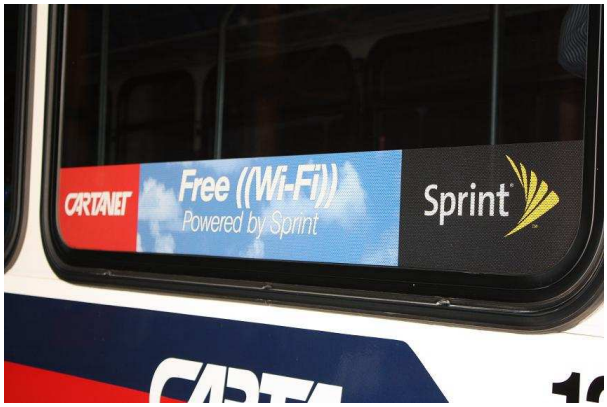


Figure 3. CARTA Free WiFi Advertising

Because deployment of the EVDO network was completed after publication of the Phase II report, few observations about this system have been previously reported. The following paragraphs summarize CARTA's experience with this technology.

The EVDO network has proven to be reliable and effective. CARTA reported few problems with the EVDO network itself, which seemed to provide reliable network connectivity between CARTA fixed locations and CARTA vehicles. CARTA first began using the system to support real-time data communications in 2008 for the bus arrival time system (see Section 3.8) and reported few problems with the EVDO network.

Providing wireless Internet to passengers can be done with very little additional cost while providing EVDO network connectivity to transit buses. CARTA purchased cellular modems that included wireless capabilities for about the same price as those without, and the EVDO service provider supported the wireless Internet at no cost beyond that of providing EVDO service to CARTA vehicles. The EVDO service provider even helped support the installation of signs advertising free wireless Internet service on CARTA.

The free wireless Internet has proven itself popular with CARTA passengers. Figure 4 supports this observation, indicating that 7 out of 37 survey respondents[4] (almost 20 percent) used the free wireless every time or almost every time they ride the bus, with nearly one-third of the respondents (12 out of 37) using the free wireless at least some of the time.

[4] These results were from a survey of CARTA website visitors.

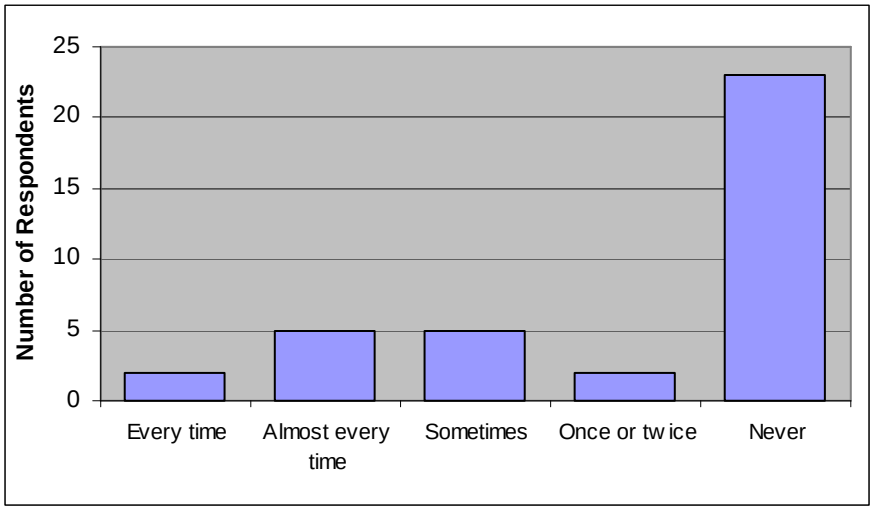


Figure 4. Number of Respondents that Use CARTA's Free Wireless Internet (N=37)

The popularity of the free wireless service is also supported by samples of the number of users logged onto the system. User counts during peak morning and evening periods indicated that, at any one time, 60 to 65 people were connected to the system. This is approximately 10 percent of the CARTA fixed route passengers that would be onboard during those periods. During interviews in 2008, CARTA staff also reported that they had reviewed WiFi usage and determined that, during peak periods, about 70 percent of vehicles had at least one person using the system.

The cellular modems used by CARTA have been more failure prone than expected. CARTA purchased cellular modems that were designed for mobile applications. However, the failure rate of these modems on CARTA buses has been higher than CARTA expected, and CARTA intends to replace these modems during a future deployment. CARTA staff suggested the agency will purchase cellular modems that are more ruggedized for transit service.

In the future, CARTA will continue to expand the use of this network. As this report was being written (in October 2009), CARTA was in the process of completing stage 1 of its CAD/AVL deployment. This deployment will use the network to support new communication tools, such as text messaging to CARTA buses and real-time updates to paratransit driver manifests. Applications in future years will use the network to transmit bus security audio and video to CARTA headquarters in the event of a security incident on a bus.

While the network connectivity did not directly provide quantitative benefits, the system is necessary to support many other systems that are expected to provide quantitative benefits (such as, CAD/AVL, real time alerts from the RDMS). The system also increased the quality of service for passengers by providing free wireless internet.

3.6 FAREBOXES AND REVENUE MANAGEMENT SYSTEM

At the start of CARTA's ITS program, CARTA was using fareboxes that had several limitations that were not consistent with the agency's long-term plans. Among these were the lack of contactless SmartCard readers and difficulty integrating the data generated with these fareboxes with the data warehouse. CARTA deployed new fareboxes and a new revenue management system in 2008. CARTA noted several benefits of the new fareboxes and revenue management system.

More accurate and more detailed fare data. The old farebox system only recorded information about cash fares – drivers visually confirmed passes before allowing other

passengers to enter. The old fareboxes also did not record time-stamped information about each transaction, whereas the new fareboxes provided time-stamped records for every passenger boarding the bus. CARTA reported that parallel checks have shown a higher degree of accuracy with the new farebox system, particularly with regard to tallies.

Figure 5. CARTA's Previous and New Fareboxes

Improved loss prevention. The SmartCards used by the new farebox system make it virtually impossible to reproduce fare media, although at this point it would be difficult to determine a dollar amount on revenue losses due to fraud. However, since the fareboxes have been installed and the proximity cards introduced, revenue has increased.

Easier access to and reporting of fare data. The old farebox system had limited reporting capabilities, whereas the new farebox system includes modern reporting tools and data integration with the data warehouse. This allows CARTA to access fare data easily in ways previously unavailable to the agency. Errors in fare media handling can be quickly resolved since the sequential numbering of each proximity card can be traced. This has enabled CARTA operators to efficiently deal with questions regarding monetary value on proximity cards, including when value was last added to a card.

Figure 6. CARTA SmartCards

Less driver interaction required. The old farebox system required drivers to confirm that non-cash passengers had a valid pass before boarding the bus. Drivers were also required to flip the direction indicator on the farebox at the beginning and end of each run so that each fare would be attributed to the proper leg of the route. The new fareboxes eliminated both types of driver interactions, allowing drivers to concentrate on their other duties.

CARTA did report on one challenge with its farebox and revenue management system, however:

Many passengers treat the SmartCards as disposable. CARTA had expected passengers to reuse their SmartCards and replace them infrequently (e.g., when lost or stolen). However, CARTA found that many passengers treated the cards as disposable items, obtaining a new card rather than recharging the old one. CARTA believes this could be because of the simplicity of obtaining a new card – drivers carry a supply of cards with them – and the low cost of replacement – about $2.

CARTA indicated that it was very happy with the new fareboxes. The agency believes that the fare data is more reliable and easier to access and anticipates that the detailed transactional fare data will help with future scheduling activities.

Information provided by our fare box system is available at the click of a mouse that previously took several hours to obtain.

Jill Veron, Director of Planning

CARTA reported that the new revenue management system saved several hours per week in time once spent analyzing data and generating reports. They noted that revenues had increased since the system was installed, which they attributed to the security of the fare media. The system also provided easier access to more accurate fare data.

3.7 NEXT STOP AUTOMATED ANNOUNCEMENT SYSTEM

The AAS was deployed in 2008 when CARTA elected to expedite the deployment of the bus arrival time system (see section 3.8). Both of these systems depended on tracking a bus's location on its route, with the AAS using this information to announce upcoming stops and the arrival time system using that information to estimate arrival time at future stops. CARTA reported that this system serves its purpose well. The Mayor's Council on Disabilities told CARTA's representative on that council that this was, from their point of view, one of the best projects CARTA had implemented and that they appreciated being included in the deployment process.

CARTA did report two lessons learned in the deployment of this system.

Consider performing a comprehensive test of the AAS before releasing it for fleet-wide use. Before using the system fleet-wide, CARTA activated the system on a single bus, downloaded the complete route network for that bus onto the AAS, and had the bus traverse the agency's entire fixed-route network. In doing so, CARTA identified and corrected several errors in the bus route database. CARTA also identified and corrected a design flaw (see the next point).

Consider the impact of closely-spaced stops in the design of the system. CARTA's initial AAS design called for the system to display the next stop prior to arriving at a stop and the date and time when departing a stop. During testing, it was discovered that, at some closely spaced stops, the time spent displaying the date-time message delayed the next-stop display. CARTA redesigned the system to eliminate this problem.

While there were no quantitative benefits related to the system, there were indications that the system improved the quality of service, as evidenced by positive feedback from the Mayor's Council on Disabilities.

3.8 BUS ARRIVAL TIME SYSTEM

CARTA elected to deploy the bus arrival time system earlier than originally planned when the UTC agreed to fund deployment of bus arrival time signs at several bus stops on the UTC campus if CARTA could have the signs operational during the 2008 calendar year.

The basic approach for estimating arrival times is to establish a number of timepoints on each route and the scheduled arrival time at each timepoint. As a bus passes a timepoint, the system compares its actual arrival time to the scheduled arrival time to determine the time difference between the actual and scheduled arrival time. In most cases, arrival times for future stops are estimated as the scheduled arrival time plus this time difference. Some timepoints include a layover time, in which case the time difference for stops beyond the layover is adjusted under the assumption that the bus will cut short its layover time to get back on schedule.

The computed arrival time estimates are then displayed at LED signs erected at selected bus stops and on the CARTA website (see Figure 7). (A separate location on the CARTA website also displays real time bus location data.)

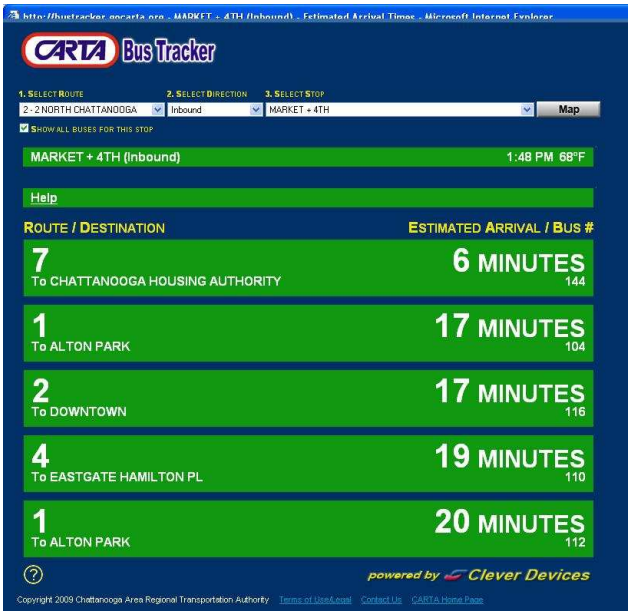


Figure 7. A CARTA Bus Arrival Time Sign and a Bus Arrival Time Webpage

For this system to operate, each bus has to track its location and correlate that location to positions on a bus route. (This is the same type of location information required to support the AAS.) The bus then transmits time-stamped location information to a central server that estimates bus arrival times and publishes those times to bus arrival time signs and on the bus arrival time webpage. CARTA reported that two factors have been key to the generation of accurate arrival times.

The system required accurate schedule information. Prior to deploying the bus arrival time system, the CARTA monitored on-time performance at several time-check locations along each route. This gave CARTA confidence in the scheduled arrival times for those locations. However, CARTA was less confident in the accuracy of the scheduled arrival times at other locations along each route. Once deployment of the location tracking portion of the bus arrival time system was complete, CARTA analyzed the data gathered by the system and compared the actual arrival time information to the schedules. This served two purposes: (1) it validated the location tracking capabilities of the system and (2) it helped CARTA adjust its schedules so that they better represented actual travel times.

The system required closely spaced timepoints. CARTA's initial tests of the system used each bus stop as a timepoint location. During testing, CARTA discovered that the accuracy of the system tended to be lower when the distance between bus stops (and, hence, timepoints) was longer. CARTA introduced additional timepoints as necessary so that the travel time between successive timepoints was five minutes or less. CARTA found this spacing sufficient to generate accurate arrival time estimates.

CARTA took advantage of the real-time bus location information to populate a real-time bus tracker webpage (see Figure 8).

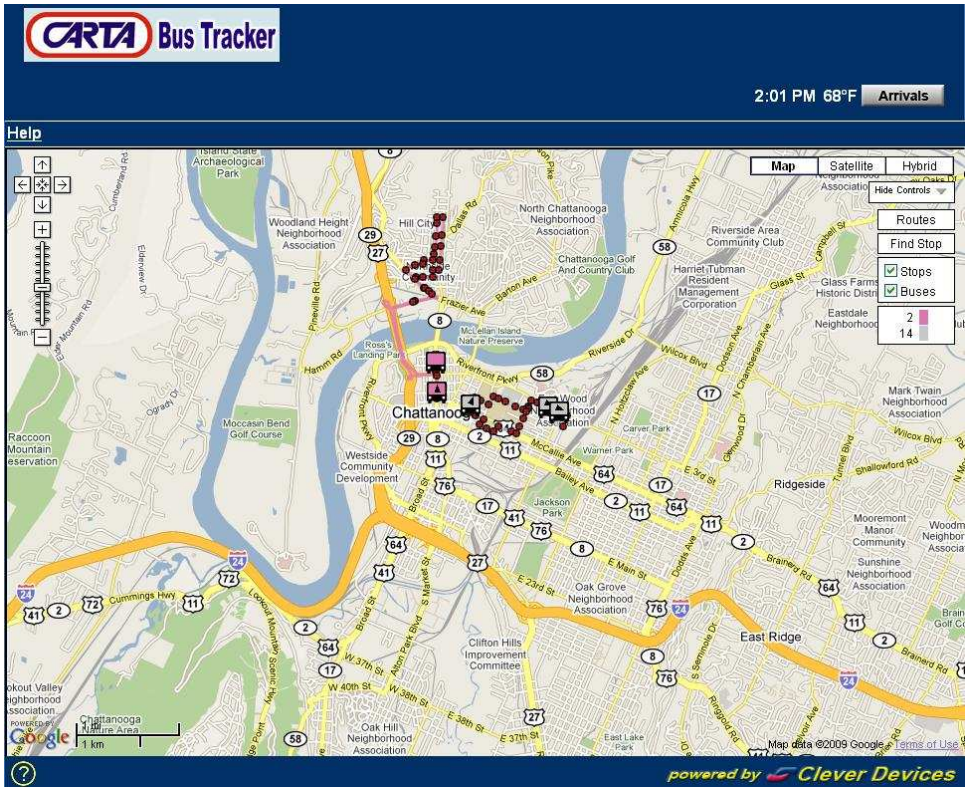


Figure 8. CARTA Bus Tracker Webpage

CARTA kept the development cost of this feature low by taking advantage of Google® map features that simplify the display of data on web maps. The web page provided another form of transit information to passengers and gave CARTA an easy way to verify that the bus location system was working correctly.

Figure 9 demonstrates the popularity of these website features.

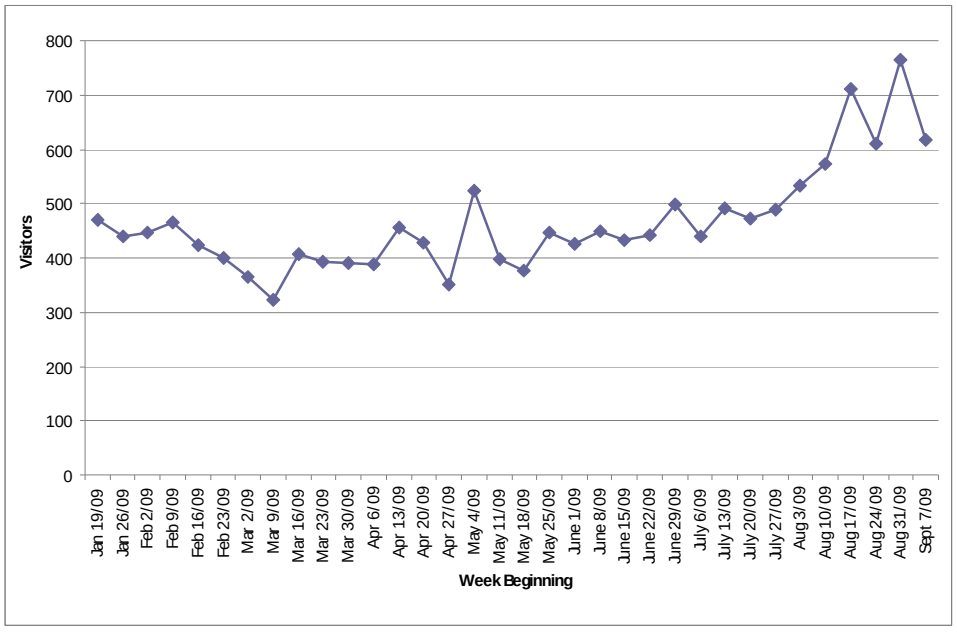


Figure 9. Number of Weekly CARTA Bus Tracker Website Visitors, Jan 2009-Sept 2009

Despite the fact that CARTA has not yet advertised this site (the agency plans to advertise the site in conjunction with a campaign that introduces CARTA's new CAD/AVL capabilities), about 500 visitors per week are using the site, and use of the site appears to be steadily increasing.

A web-based survey conducted of CARTA website users in September 2009 indicated that the bus arrival time system is popular among website users. Figure 10 depicts the frequency of use of the bus arrival time system among a survey of CARTA website users, and Figure 11 depicts the frequency of use for respondents who frequently ride the bus (i.e., at least one to four times per week) versus those who ride less frequently.

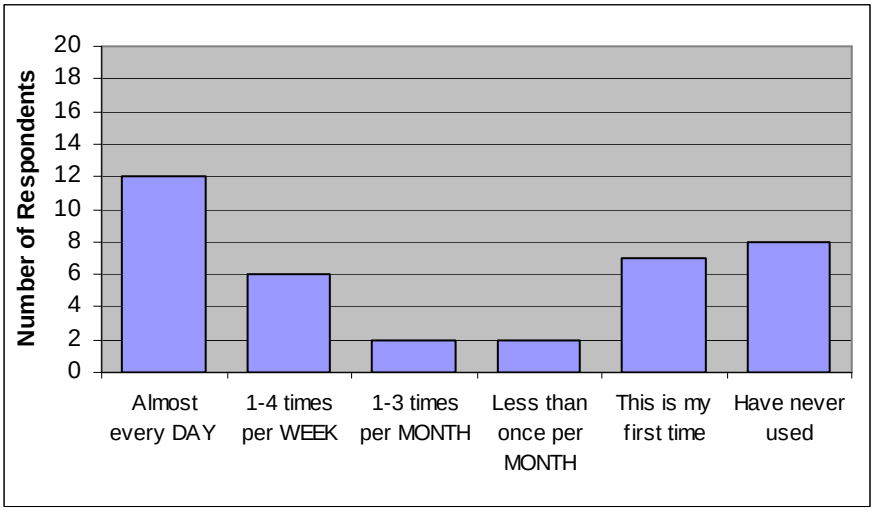


Figure 10. Frequency of Use of the Bus Arrival Time System (N=37)

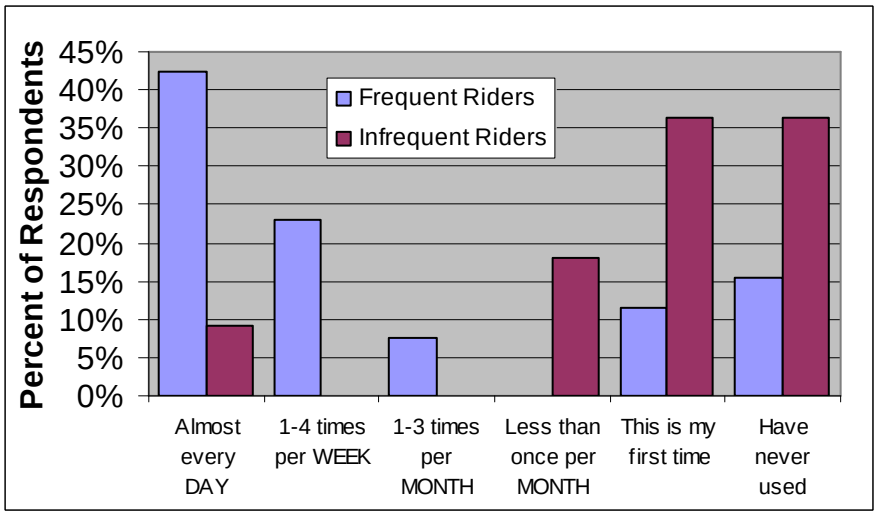


Figure 11. Frequency of Use of the Bus Arrival Time System for Frequent and Infrequent Bus Riders (N=37)

Nearly 50 percent of respondents use the bus arrival time system one to four times per week or more. This indicates that this feature is an important attraction on the CARTA website. For those who often ride the bus, this percentage increased to 65 percent.

The most common reasons cited for using the bus arrival time system were related to avoiding a wait at the bus stop. As shown in Figure 12, 19 of 27 respondents (65 percent)

cited the desire to minimize wait time at the bus stop (12 respondents) or to finish doing something before leaving for the bus stop (7 respondents).

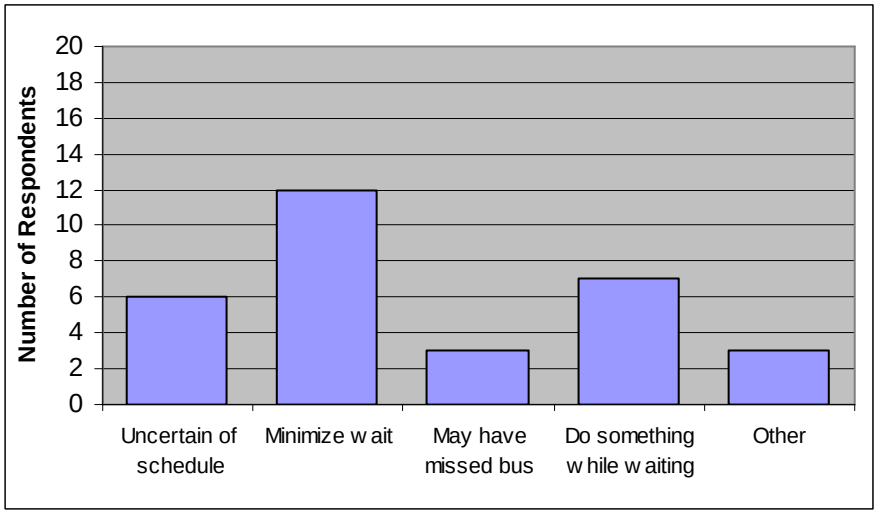


Figure 12. Reasons for Using the Bus Arrival Time System (N=29)

It appears that the users of the bus arrival time system are using it to guide their travel decisionmaking. This is further reinforced by Figure 13, which indicates that most respondents had acted on the information received from the bus arrival time system.

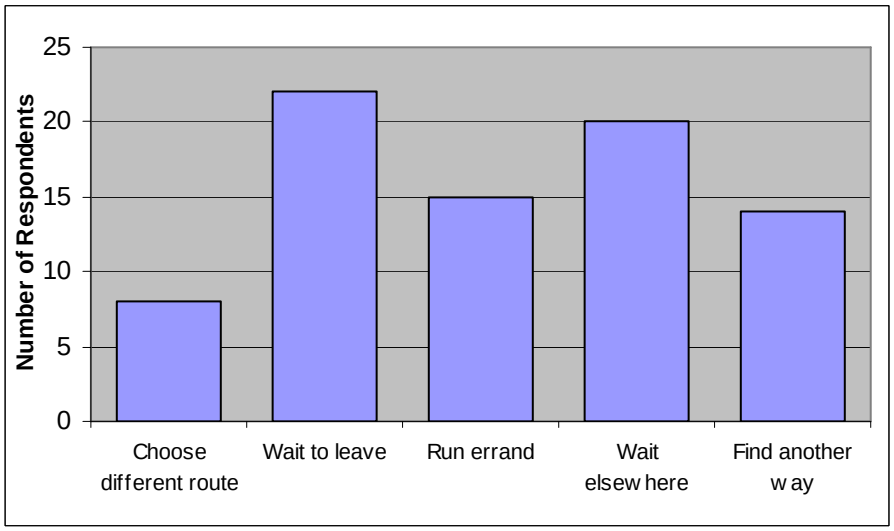


Figure 13. Actions Taken after Consulting the Bus Arrival Time System (N=29)

Because the bus arrival time system users were acting on this information, many felt that the system saved them time. Figure 14 depicts the extent to which respondents agreed with the statement "CARTA's Bus Arrival Time System saves me time." Most of the respondents (24 of 29) either agreed (6) or completely agreed (18) with this statement.

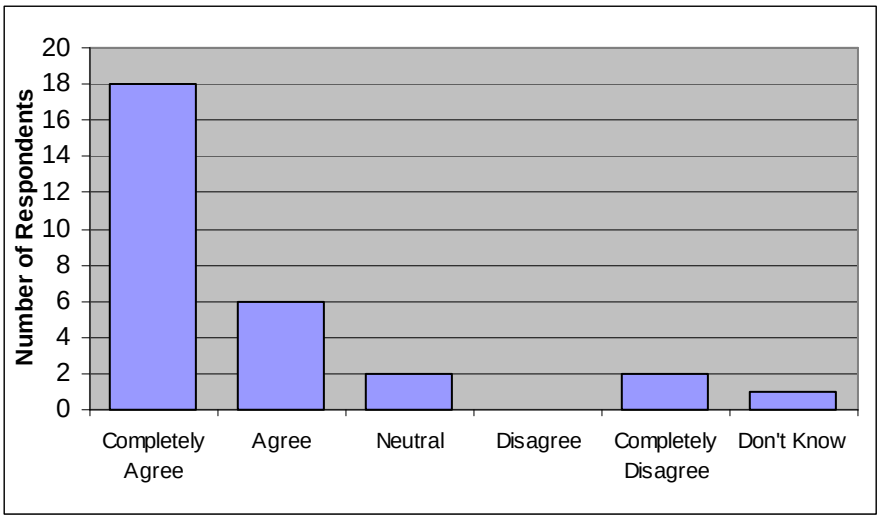


Figure 14. Respondents Agreement that the Bus Arrival Time System Saved Them Time (N=29)

This is reflected in the impact of the system on the respondents' satisfaction with CARTA's bus services. As shown in Figure 15, 76 percent (22 of 29) of respondents indicated that they either agreed (3) or completely agreed (19) with the statement that "CARTA's Bus Arrival Time System increases my satisfaction with bus services." This is important because it directly demonstrates a positive impact of a bus arrival time system on customer satisfaction.

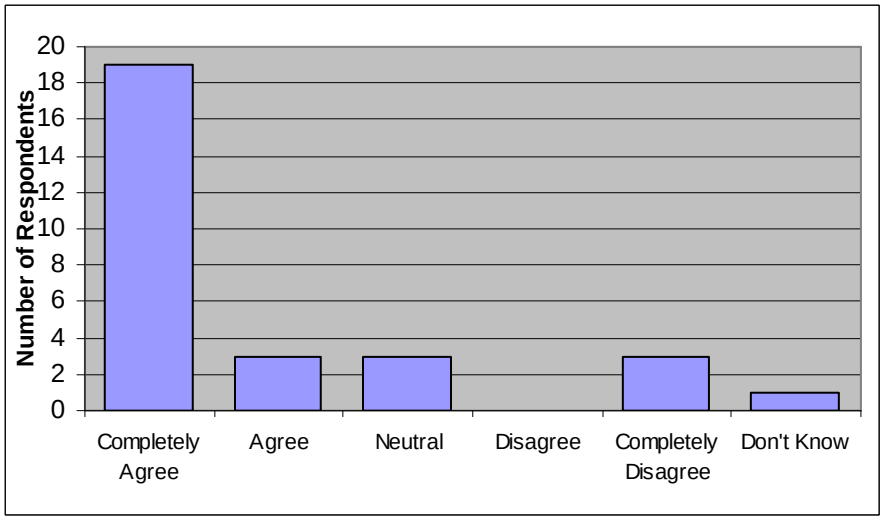


Figure 15. Respondents Agreement that the Bus Arrival Time System Made Them More Satisfied with Transit (N=29)

Moreover, Figure 16 indicates that this increased satisfaction results in an increase in ridership – 18 respondents either agreed (6) or completely agreed (12) with the statement "CARTA's Bus Arrival Time System causes me to ride the bus more often."

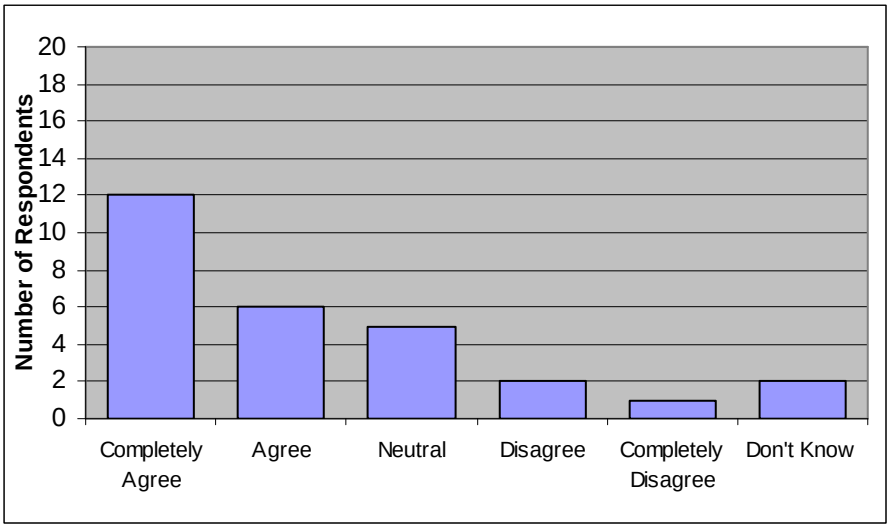


Figure 16. Respondents Agreement that the Bus Arrival Time System Caused Them to Use Transit More Often (N=29)

This system appeared to increase customer satisfaction – about three-fourths of CARTA website users surveyed agreed that the bus arrival time system made them more satisfied. In fact, about two-thirds of respondents indicated that the system caused them to use transit more often.

Similar results hold for the bus location map feature on the CARTA website – see Appendix B for more details.

3.9 REMOTE DIAGNOSTIC MAINTENANCE SYSTEM

CARTA began preparing to deploy an RDMS in 2006, when the agency included hardware designed to increase the amount of vehicle performance data available to an RDMS on new vehicle purchases. The integration of the MDC with the onboard systems for monitoring vehicle performance occurred in 2008 when the MDCs were deployed to support the AAS and the bus arrival time system. The next step in the RDMS deployment was the deployment of software on the MDC to monitor and store the vehicle performance data during the day and, when in range of the WLAN deployed at the CARTA maintenance garage, automatically download the RDMS data to a RDMS server deployed there. More details on the RDMS and lessons learned during its deployment and use are in section 4 of this report.

3.10 AUTOMATIC PASSENGER COUNTER

The hardware for the APC was deployed in 2008, along with other onboard hardware to support AAS and the bus arrival time system. But, testing did not begin until after the AAS and bus arrival time systems testing were complete. Early CARTA testing revealed some anomalies. More detailed testing identified the fact that the APC software sometimes delayed recording tallies when passengers embarked or disembarked. While the total passenger counts were accurate, the stop-by-stop embarkation and disembarkation counts were not always correct. The vendor reviewed the software and identified a problem: the software was sometimes slow

Figure 17. An Installed APC Device

to post riders entering or exiting the vehicle, so that the posting would sometimes be related to adjacent stops.

After the APC software repairs were completed, CARTA re-tested the system and verified that the system correctly assigned embarkations and disembarkations to the correct stops. However, agency staff noted other anomalies during the re-testing and were not willing to accept the system until they performed additional tests. With the deployment of the first stage of the CAD/AVL system nearing completion, CARTA elected to delay completion of the APC deployment so it could focus limited resources on completing CAD/AVL. The agency now expects to complete the APC deployment in early 2010.

Once completed, the APC system will provide CARTA with several benefits.

The APC will reduce the amount of time spent collecting passenger count information. At the time the APC was deployed, CARTA was required to perform manual passenger count surveys on 11 trips per week (572 trips per year) in order to verify passenger counts. These surveys required about a quarter of a full-time equivalent over the course of each year. After the APC deployment is complete, CARTA will only be required to perform manual passengers counts on about 100 trips per year – an 82 percent drop in the time required for manual passenger count surveys.

The APC will simplify the process of producing passenger counts. Prior to deploying the APC system, CARTA estimated passenger counts based primarily on the farebox data, with adjustments made based on the passenger count surveys conducted each week. With both the new farebox and APC systems reporting data to the data warehouse, CARTA will be able to automate the passenger count process.

The APC will provide real-time validation of the farebox data. With both the new farebox and APS systems providing time-stamped passenger count information, these two systems can be used to validate each other. Additionally, CARTA staff will be able to identify problems that may occur with either these systems more quickly, since problems will be apparent as inconsistencies in these two sources of passenger information. The result will be higher quality farebox and APC data.

3.11 CAD/AVL

This deployment referred to the integration of CAD capabilities into CARTA's fixed-route, flex-route, and paratransit operations software. Many other elements required for the CAD/AVL system were already in place when this integration began in 2009, including vehicle tracking and real-time communication of vehicle locations to CARTA servers. The main new capabilities were tools to display real-time system status information to dispatchers and to improve communications between dispatchers and drivers.

Figure 18. CARTA Supervisor Using the Fixed-route CAD/AVL System

This deployment occurred in three stages. The first stage was the integration of CAD capabilities into the fixed-route operations software – see Figure 18. As of October 2009, this stage was nearly complete; only integration of voice communication services into the dispatcher interface was yet to be performed. The second stage, planned for early 2010, was the integration of CAD capabilities into flex-route and paratransit operations. Stage 3 will be the integration of these systems with the data warehouse.

The main benefit CARTA was hoping to receive after stage one was improved situational awareness of the system status. CARTA fixed-route supervisors could easily review system status information, both in tabular and map formats. It was expected that this would improve system performance by helping managers respond more quickly to any problems that occurred.

Figure 19. The Fixed-route CAD/AVL Map Display Screen

CARTA was anticipating more direct benefits with completion of stage 2. Previously, CARTA's ability to change the plans for passenger pick-ups and drop-offs for flex-route and paratransit vehicles was limited by two factors. First, CARTA did not have real-time information about vehicle locations. This prevented software from using actual vehicle locations to plan passenger pick-ups and drop-offs. This was particularly important for flex-route service, where callers were often ready for immediate pick-up when they called in. Second, CARTA drivers used paper manifests to track passenger pick-ups and drop-offs. Making significant changes to these schedules (e.g., to accommodate a same-day request) would require long radio communications with many drivers to inform them of changes to their manifests. Because of the difficulty of this process, CARTA made few same-day changes to these schedules once the manifests were printed at the start of each day. With

the completion of stage two, however, drivers will use electronic manifests viewed on the MDC display. Eliminating the need to update paper manifests manually will remove a significant barrier to same-day schedule changes.

The third stage, integration with the data warehouse, is expected to produce two types of benefits. First, it will provide CARTA with an improved ability to analyze historical data, when needed, to support operational decisionmaking. Second, it will allow CARTA to develop a dashboard system that will summarize and display, in real-time, key operating characteristics.

4 THE REMOTE DIAGNOSTICS MAINTENANCE SYSTEM

One of the systems that CARTA deployed between the time of the Phase II evaluation report and this report was the remote diagnostics maintenance system. This section of the report describes CARTA's experience with deploying and operating the remote diagnostics maintenance system and the benefits of the system that the agency has observed.

4.1 BACKGROUND

The CARTA remote diagnostics maintenance system monitors vehicle performance and provides feedback to CARTA staff on critical components of each vehicle. The system is expected to reduce annual maintenance costs and reduce the number of on-road vehicle failures due to maintenance issues. The evaluation team gained an understanding of how CARTA's system worked by interviewing CARTA's Director of Transportation, Director of Technology, Head of Maintenance, General Manager, and maintenance staff. The CARTA team envisioned that the system would save CARTA both material and labor costs, improve customer service, and help CARTA maintain a positive reputation with the public. The study team also looked at maintenance records along with case studies that the Head of Maintenance gave the evaluation team.

Figure 20. CARTA Vehicle Being Repaired


Figure 21. CARTA Mechanic at RDMS Terminal

A typical bus has an electronic computer module (ECM) that monitors the bus's major components and communicates an alert if a problem occurs. The ECM then logs a code that can be displayed by maintenance staff when they plug into the bus to diagnose problems. For the deployment of this technology, CARTA has added a mobile data computer (MDC) onto each of the buses. RDMS software allows the agency to track bus alerts when they happen, and a multiplex plugs into multiple other engine systems so that alerts can be tracked over time. As of September of 2009, this information is archived onboard on the MDC and then a bulk data transfer occurs via a wireless local area network (WLAN) when the bus returns to the garage. These alerts are then compiled into a report for each vehicle and emailed to CARTA's Head of Maintenance so that he can monitor alerts. This system is installed on all of the fixed route buses and combines data from several subsystems on the bus to produce a single stream of system performance data. CARTA currently has plans to integrate a real time communications by early 2010 to allow time-sensitive data to be transmitted back to the central system (including appropriate staff

notifications to trigger immediate action) once additional onboard enabling systems are deployed as part of the CAD/AVL software and onboard systems project.

The first stage of the deployment began in 2006 and included mobile data computers collecting data on various characteristics (i.e. engine temperature, error codes, etc.). This stage allowed maintenance staff to plug into the system and determine what was happening with the bus, which is typical with most agencies. In this stage of the deployment, the maintenance staff only used this information if there was an apparent problem reported by the bus driver. This narrowed the potential problems to a certain area of the bus, which was much better than not knowing there was a potential problem or being notified by a driver that a check engine light had come on. It was also during this stage that permanent archives were created on the multiplex system, which allowed maintenance staff to check past problems with each individual vehicle. For example, during the interview process with the maintenance staff, one individual informed the evaluation team that a problem had occurred on a bus and a maintenance staff member had fixed the problem out in the field. After completing the repair, the mechanic cleared the entry from the ECM, which is oftentimes done after completing a repair. Later on, the same problem occurred on the bus and a different maintenance staff member came in and checked the permanent archive on the bus. He noted that this problem had occurred multiple times and was able to better pinpoint the underlying issue as a result (i.e., without the new system he would have not known about the previous problems).

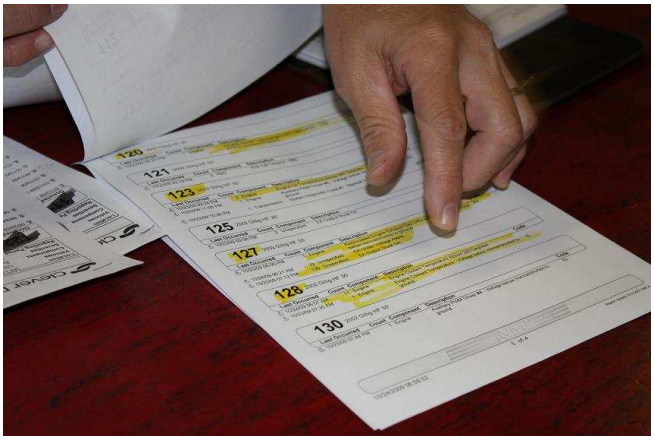


Figure 22. CARTA Staff Reviewing RDMS Report

The second stage of the deployment started in January 2009 and included setup of the WLAN. In this stage of the deployment, data was collected from the buses each night when they pulled into the garage. However, this feature was not released to the maintenance staff until March 2009 so that IT staff could "tune" the system. This allowed CARTA to take a proactive approach to maintenance by developing a data warehouse report for certain characteristics. Following these initial reports, CARTA's IT staff developed advanced filters to sort out the major problems and bring them to the staff's attention. CARTA has two types of road calls, Policy and Procedure (minor) Road Calls, and Major Road Calls. Minor road calls are for vehicles that CARTA changes out due to non breakdown issues (such as a wheelchair lift being stuck in the non-extended position) while major road calls are breakdowns that require mechanics to work on the bus. During the second stage of deployment, a year-over-year comparison of the number of road calls shows that the number of minor road calls has increased for the entire fleet and the number of major road calls has gone down with the exception of August and September. This information is shown in the following charts, which shows the major and minor repairs from February 2008 to September 2009. CARTA maintenance staff also noted that during this same period there was a large influx of new drivers, which might have contributed to these numbers. In general, a new bus driver will see a problem and immediately call in the problem because he is not experienced enough to know the "ins and outs" of how the bus operates.

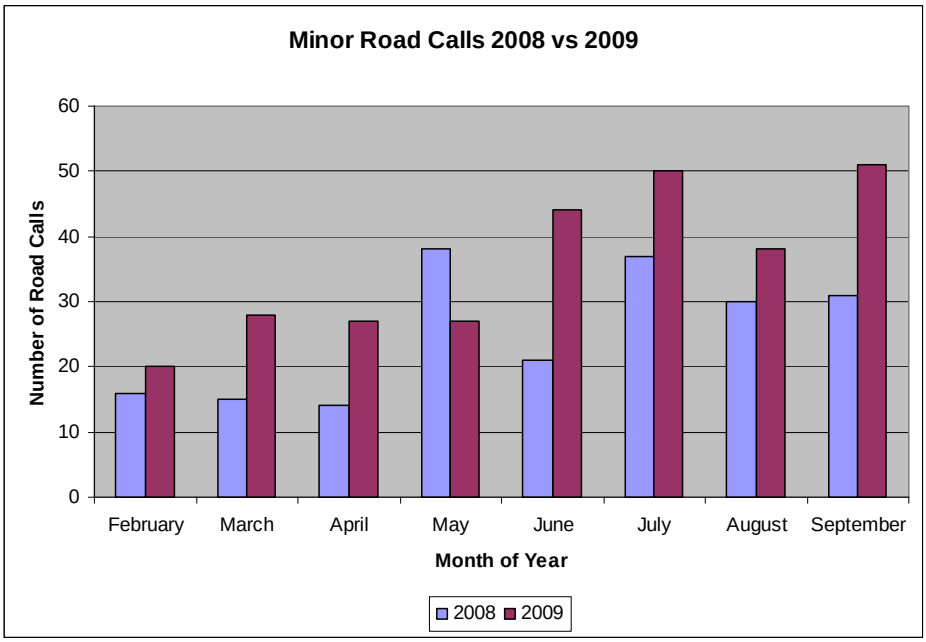


Figure 23. Month-by-Month Comparison of Minor Road Calls, 2008 vs 2009

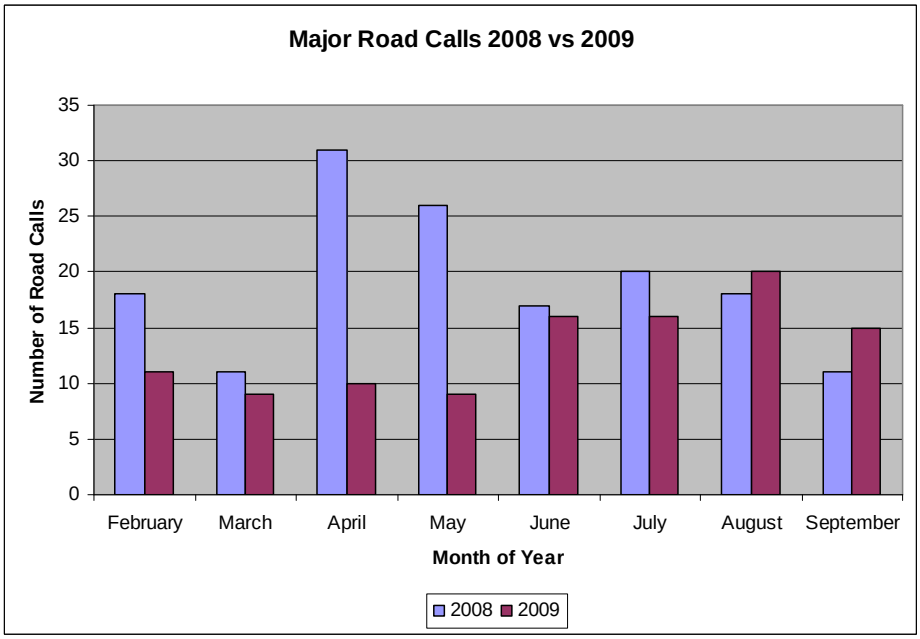


Figure 24. Month-by-Month Comparison of Major Road Calls, 2008 vs 2009

In the time since March to October, the maintenance staff have identified a total of nine examples where the staff took a proactive approach to solving issues that most likely would not have been identified by the bus drivers. When these alerts occur, the maintenance staff use the system to determine areas where routine maintenance can be incorporated with the alert message. For example, if a bus alerts the system of a problem and it is also due for an oil change in the near future, the mechanics will incorporate these two procedures while the bus is in the garage. The following are a few examples of how the maintenance staff is utilizing the system and the pitfalls and benefits of the system.

- The example of Bus 123 shows that the alerts are notifying the maintenance staff of an issue, but the staff are having a hard time pinpointing the issue(s). In August, Bus 123 started displaying alert codes that the engine oil temperature was above normal conditions for short periods of time throughout the day. The maintenance staff took an aggressive, proactive approach and began to address the issue with repairs. The staff began with fairly minor repairs but eventually they began to replace component parts. The following are some of the repairs the maintenance staff tried: checking the air compressor, replacing coolant, steaming the radiator, replacing the temperature value, and eventually changing the coolant flow control value. Each time a repair was completed, the bus was tested to see if would respond with an error code and, once cleared, was then put back into service. Once back in service, however, the bus would eventually respond with more alert codes, so the maintenance staff would pull the bus back in for repairs. This process took about 2 months of Bus 123 being in and out of service. The problem initially surfaced in August and the maintenance staff felt confident that they had fixed the problem by October. This is an example of additional workload resulting from the system.
- On the flip side, there were two cases where an aggressive, proactive maintenance approach has prevented major repairs.
    - One example is where the bus indicated alerts that typically would not be displayed and seen by the bus driver. This alert was displayed in the daily morning report, but was not caught by the bus driver. With the alert being drawn to their attention, the maintenance staff investigated the issues. During the investigation, the maintenance staff discovered a major problem — a barring was out of balance. This problem could have eventually led to the engine being completely destroyed. As the Head of Maintenance explained, the cost of an engine is typically between $30,000 and $40,000.
    - Another example is a case in which the RDMS notified the maintenance staff of a potential problem with a turbo charger. This example is similar to the previous example, where, when the maintenance staff fully investigated the problem, they noticed that the turbo charger was in the early stages of needing to be replaced. Failure of the turbo charger would not only affect the turbo charger component, but also other engine parts and could have resulted in a catastrophic engine failure.

The third stage of this deployment will incorporate real-time diagnostics of potential mechanical problems and will be incorporated when the CAD/AVL system is fully integrated. Based on interviews, the CARTA staff envisions that the remote maintenance system will save CARTA both material and labor costs, improve customer service, and help CARTA maintain a positive reputation with the public. When viewing data through the maintenance system, a maintenance supervisor may instruct the bus operator to bring the bus to the maintenance yard immediately, to stop the bus and wait for a mechanic to come out, or to keep driving because the issue can be resolved once the bus finishes for the day. By enabling the maintenance supervisor and driver to take appropriate action based on system data, they are increasing the chances for mechanical issues to be resolved before the bus fails on the road. This information should also limit the number of engine failures experienced by CARTA. The maintenance supervisor is hopeful that the real-time information will allow them to make repairs to engines before they fail on the road, something that could save CARTA thousands of dollars each year.

CARTA hopes to greatly increase the miles between road failures and to ultimately have zero road failures. When buses break down on the road, customers are inconvenienced and the reputation of CARTA as a reliable, customer-friendly transit service is potentially damaged. By preventing or limiting road failures, CARTA can not only provide more reliable

customer service, but also avoid damage created by "word of mouth" that occurs when the public sees a bus broken down and riders stranded.

By putting the diagnostic information in the hands of the maintenance staff while the bus is in the field, the staff can likewise prevent drivers from unnecessarily off-loading passengers and returning to the maintenance yard for maintenance issues that do not require immediate attention. This will save CARTA the costs associated with bringing out another bus to pick up those passengers and prevent unnecessary passenger delays.

Similarly, maintenance staff will no longer have to rely on bus drivers to verbally explain the mechanical problems being experienced. With the remote diagnostics system, the maintenance supervisors will be able to quickly determine what is wrong with the bus, streamlining situations where a mechanic goes out to the field to repair the bus. The diagnostic information will also enable the maintenance supervisor to send out a mechanic with the skill set and tools necessary for the in-field repair.

4.2 IMPACTS/SUMMARY

In summary, the CARTA staff interviewed anticipate that the remote diagnostics maintenance system will reduce maintenance costs and on-the-road failures as well as improve customer service and the public's perception of CARTA's reliability. The evaluation team tested key hypothesis 5, "the addition of a remote diagnostics maintenance system will result in reduced annual maintenance costs and will reduce the incidence of on-road maintenance-related vehicle failures" by reviewing maintenance repair data and analyzing interviews on the perception of usefulness of remote diagnostics. Overall the evaluation team feels that there is insufficient data to confirm this hypothesis. However, there are some realized benefits from looking at the number of major road calls are reduced, although the number of minor repairs have increased. There is other cost savings from mechanics being able to narrow or pinpoint problems on the buses, thus reducing the amount of time spent on each repair. In addition, the RDMS software has already identified potential large problems that could destroy engines and allows the agency to address smaller issues before they become larger issues.

5 REVIEW OF THE CARTA SYSTEMS ENGINEERING PROCESS

One of the activities performed during the evaluation documented in this report was a review of CARTA's systems engineering process. The results of this review were documented in the report titled *A Case Study on Applying the Systems Engineering Approach: Best Practices and Lessons Learned from the Chattanooga SmartBus Project*. This section summarizes the results of this previous report and provides additional information on CARTA's CAD/AVL deployment and on the transition that occurred after CARTA's Manager of Technology left the organization.

5.1 OVERVIEW OF THE CARTA SYSTEMS ENGINEERING PROCESS

CARTA's ITS program effectively began in 2002 with a grant application under the ITS Integration Program and the subsequent award under the FY 2002 and 2003 ITS Integration Programs. The following paragraphs trace CARTA's systems engineering processes from that beginning to October 2009.

Defining the Vision. The first step in CARTA's systems engineering process was to define the long-term vision for ITS at CARTA. The grant application was a first step in doing that. In the 2 years following the grant award, CARTA further refined its vision through a review of the Regional ITS Architecture, a regional stakeholder workshop, and a review of available ITS technologies. This process culminated in the production of a System Overview Update – 2004 report, completed in January 2004. A key feature of this report was the system overview diagram (see Figure 25), which summarized CARTA's long-term vision for its ITS program by depicting how the various technologies would be integrated into an overall system.

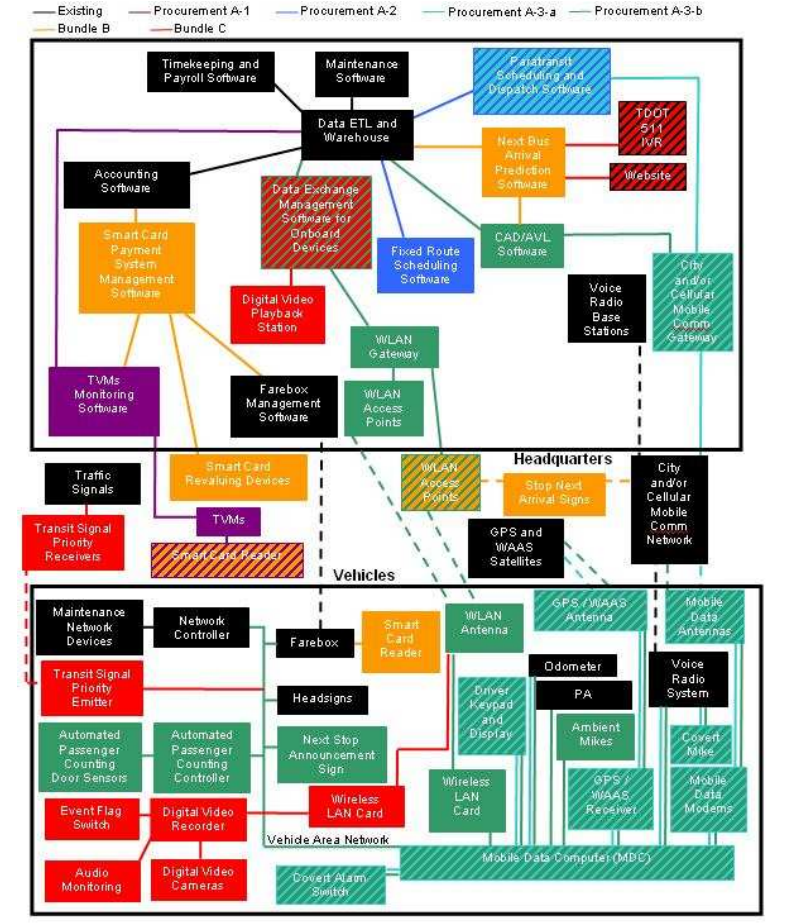


Figure 25. The CARTA ITS System Overview Diagram

Planning the Deployments. After defining the long-term vision for ITS, CARTA began the process of planning its ITS deployments. CARTA first identified the sequence in which the ITS projects would be deployed, and also identified infrastructure enhancements (e.g., network upgrades) needed to support the projects. Then, CARTA established the deployment schedule for these projects and the procurement procedures they would follow in pursuing the deployments. CARTA integrated this information in the System Overview Update report and started annually updating that report to reflect the current status of the

agency's ITS deployments and to identify the planned deployment activities for the upcoming year.

Deploying Technologies. CARTA's first ITS deployments were to upgrade the agency's infrastructure to prepare for future deployments. This included deploying the CARTA Data Warehouse, deploying new timekeeping and payroll software, and integrating the new software with the data warehouse. With each deployment, CARTA developed a project deployment plan that included the following topics:

- A project overview that described the project.
- Description of how the system would operate and be maintained once deployed.
- Project stakeholders and their roles in the deployment.
- Approaches for monitoring and evaluating the performance of the deployment.
- Suggestions for outreach activities to accompany the deployment.

The technical topics related to each project were addressed through a series of standard systems engineering documents – a specifications document, a design review, test procedures, test results, etc.

Maintaining the Vision. As technologies were deployed, CARTA's vision for its ITS program evolved. As a result, CARTA updated its System Overview annually to reflect (a) technologies that were already deployed and (b) changes to the technologies that were planned for deployment. Maintaining this document helped CARTA ensure that the agency's vision for ITS remained consistent with evolving technologies and that its ITS deployment activities remained consistent with the vision.

5.2 THE CAD/AVL AND ONBOARD SYSTEMS DEPLOYMENT

This section exemplifies CARTA's systems engineering approach by providing details about the CAD/AVL and onboard systems deployment. This deployment included CAD/AVL software, onboard MDCs, paratransit and flex-route scheduling and dispatch software integration, covert alarms and microphones, next bus arrival time prediction, APCs, AAS, WLAN bulk data transfer, RDMS, integration of these systems with the data warehouse, and a dashboard system to display summaries of real-time operating characteristics.

Despite the fact that CARTA treated these as a single procurement, the deployment of these technologies actually occurred as a series of smaller deployment projects with each project building on the capabilities of the previous one and providing demonstrable benefits to CARTA. The first step was completion of the overall design. This was necessary in order to ensure that technologies first deployed would provide the capabilities needed for later steps in the deployment. (This was also a reason for combining the deployment of these technologies into a single procurement – there was a high degree of dependency between these technologies, so having a single vendor responsible for their integration helped ensure that the overall needs were considered during each step of the deployment.)

The first target for the deployment was to deploy the systems necessary to support a bus arrival time system and AAS. The former was selected because of an opportunity to obtain additional funds for a bus arrival time system, if that system were operational by the end of the 2008 calendar year. (Before being offered that opportunity, CARTA had planned on deploying the CAD/AVL software for fixed-route services as its first target.) The latter was selected because the core capability needed to support the bus arrival time system, vehicle location tracking, and daily transmission of route data to the buses would also support AAS. Both of these systems were operational by the end of 2008.

CARTA's plans for 2009 called for deploying the RDMS and APC systems early in the year, with the remainder of the year focused on the CAD/AVL software. The RDMS took advantage of two of the systems installed to support the bus arrival time system and AAS – the MDC and the WLAN. The agency complemented these systems with installation of a RDMS server at CARTA, MDC software to manage the collection of RDMS data from the onboard system and transmission of that data to the RDMS server, and software on the server to support use of the RDMS data by CARTA maintenance staff. This system was operational in January 2009, and was released for use (after testing) in March 2009.

The APC system was similar, taking advantage of the MDC to manage APC data and using the WLAN to transmit data to a newly installed APC server. In the case of the APC, however, system testing identified problems with the system and its release for use to support CARTA operations was delayed. To prevent development and testing demands of the APC system from interfering with the development and testing of the CAD/AVL software, CARTA assigned a low priority to further testing of the APC system until the CAD/AVL deployment was complete.

The initial stage of the CAD/AVL deployment, which provided operational support for fixed-route services, was being tested in October 2009, and it appeared that this stage would be completed in late 2009. This deployment added another new capability to the CARTA system – a real-time transmission of data between CARTA vehicles and CARTA servers.

At the time when this report was written, CARTA's plans were to integrate CAD/AVL into its paratransit and flex-route scheduling and dispatch software early in 2010. (This integration would take advantage of the real-time data transmission capabilities proven in the fixed-route CAD/AVL deployment.) CARTA next planned to integrate these systems with the data warehouse and to complete the APC deployment.

5.3 TRANSITIONING AFTER THE DEPARTURE OF THE MANAGER OF TECHNOLOGY

Another test of the robustness of CARTA's systems engineering processes occurred in July 2009, when CARTA's Manager of Technology left the organization. Because the Manager of Technology was the only CARTA staff member with day-to-day involvement in the CARTA ITS program, the loss of the Manager of Technology had the potential to disrupt the deployments. During the limited time available for observation after the resignation of the Manager of Technology and before this report was completed – from July through October 2009 – this did not appear to be the case. Discussions with CARTA staff suggested several reasons for the apparent success of this transition.

Having a consultant on board helped bridge the knowledge gap during the transition. Although CARTA had only one full time staff member focused on the ITS deployments, an outside consultant had been assisting CARTA throughout the process. This consultant continued to work on the project throughout the transition period. In fact, the consultant assumed some additional responsibilities that were previously performed by the Manager of Technology.

The systems engineering process and resulting documentation helped facilitate the transition. CARTA's systems engineering documentation described CARTA's ITS plans and schedules. This helped the staff now responsible for those plans to understand them so they could continue to carry them out. Also, the CARTA contractors that were deploying the systems had been working with CARTA for several years; they were familiar with the systems engineering processes that were being used and could continue to apply those processes.

CARTA also noted that the need for a full-time Manager of Technology had lessened as the deployment stage of the ITS program was winding down. In the early stages of the

deployment, many new features were being added and strong oversight was needed to ensure that these features were consistent with the long-term vision for ITS at CARTA. A large number of technical skills were needed at CARTA, such as skills to develop reports for the data warehouse, to oversee the system designs, and to establish maintenance procedures for installed equipment. By 2009, much of this technical work was done and a large part of the work that remained was in maintaining the installed systems.

5.4 SUMMARY OF LESSONS LEARNED

The following list summarizes lessons learned documented during the systems engineering review. Some of these lessons learned are exemplified by information provided in this chapter of this report, and more details regarding all of them are in the *Case Study on Applying the Systems Engineering Approach* report.

- Documenting the long-term vision for ITS helps ensure that long lead-time activities are completed in time to support future plans. In 2006, CARTA began requiring RDMS support hardware on all new bus purchases, though the RDMS was not deployed until 2008.
- Taking advantage of opportunities that arise may require being flexible regarding the deployment schedule. CARTA delayed the CAD/AVL deployment in order to move forward the bus arrival time deployment to take advantage of a funding opportunity.
- Avoid the temptation to do too much too fast. In order to expedite the bus arrival time system deployment, CARTA delayed the CAD/AVL deployment rather than trying to compress both into a single year.
- Be willing to accept schedule delays when needed to help manage deployment risks. When rework of the APC system was required to correct problems discovered during testing, CARTA delayed completion of the APC system so as not to take focus away from the CAD/AVL deployment.
- Using a data warehouse can reduce overall system complexity by reducing the number of systems that must be integrated. Most operational reports that relied on data from multiple systems were created within the data warehouse. This meant that the individual systems did not have to be integrated with each other in order to produce integrated reports – they only had to be integrated with the data warehouse.
- Using virtual servers and ensuring that all applications use a single database engine can reduce the time required to maintain the IT infrastructure. Since CARTA relied on a single person to provide most of its IT support, it was important to reduce the demands on this person (e.g., by only requiring the person to be familiar with a single database technology).
- Including a broad range of stakeholders, including those skeptical of ITS, can improve the final product and its level of acceptance. Before starting the CAD/AVL deployment, CARTA formed ITS Oversight Committees to provide feedback on plans for the deployment of onboard systems. These committees included union representatives and many drivers, as well as several employees who had preconceived negative opinions regarding these particular technologies. In addition, committee members were paid to participate in committee meetings.
- Search for easy-to-implement projects that will produce easy-to-see benefits. CARTA's first ITS projects were self-contained deployments that provided easy-to-see benefits – a data warehouse that simplified internal CARTA reporting processes, Incline Rail TVMs, etc. Each successive deployment built on the proven technologies of previous steps – the AAS proved the vehicle location system, and the CAD/AVL built on that capability.

- Commit to testing systems thoroughly before introducing them to operations. CARTA thoroughly tested its systems before accepting them for use. In several cases, these tests revealed problems; for example, AAS sign messages that did not display on time due to timing conflicts, APC passenger counts allocated to the wrong stop. These problems would have been more difficult to correct if the system had already been accepted for operational use.

The following statement summarizes CARTA's experience with systems engineering:

> ***From the beginning of its ITS development program, CARTA accepted the need to apply the system engineering approach comprehensively. This was due to the complexity and scope of the technologies, and the understanding that significant impacts would need to be carefully managed. As the deployments progressed, CARTA also came to see value from the acceptance testing since this was ensuring that the systems as delivered included all the capabilities that had been promised by the vendors.***
>
> **Doug Parker, Integration Consultant**

6 SUMMARY AND CONCLUSIONS

While the technologies deployed at CARTA have had many direct impacts, the biggest change observed during this period was that CARTA is beginning to make better use of its data archives to support operational decision making. Prior to SmartBus, key performance data was maintained in a variety of paper logs, electronic spreadsheets, and proprietary software applications. Data was often collected by one application, then had to be re-keyed into a second application that had need for the same data. These manual and semi-automated methods for collecting and maintaining data had several intrinsic limitations. The deployment of a data warehouse at CARTA has provided the agency with some notable advantages. It has helped CARTA automate monthly and annual reporting processes, saving CARTA time and money, and has opened up access to data previously locked up in proprietary systems. This has made it possible for CARTA to take ownership of its reports based on that data rather than relying on outside consultants to produce them. The simplicity of CARTA's data warehouse tool has also allowed the agency to take ownership of the data warehousing process, keeping down the cost of maintaining the scripts needed to load data into the data warehouse. The data warehouse has done more than just improve CARTA operations, it has provided CARTA with new capabilities, such as the ability to efficiently produce special reports to support operational decision making. The CARTA data warehouse has not only helped CARTA operate better now, it promises to continue to improve operations well into the future.

Another area where CARTA is just beginning to see benefits is the remote diagnostic maintenance system. The remote diagnostic maintenance system is being monitored through the RDMS and is putting the diagnostic information in the hands of the maintenance staff rather than the maintenance staff having to rely on the bus drivers to self-report all alerts. In the short term, this is leading to more minor road calls and reducing major road calls; however, CARTA expects the system will reduce on-the-road failures. This reduction is expected to be enhanced when the real-time information starts streaming to the maintenance staff after the CAD/AVL is fully integrated. This information will allow the maintenance staff to actively manage bus alerts to reach the Head of Maintenance's goal of zero road calls.

Other benefits and lessons learned from the deployments are summarized below:

Data Warehouse

- The data warehouse saves staff time by automating the process for producing a number of monthly and annual reports. This allows CARTA staff to spend more time improving operations rather than generating and manipulating data to fulfill reporting requirements. CARTA's purchaser uses some of these reports to save about 2 days per month on monthly reports. (See sections 5.2.3 and 5.3 of the Phase II evaluation report.)
- The data warehouse saves money by allowing CARTA staff to create custom reports, a task that they previously outsourced to contractors. By 2009, CARTA had developed more than 120 data warehouse reports. CARTA reports saving roughly $72,000 for producing reports.
- The data warehouse helps CARTA make more informed decisions. By consolidating data from many different sources and providing sophisticated reporting tools, the data warehouse allows CARTA staff to analyze operations data in new ways in order to provide support to decision makers.
- The existence of a data warehouse simplified development of some IT systems at CARTA by providing reporting tools, eliminating the need for sophisticated reporting tools in

some of CARTA's IT applications. For example, the new revenue management system, when first delivered, did not include six reports that were critical to CARTA operations. CARTA staff were able to quickly develop versions of these missing reports using reporting tools from the data warehouse.

- The existence of a data warehouse simplifies the integration between IT systems at CARTA because each system can be integrated with the data warehouse. This was simpler to develop and maintain than separately integrating the individual IT systems together.

Vehicle Fuel Usage System

- The upgrade vehicle fuel usage system at CARTA builds on the success of the data warehouse deployment by automating an important data feed to the data warehouse, the vehicle fuel and oil usage data. This simplifies and makes less error prone a previously tedious task. It also helps demonstrate the power of the data warehouse by allowing CARTA to automate fuel usage reports. The early success of this project helped build support for ITS at CARTA. CARTA reports that the vehicle fuel usage system saved them about one person-hour per day entering data into the system.

Ticket Vending Machines

- The TVM system reduces man power requirements. CARTA estimates that the TVM system saves one man year of time spent on ticket sales, though CARTA has chosen not to reduce staff. Instead, they used that time to improve customer service.
- The TVM system provides better loss prevention than the previous manual system. The previous manual system provided little accounting of the ticket transactions and also required that workers handle large quantities of cash.
- The TVM system provides CARTA with much more detailed sales data than was previously available. With the previous manual system, ticket sales data was limited to the total number of daily ticket sales at each location. With TVMs, the exact time of each ticket sale is recorded and archived.
- The TVM system and its integration with the data warehouse allows CARTA to analyze Incline Rail ticket sales data in new ways. When CARTA was considering reducing Incline Rail hours of operation, the agency queried the TVM data in the data warehouse to generate a report on tickets sales by hour of day in order to estimate the potential impact on ticket sales.
- The TVM system helps CARTA resolve credit card disputes. Resolving questions regarding credit card payments previously required manual searches through paper records to find credit card purchase slips. Now, a query of the archived TVM data provides a record of credit card payments for resolving disputes.

Fixed Route Operations Software

- The software significantly decreases the time required to perform runcutting. The new software can perform runcutting calculations in about 5 minutes, which allows CARTA staff to quickly run many different scenarios in search of an optimal one. The software also automates production of headway sheets and paddles, eliminating a previously time-consuming, manual activity. The benefits CARTA estimates from using the operations software includes saving almost 2 weeks every run cut, which CARTA does twice a year.
- The software can consider many different parameters in its calculations, such as hourly rates, overtime rates, overtime policies, and driver break policies and sometimes is able to find a lower cost solution (by considering a wider range of variations in these factors)

than was found using more manual methods. The new software has produced runcuts requiring one fewer bus operator than previously required. The run cutting software has also reduced the total operator time required by 60 hours per week while still satisfying CARTA's fixed route schedule requirements.

- The software captures CARTA's institutional knowledge of runcutting, making the agency less dependent on the specialized expertise of the runcutting staff.

Paratransit Operations Software

- CARTA reports that the time required to book a trip is about 50 percent higher than it was using the former system. However, CARTA expects this cost to be offset by improved efficiencies when the CAD/AVL and electronic manifest capabilities become available.
- The software has improved some parts of the paratransit scheduling process. CARTA reports that the software did speed up the process of mixing together the call-in reservations with the standing orders to develop routes for the day. However, other processes seem more difficult than before, and CARTA reports that the software has not resulted in significant time savings.
- CARTA entered most of its business practices into the paratransit operations software, so that the software usually produces schedules that comply with CARTA practices and policies. However, the software did not accommodate all CARTA business practices, so CARTA staff sometimes have to override recommendations made by the system. This can slow the scheduling process.

Network Connectivity for CARTA Vehicles

- The EVDO network has proven to be reliable and effective. CARTA reports few problems with the EVDO network, though the cellular modems used by CARTA have been more failure prone than expected.
- Providing wireless Internet to passengers can be done with very little additional cost while providing EVDO network connectivity to transit buses. The costs of the EVDO modems, with or without wireless Internet capability, were similar.
- The free wireless Internet has proven itself popular with CARTA passengers. CARTA observed 60 to 65 users of the service during peak hours. About 20 percent of website users surveyed indicated that they use the free wireless Internet service almost every time or every time they use a bus.

Fareboxes and Revenue Management System

- More accurate and more detailed fare data. The fare data from the new fareboxes is now time stamped and CARTA reports fewer inconsistencies when cross checking the fare data. CARTA reports that the new revenue management system saved several hours per week in time once spent analyzing data and generating reports.
- Less driver interaction required. Drivers are no longer required to manually record when passengers use a pass to board a bus. This allows them to focus on driving the bus and greeting passengers.
- The new system provides a more secure transaction process. CARTA notes that fare revenues had increased since the system was installed, which the agency attributes to the security of the fare media.
- Many passengers treat the SmartCards as disposal. As a result, CARTA has had to replenish its supply of SmartCards much sooner than expected.

Next Stop Automated Announcement System

- A comprehensive test of the AAS should be performed before releasing it for fleet-wide use. CARTA identified one problem in system design and several problems in the route database while testing the system.
- Closely-spaced stops will have an impact and should be considered in the design of the system. In the midst of testing, CARTA discovered that the AAS could not complete the planned message sequence for closely spaced stops.
- The system increases customer satisfaction. There were indications that the system improved the quality of service, as evidenced by positive feedback from the Mayor's Council on Disabilities.

Bus Arrival Time System

- The bus arrival time system requires accurate schedule information. CARTA has had to recalibrate parts of its bus schedules to achieve the desired accuracy for the bus arrival time system.
- The bus arrival time system requires closely spaced time points. In order to achieve the desired bus arrival time accuracy, CARTA has had to define a large number of new checkpoints used solely for the bus arrival calculations.
- This system appears to increase customer satisfaction. About three-fourths of CARTA website users surveyed agree that the bus arrival time system makes them more satisfied, and two-thirds of respondents indicate that the system causes them to use transit more often.

Remote Diagnostic Maintenance System

- RDMS helps mechanics perform diagnostics. Mechanics note that the detailed RDMS failure codes helped to narrow or pinpoint problems on the buses, thus reducing the amount of time spent on each repair.
- RDMS helps identify problems before failure occurs. CARTA notes two cases where maintenance activities initiated because of RDMS failure codes led to identification of problems that could have resulted in significant failures if left unattended. In one of those cases, the problem could have eventually led to an engine failure; CARTA estimates the cost to repair a failed engine to be at least $30,000. CARTA also notes that the number of major road calls dropped after it deployed the RDMS.
- RDMS does result in unnecessary maintenance activities. After the initial RDMS release, the number of failure codes reported by the system was high and CARTA updated the system to report only failure codes deemed significant. Even after this update, there were cases where the RDMS persistently reported failure codes despite maintenance activities.

Other Systems

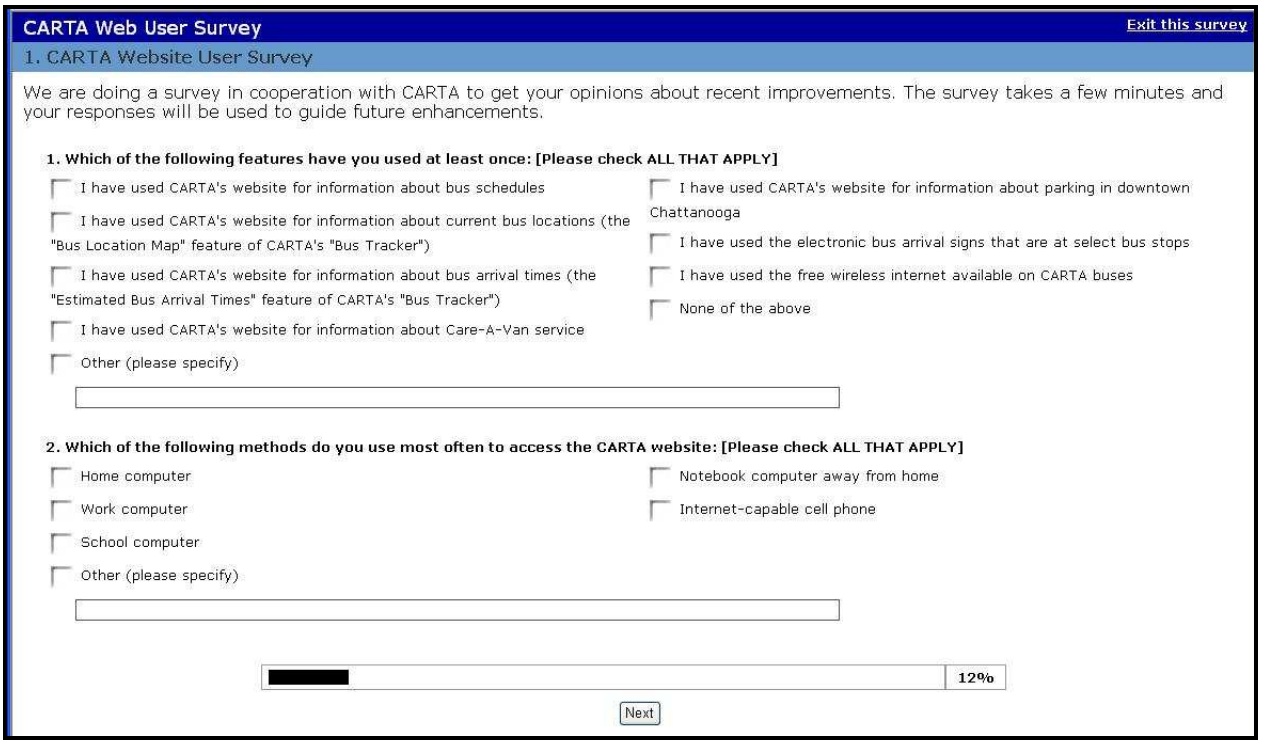
At the time of this report, the deployments of the APC and CAD/AVL were ongoing, but incomplete. The benefits of these systems is yet to be determined.

APPENDIX A – SURVEY OF WEBSITE USERS

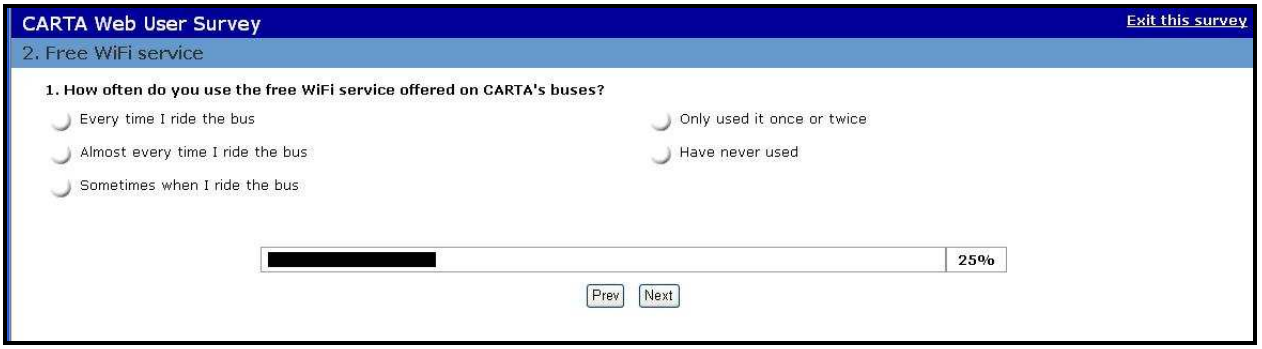
During an approximate 5-week period starting on September 18, 2009, the evaluation team conducted an online survey of CARTA website users. A button was placed on the main page of CARTA's website (see below), and also on pages associated specifically with the bus arrival time and Bus Tracker and systems.

Clicking on the button opened up a new browser window that administered a survey. The focus of the survey was on the users experiences with the bus arrival time and Bus Tracker systems. The remainder of this appendix depicts screenshots of the survey.

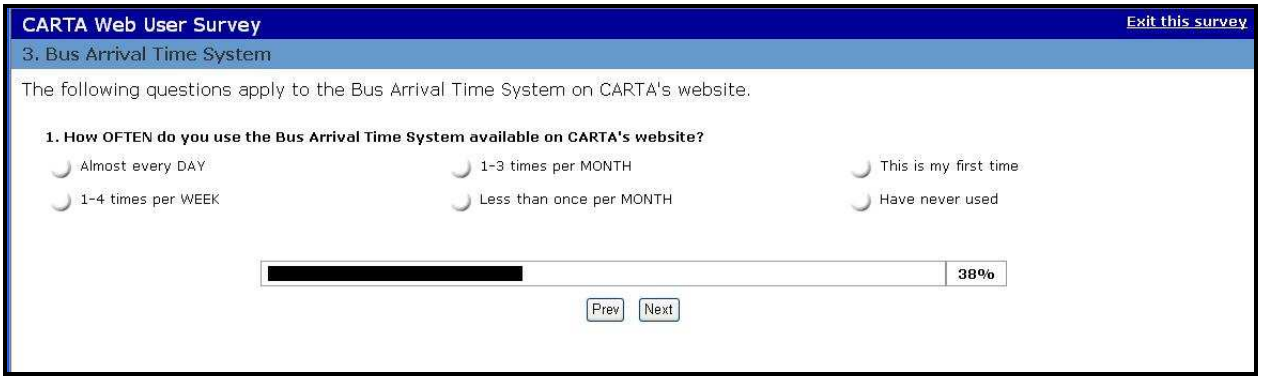
PAGE 1



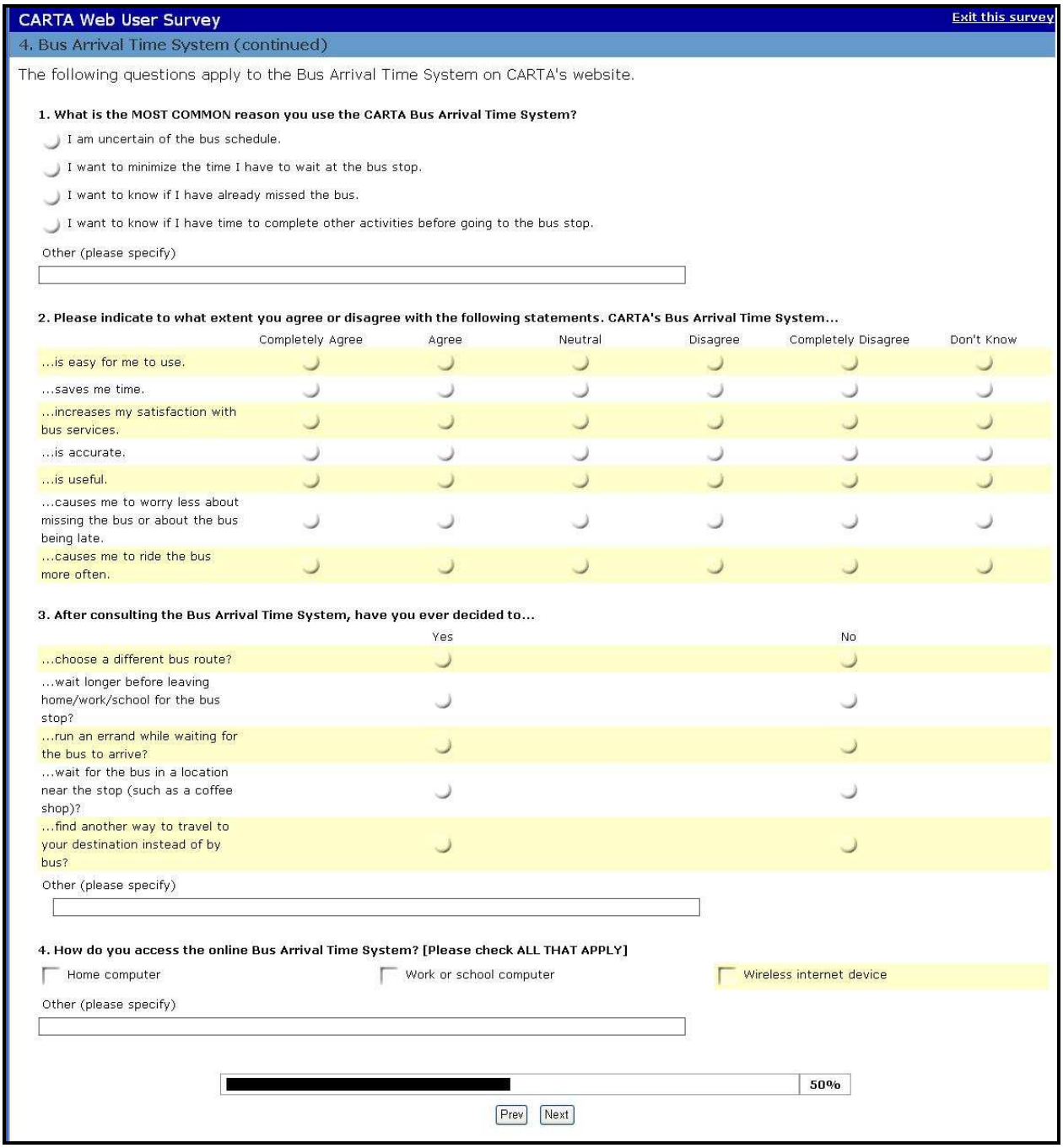
PAGE 2



PAGE 3



PAGE 4



CARTA Web User Survey

Exit this survey

4. Bus Arrival Time System (continued)

The following questions apply to the Bus Arrival Time System on CARTA's website.

1. What is the MOST COMMON reason you use the CARTA Bus Arrival Time System?

- I am uncertain of the bus schedule.
- I want to minimize the time I have to wait at the bus stop.
- I want to know if I have already missed the bus.
- I want to know if I have time to complete other activities before going to the bus stop.

Other (please specify)

2. Please indicate to what extent you agree or disagree with the following statements. CARTA's Bus Arrival Time System...

	Completely Agree	Agree	Neutral	Disagree	Completely Disagree	Don't Know
...is easy for me to use.						
...saves me time.						
...increases my satisfaction with bus services.						
...is accurate.						
...is useful.						
...causes me to worry less about missing the bus or about the bus being late.						
...causes me to ride the bus more often.						

3. After consulting the Bus Arrival Time System, have you ever decided to...

	Yes	No
...choose a different bus route?		
...wait longer before leaving home/work/school for the bus stop?		
...run an errand while waiting for the bus to arrive?		
...wait for the bus in a location near the stop (such as a coffee shop)?		
...find another way to travel to your destination instead of by bus?		

Other (please specify)

4. How do you access the online Bus Arrival Time System? [Please check ALL THAT APPLY]

- Home computer
- Work or school computer
- Wireless internet device

Other (please specify)

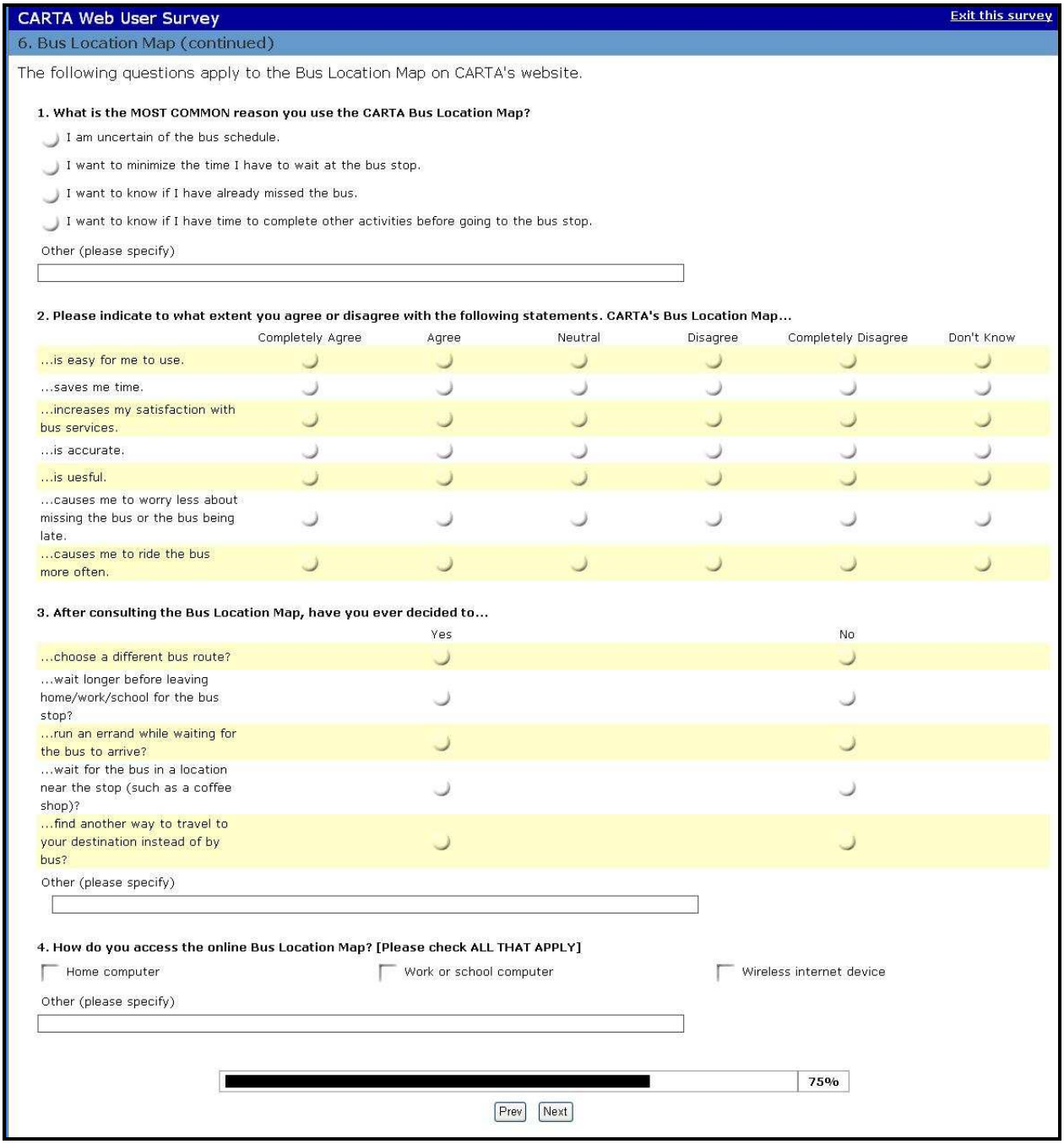
50%

Prev Next

PAGE 5


CARTA Web User Survey
Exit this survey
5. Bus Location Map
The following questions apply to the Bus Location Map on CARTA's website.
1. How OFTEN do you use the Bus Location Map available on CARTA's website?
Almost every DAY
1-3 times per MONTH
This is my first time
1-4 times per WEEK
Less than once per MONTH
Have never used
62%
Prev
Next

PAGE 6



CARTA Web User Survey

Exit this survey

6. Bus Location Map (continued)

The following questions apply to the Bus Location Map on CARTA's website.

1. What is the MOST COMMON reason you use the CARTA Bus Location Map?

- I am uncertain of the bus schedule.
- I want to minimize the time I have to wait at the bus stop.
- I want to know if I have already missed the bus.
- I want to know if I have time to complete other activities before going to the bus stop.

Other (please specify)

2. Please indicate to what extent you agree or disagree with the following statements. CARTA's Bus Location Map...

	Completely Agree	Agree	Neutral	Disagree	Completely Disagree	Don't Know
...is easy for me to use.						
...saves me time.						
...increases my satisfaction with bus services.						
...is accurate.						
...is uesful.						
...causes me to worry less about missing the bus or the bus being late.						
...causes me to ride the bus more often.						

3. After consulting the Bus Location Map, have you ever decided to...

	Yes	No
...choose a different bus route?		
...wait longer before leaving home/work/school for the bus stop?		
...run an errand while waiting for the bus to arrive?		
...wait for the bus in a location near the stop (such as a coffee shop)?		
...find another way to travel to your destination instead of by bus?		

Other (please specify)

4. How do you access the online Bus Location Map? [Please check ALL THAT APPLY]

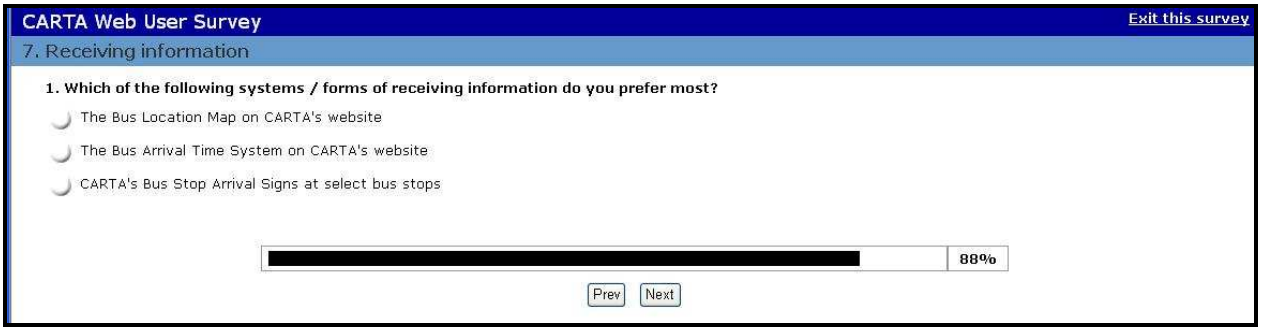
- Home computer
- Work or school computer
- Wireless internet device

Other (please specify)

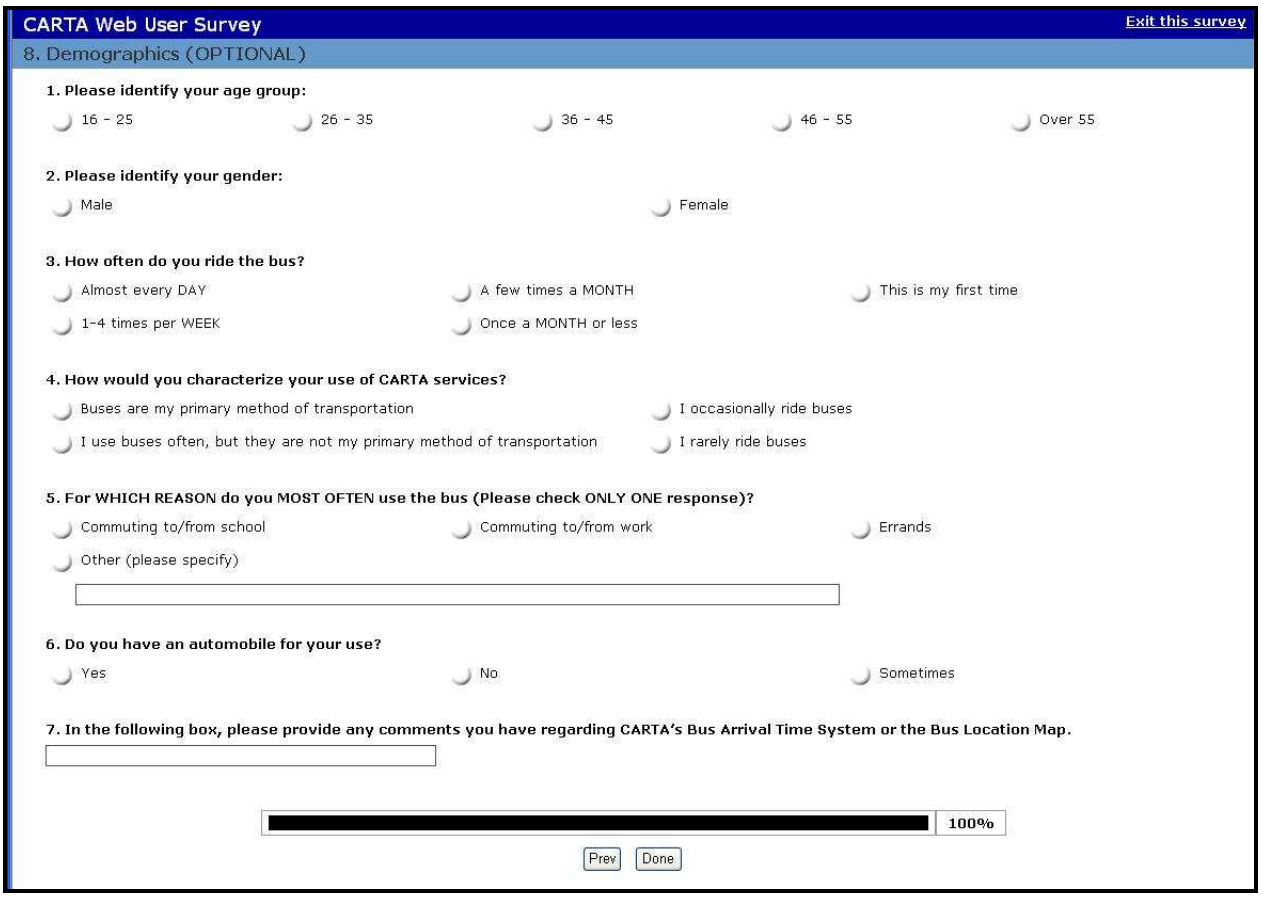
75%

Prev Next

PAGE 7


CARTA Web User Survey
Exit this survey
7. Receiving information
1. Which of the following systems / forms of receiving information do you prefer most?
The Bus Location Map on CARTA's website
The Bus Arrival Time System on CARTA's website
CARTA's Bus Stop Arrival Signs at select bus stops
88%
Prev
Next

PAGE 8

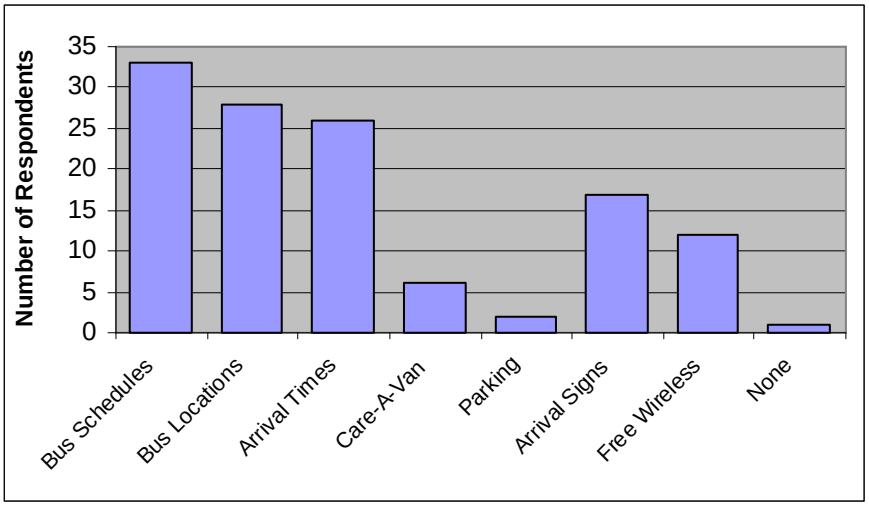

CARTA Web User Survey
Exit this survey
8. Demographics (OPTIONAL)
1. Please identify your age group:
16 - 25
26 - 35
36 - 45
46 - 55
Over 55
2. Please identify your gender:
Male
Female
3. How often do you ride the bus?
Almost every DAY
A few times a MONTH
This is my first time
1-4 times per WEEK
Once a MONTH or less
4. How would you characterize your use of CARTA services?
Buses are my primary method of transportation
I occasionally ride buses
I use buses often, but they are not my primary method of transportation
I rarely ride buses
5. For WHICH REASON do you MOST OFTEN use the bus (Please check ONLY ONE response)?
Commuting to/from school
Commuting to/from work
Errands
Other (please specify)
6. Do you have an automobile for your use?
Yes
No
Sometimes
7. In the following box, please provide any comments you have regarding CARTA's Bus Arrival Time System or the Bus Location Map.
100%
Prev
Done

APPENDIX B – SURVEY RESULTS

Over the survey period, 46 people began the survey and 37 completed it. The remainder of this appendix presents the results from analyzing the responses of the 37 respondents who completed the survey.

INTRODUCTORY QUESTIONS

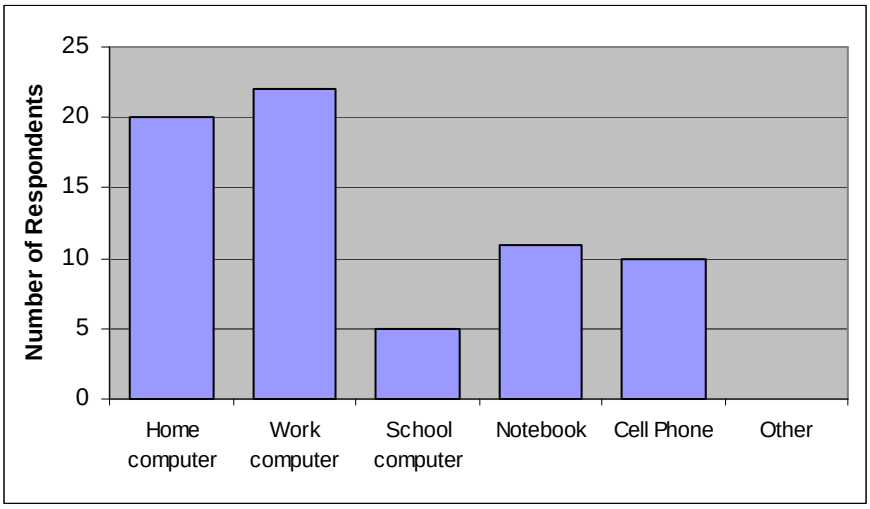
Which of the following features have you used at least once?



Almost all respondents (89 percent) indicated that they use the bus schedules feature on the website. The bus location and arrival times features were used by most respondents (76 percent and 70 percent, respectively). Of the 32 people who indicated that they have used at least one of these systems, most (68 percent) used both.

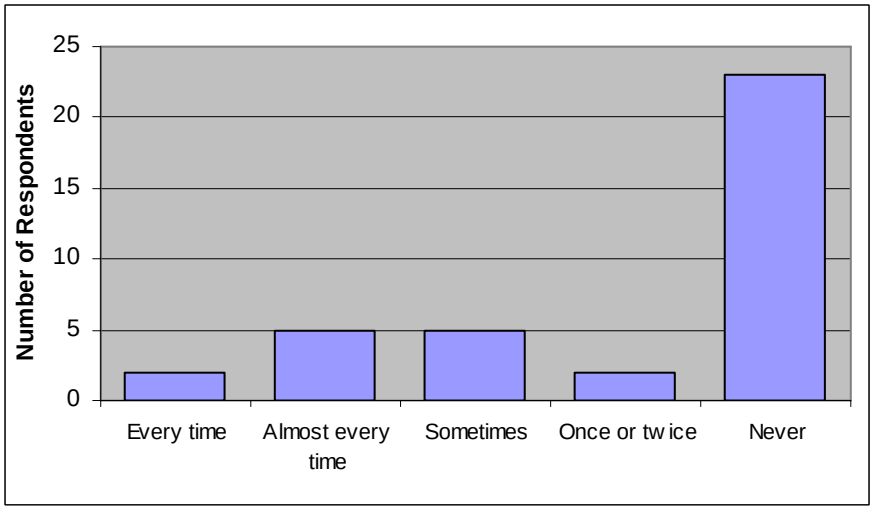
		Used Arrival Time Pages	
		False	True
Use Bus Tracker Pages	False	5	4
	True	6	22

Which of the following methods do you use most often to access the CARTA website?



Most users accessed the system through home and work computers, though a significant number (27 percent) accessed it through their cell phone. Most people (54 percent) accessed the system through more than one method.

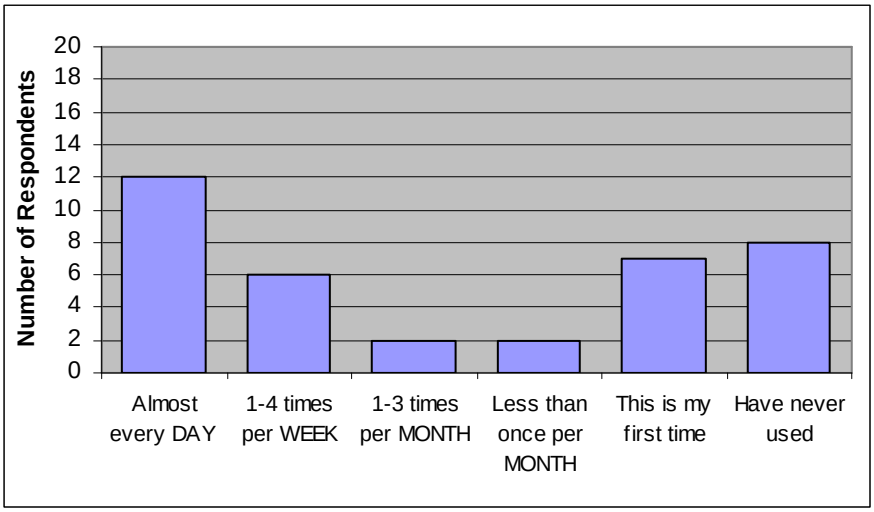
How often do you use the free WiFi service offered on CARTA's buses?



About 20 percent of respondents indicated that they use the free WiFi service almost every time or every time they use a bus. About one-third of respondents at least sometimes use the free WiFi service.

BUS ARRIVAL TIME SYSTEM

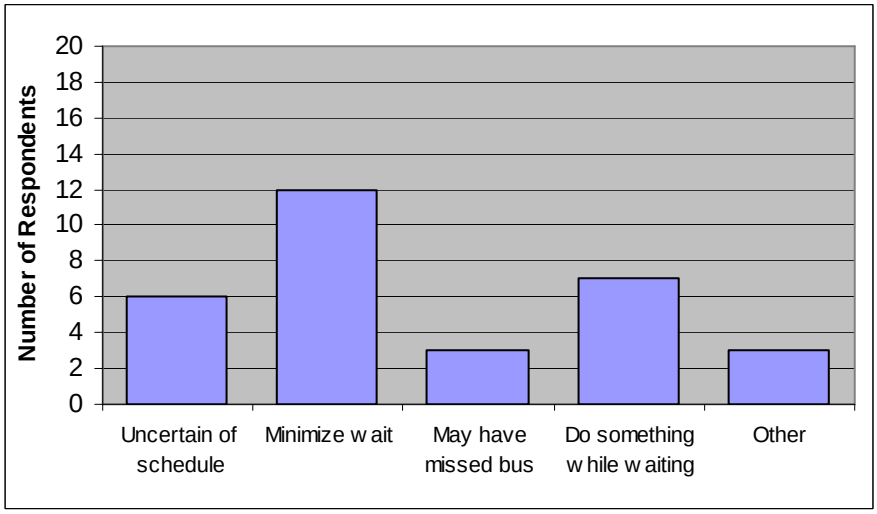
How OFTEN do you use the Bus Arrival Time System available on CARTA's website?



Most respondents (29 out of 37) indicated that they use the bus arrival time system. Of these, about 32 percent use it almost every day.

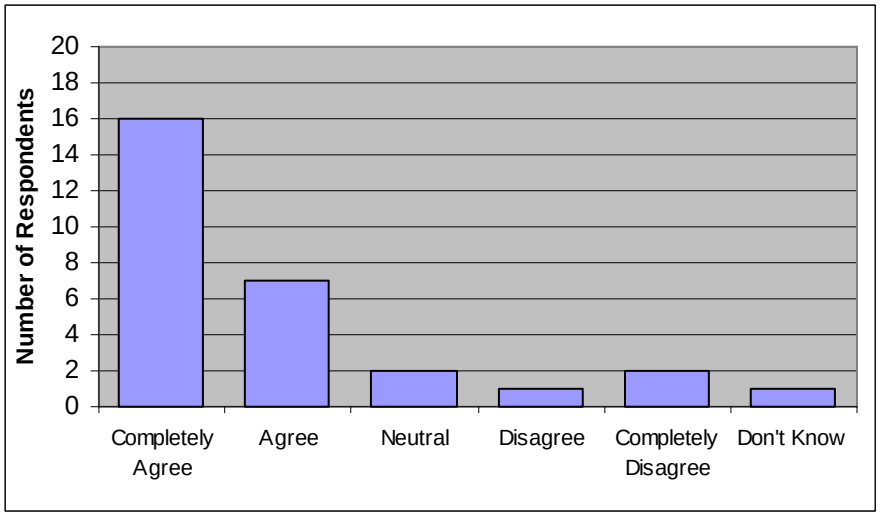
The remaining questions in this section were restricted to the 29 respondents who indicated that they have used the bus arrival time system.

What is the MOST COMMON reason you use the CARTA Bus Arrival Time System?



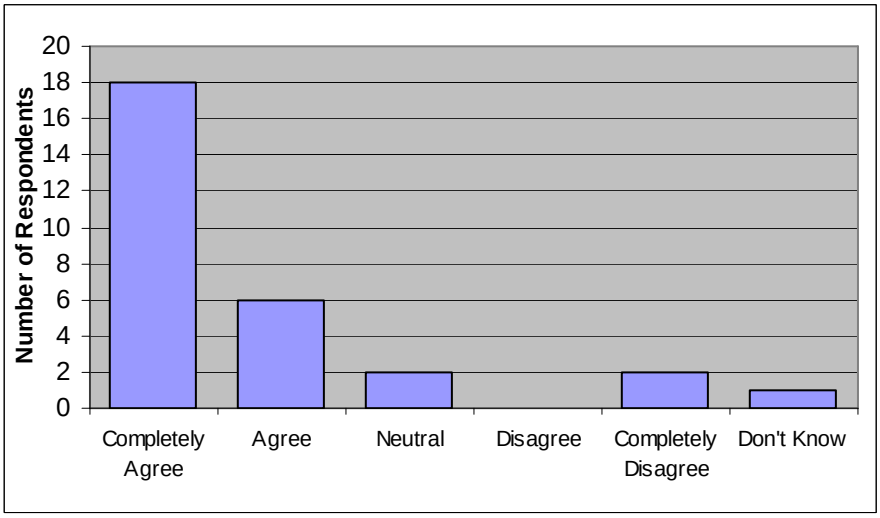
The most common reason cited for using the bus arrival time system was to minimize the time spent waiting at the bus stop (41 percent).

Agree or disagree: CARTA's Bus Arrival Time System is easy for me to use.



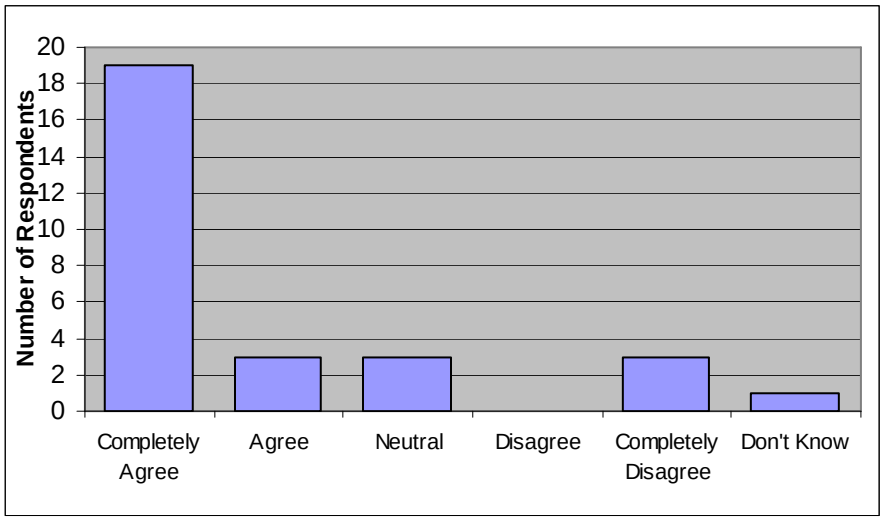
Most respondents (79 percent) agreed that the system is easy to use.

Agree or disagree: CARTA's Bus Arrival Time System saves me time.



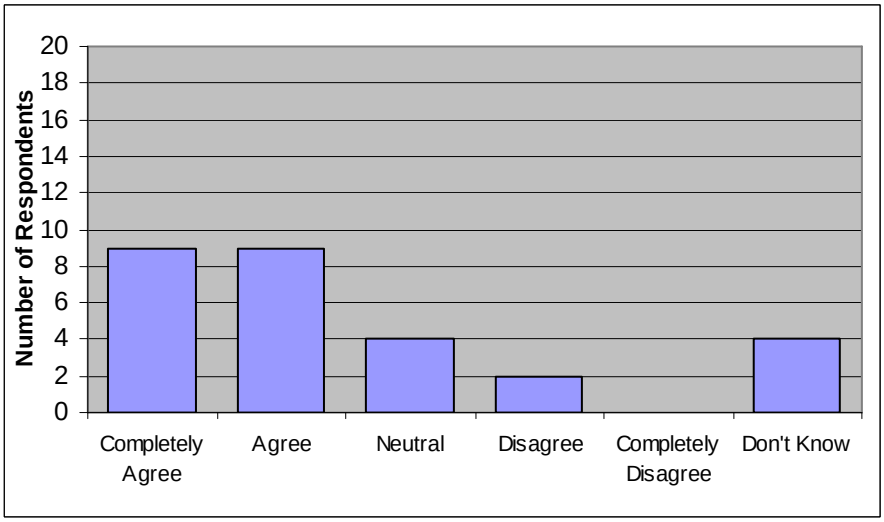
Most (83 percent) also agreed that the system saved them time.

Agree or disagree: CARTA's Bus Arrival Time System increases my satisfaction with bus services.



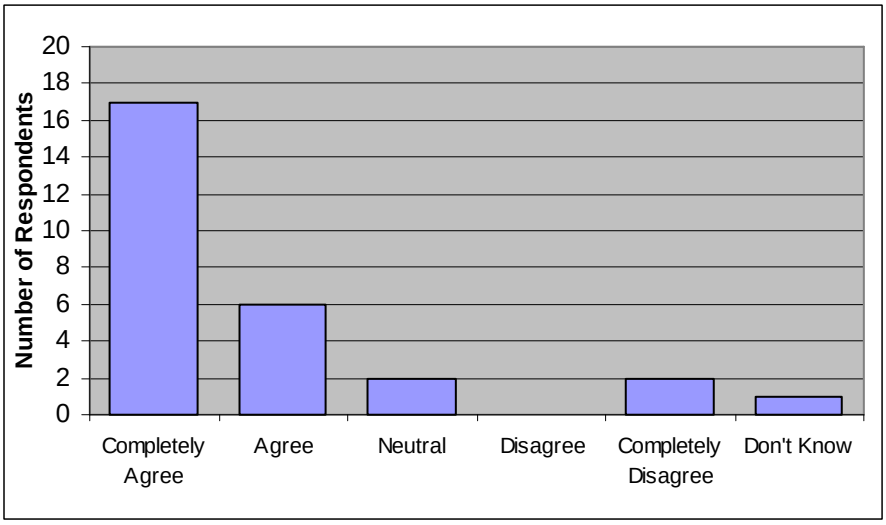
76 percent agreed that the system increases satisfaction with the bus service.

Agree or disagree: CARTA's Bus Arrival Time System is accurate.



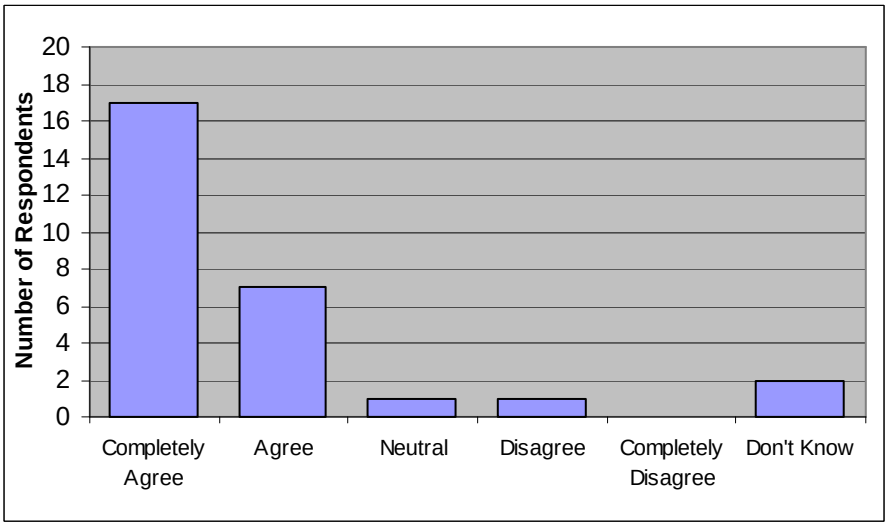
Only 62 percent agreed that the system was accurate.

Agree or disagree: CARTA's Bus Arrival Time System is useful.



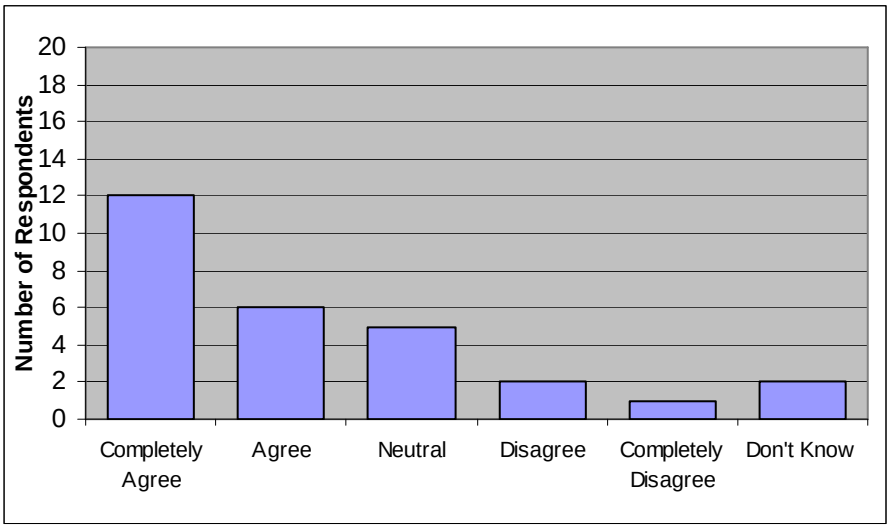
Most (80 percent) agreed that the system was useful.

Agree or disagree: CARTA's Bus Arrival Time System causes me to worry less about missing the bus or about the bus being late.



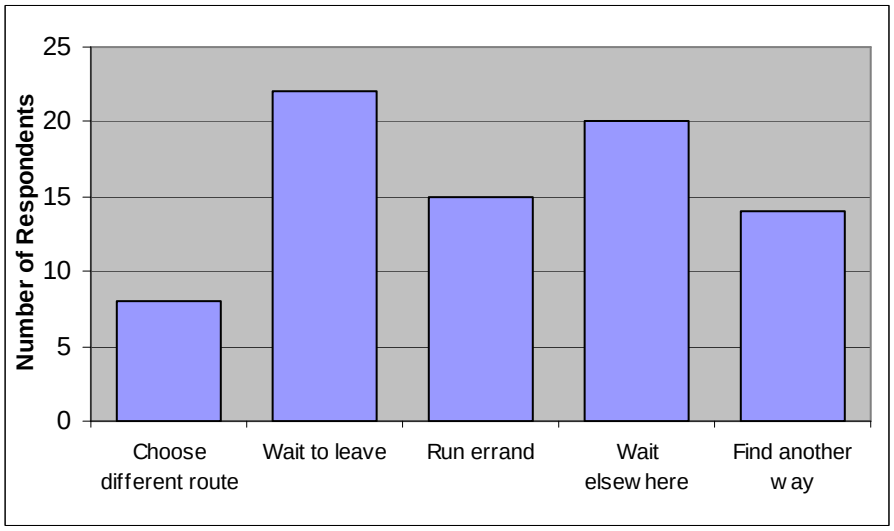
Most (83 percent) agreed that the system caused them to worry less about missing the bus or about the bus being late.

Agree or disagree: CARTA's Bus Arrival Time System causes me to ride the bus more often.



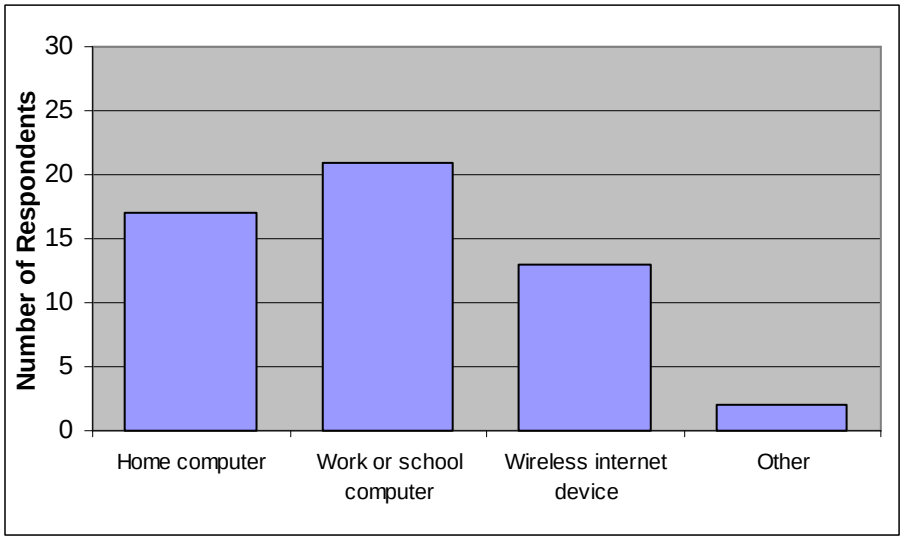
Many (62 percent) agreed that the system caused them to ride the bus more often.

After consulting the Bus Arrival Time System, have you ever decided to choose a different bus route, wait longer before leaving home/work/school for the bus stop, run an errand while waiting for the bus to arrive, wait for the bus in a location near the stop (such as a coffee shop), or find another way to travel to your destination instead of by bus?



The most popular responses to information from the bus arrival time system were actions to avoid waiting at the bus stop – waiting before leaving for the bus stop (76 percent), waiting somewhere besides the bus stop (69 percent), and running an errand (52 percent). A sizable fraction (48 percent) sometimes found another way to their destination other than taking the bus.

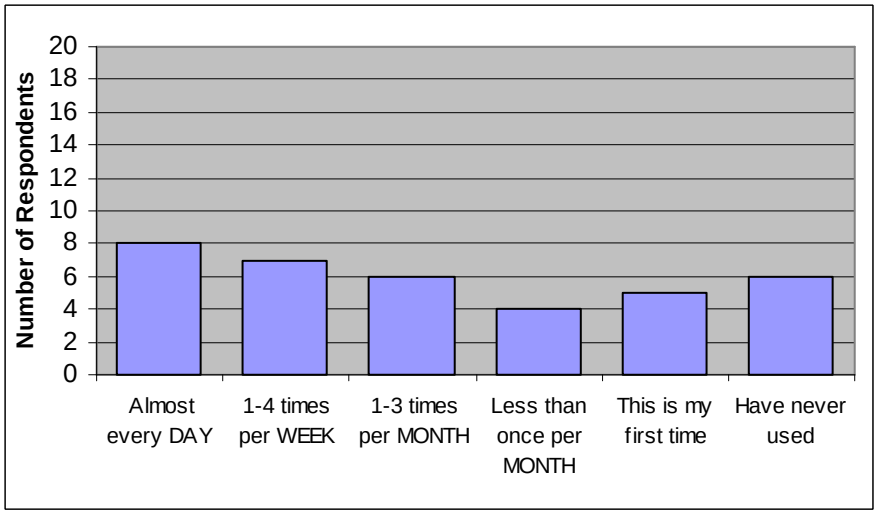
How do you access the online Bus Arrival Time System?



Most people accessed the system via their work or school computer (72 percent) or their home computer (59 percent). A sizable number (45 percent) sometimes accessed the system through a wireless internet device.

BUS LOCATION MAP

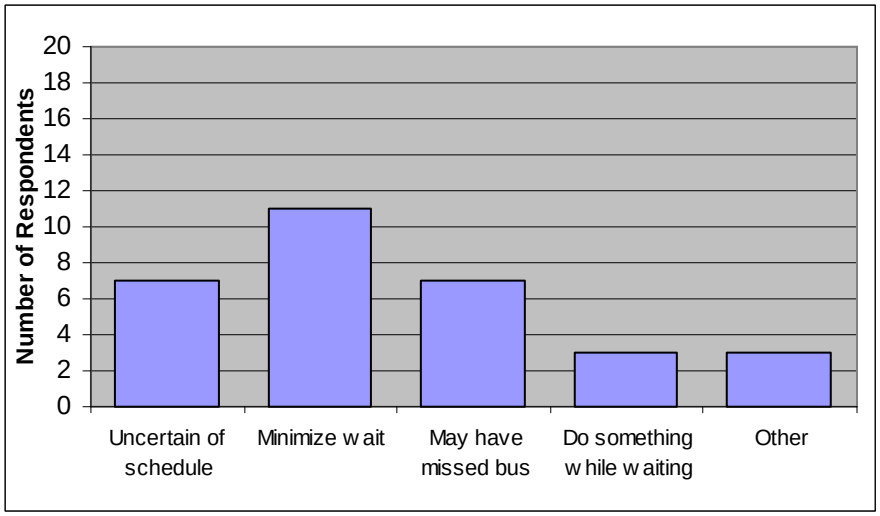
How OFTEN do you use the Bus Location Map available on CARTA's website?



Thirty respondents indicated that they used the bus tracker system. Of these, about 22 percent used it almost every day.

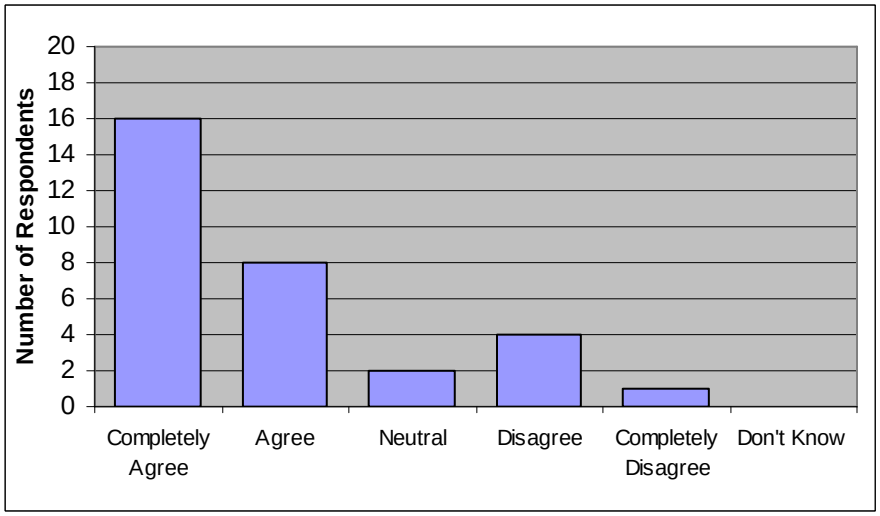
The remaining questions in this section were restricted to the 30 respondents that have used the bus tracker system.

What is the MOST COMMON reason you use the CARTA Bus Location Map?



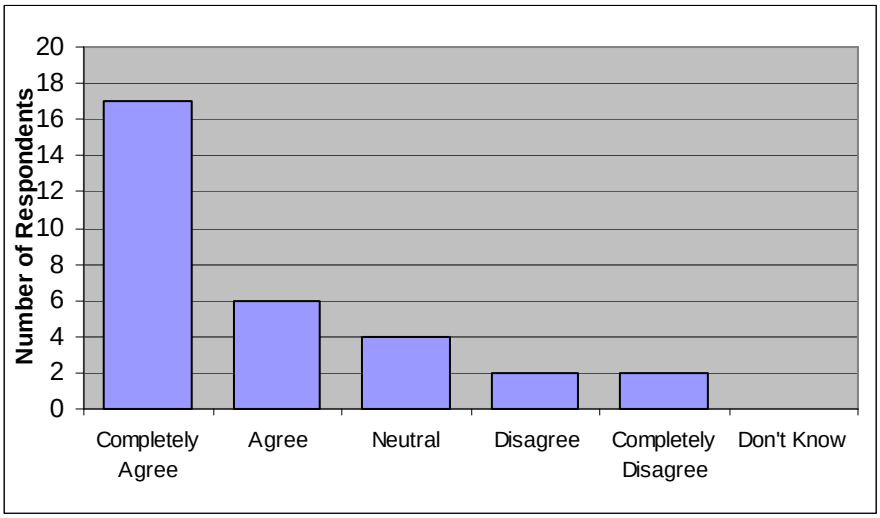
The most common reason cited for using the bus location map was to minimize the time spent waiting at the bus stop (30 percent).

Agree or disagree: CARTA's Bus Location Map is easy for me to use.



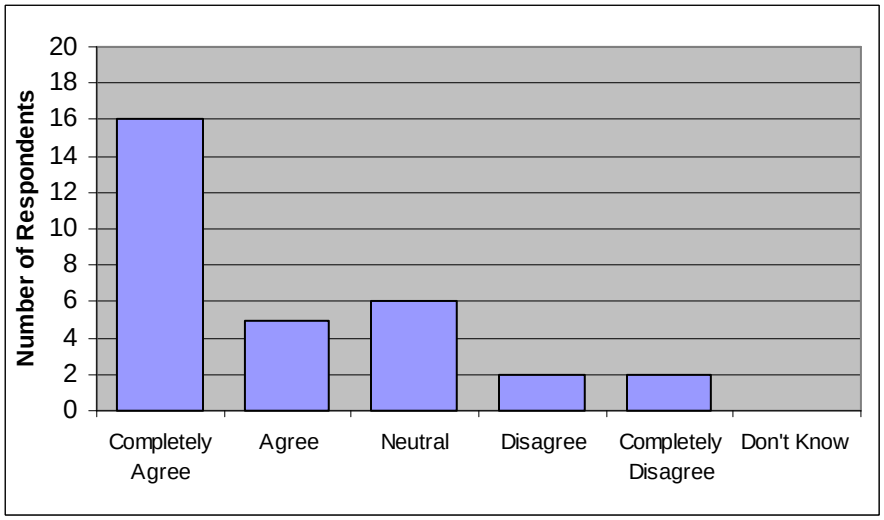
Most respondents (80 percent) agreed that the system is easy to use.

Agree or disagree: CARTA's Bus Location Map saves me time.



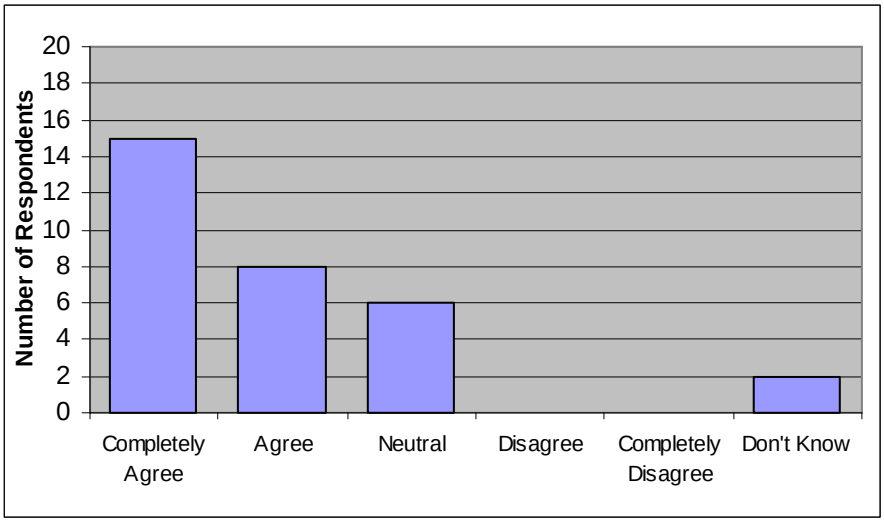
Most (77 percent) also agreed that the system saved them time.

Agree or disagree: CARTA's Bus Location Map increases my satisfaction with bus services.



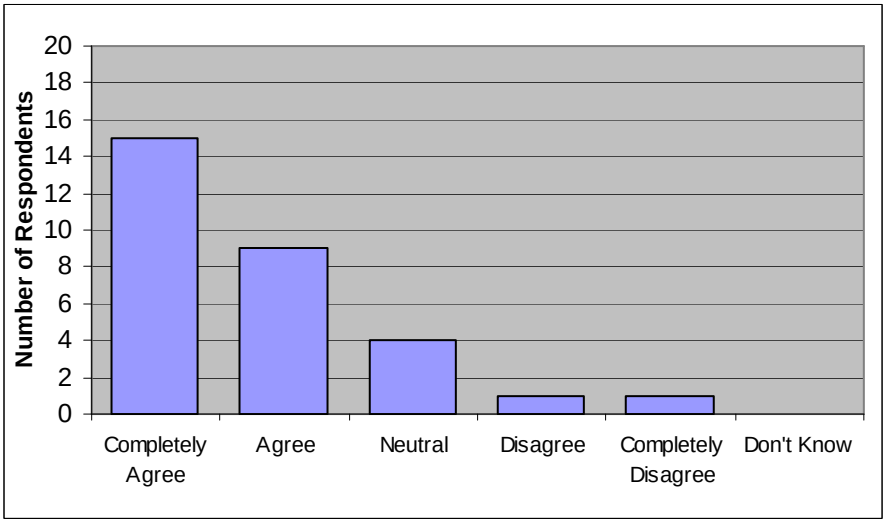
70 percent agreed that the system increased satisfaction with the bus service.

Agree or disagree: CARTA's Bus Location Map is accurate.



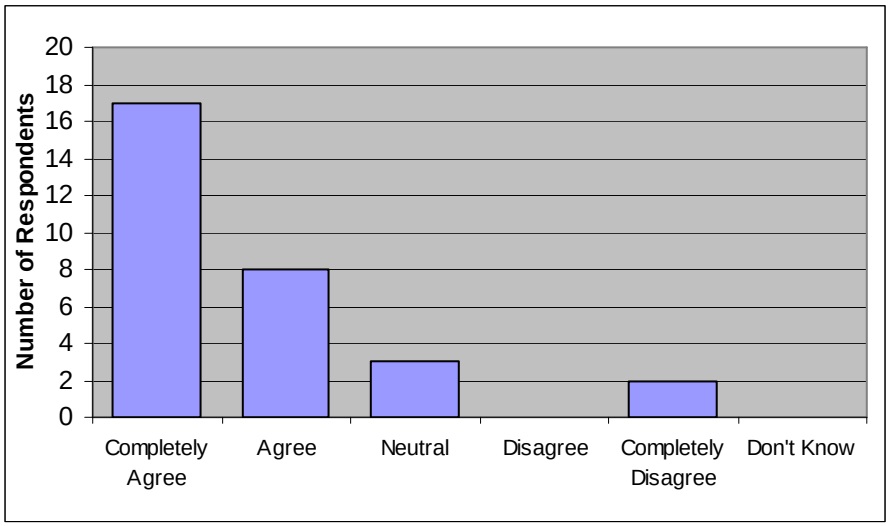
Most (77 percent) agreed that the system is accurate.

Agree or disagree: CARTA's Bus Location Map is useful.



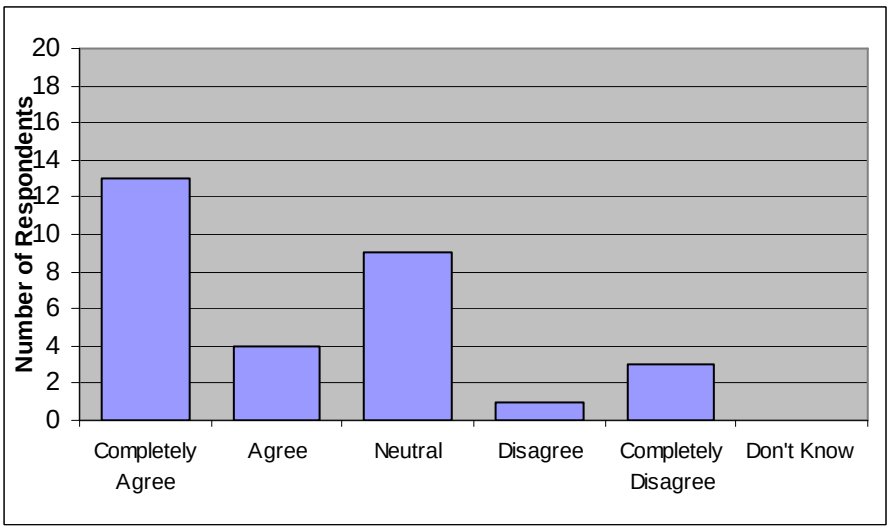
Most (80 percent) agreed that the system is useful.

Agree or disagree: CARTA's Bus Location Map causes me to worry less about missing the bus or about the bus being late.



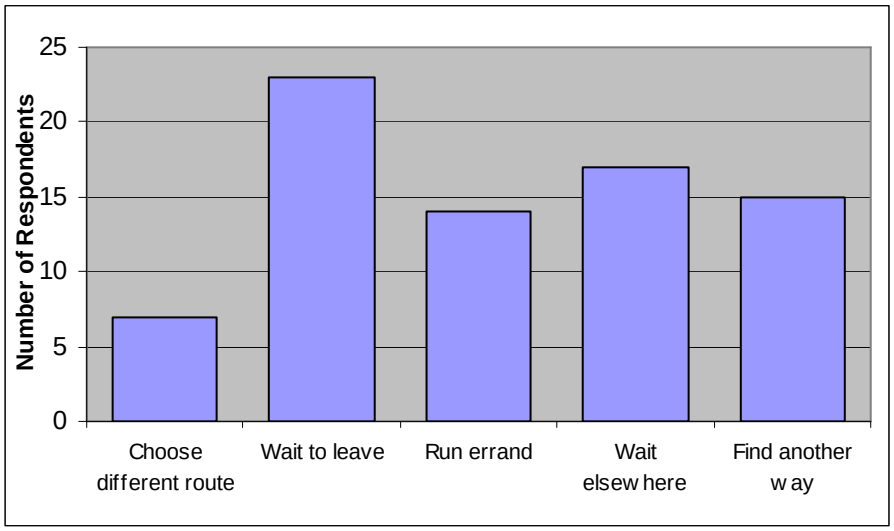
Most (79 percent) agreed that the system caused them to worry less about missing the bus or about the bus being late.

Agree or disagree: CARTA's Bus Location Map causes me to ride the bus more often.



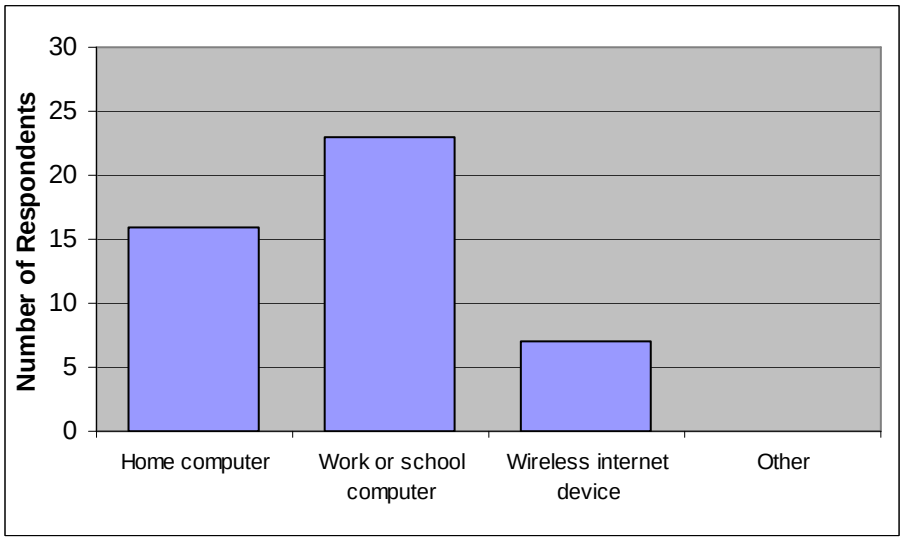
Many (56 percent) agreed that the system caused them to ride the bus more often.

After consulting the Bus Location Map, have you ever decided to choose a different bus route, wait longer before leaving home/work/school for the bus stop, run an errand while waiting for the bus to arrive, wait for the bus in a location near the stop (such as a coffee shop), or find another way to travel to your destination instead of by bus?



The most popular responses to information from the bus location map were actions to avoid waiting at the bus stop – waiting before leaving for the bus stop (77 percent), waiting somewhere besides the bus stop (57 percent), and running an errand (47 percent). A sizable fraction (50 percent) sometimes found another way to their destination other than taking the bus.

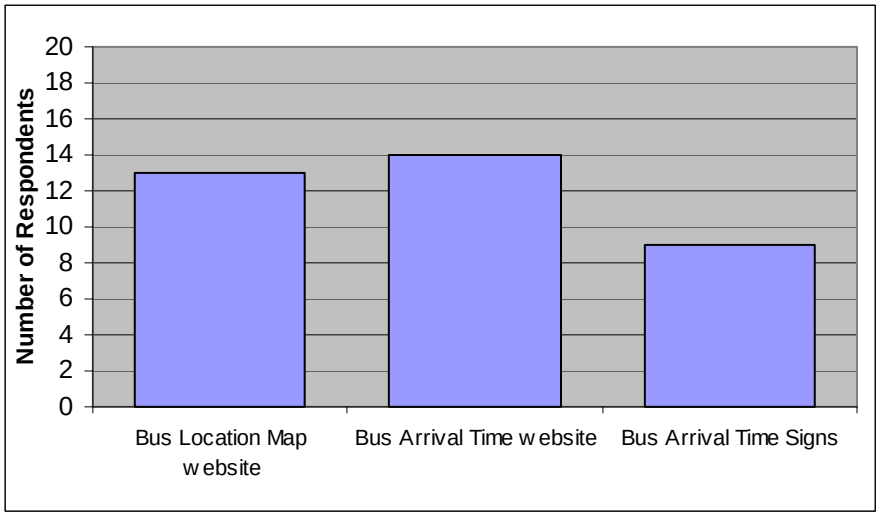
How do you access the online Bus Location Map?



Most people accessed the system via their work or school computer (77 percent) or their home computer (53 percent). A few (23 percent) sometimes accessed the system through a wireless internet device. (The graphics nature of the bus location map makes it less suitable for many wireless internet devices than the bus arrival time system.)

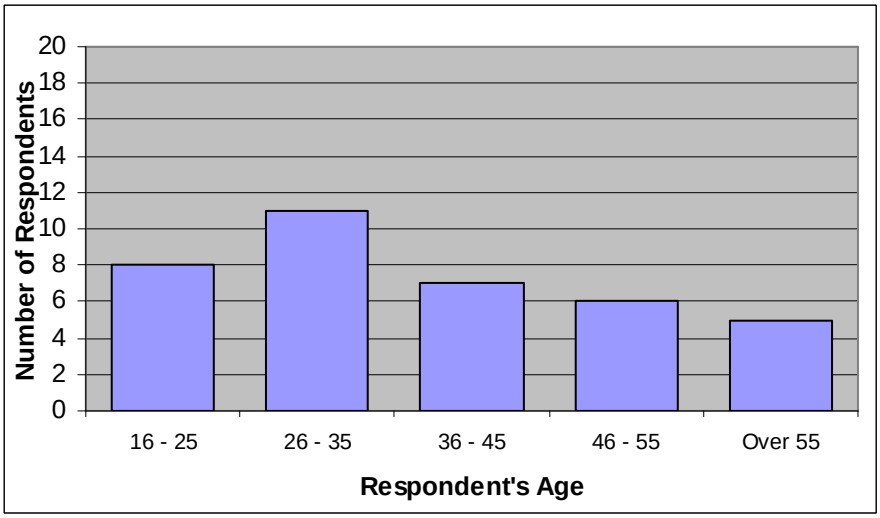
SUMMARY AND DEMOGRAPHICS

Which of the following systems / forms of receiving information do you prefer most?



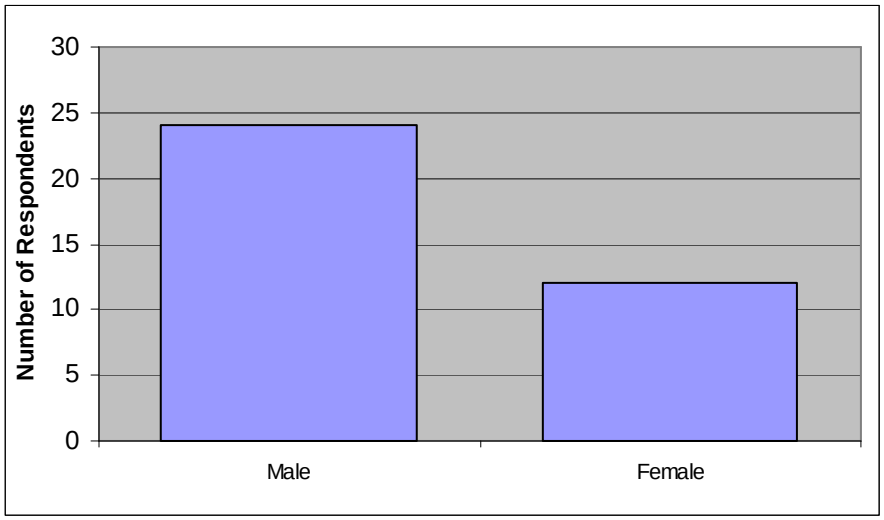
The preference for the use of these systems was relatively evenly split.

Please identify your age group:



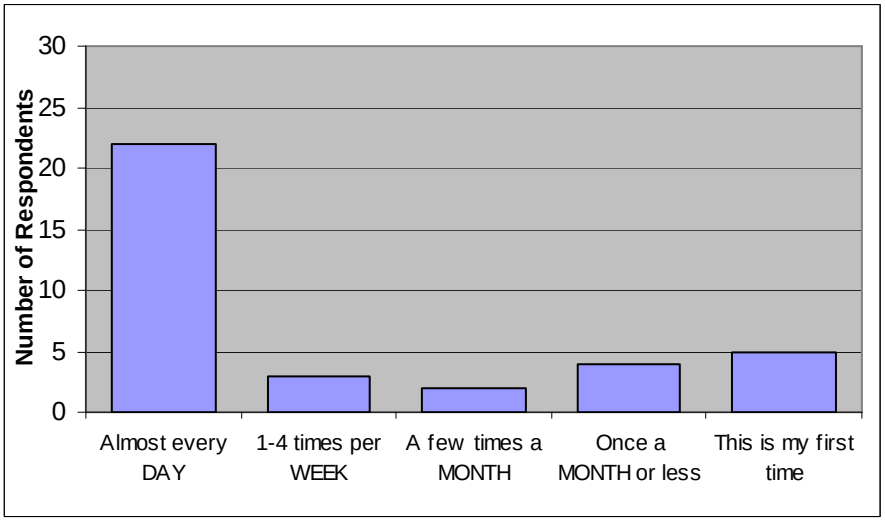
The age distribution of respondents was fairly broad.

Please identify your gender:



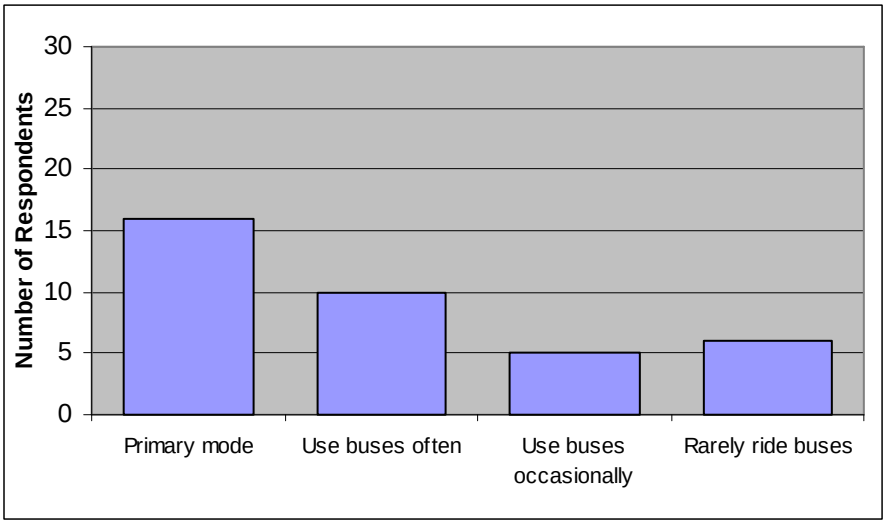
Interestingly, about twice as many males as females responded to the survey.

How often do you ride the bus?



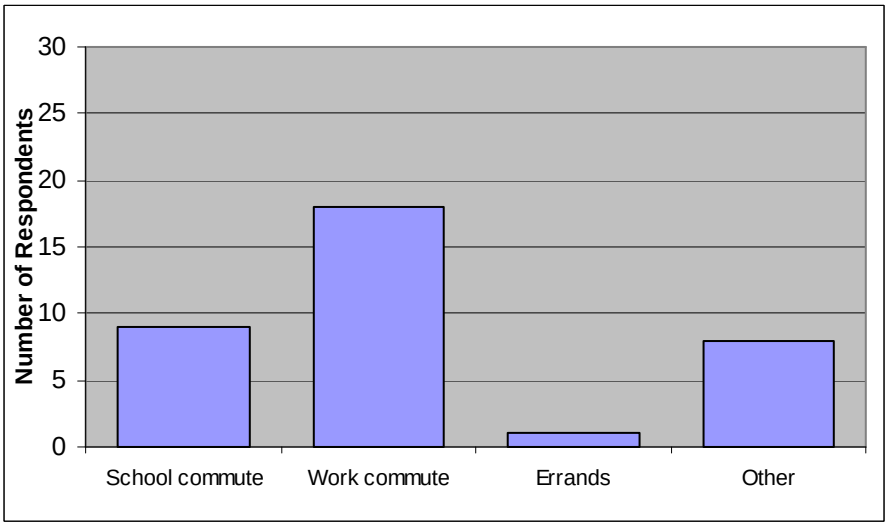
Most (60 percent) of the respondents indicated that they ride the bus every day.

How would you characterize your use of CARTA services?



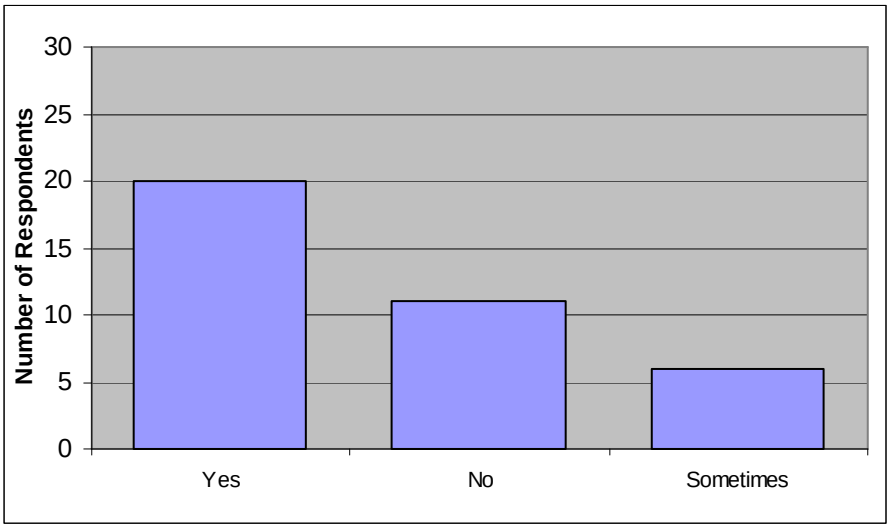
For 43 percent of respondents, the bus was their primary mode of transportation. Another 27 percent used buses often.

For WHICH REASON do you MOST OFTEN use the bus?



Most respondents used the bus to commute either to and from work (49 percent) or to and from school (24 percent).

Do you have an automobile for your use?

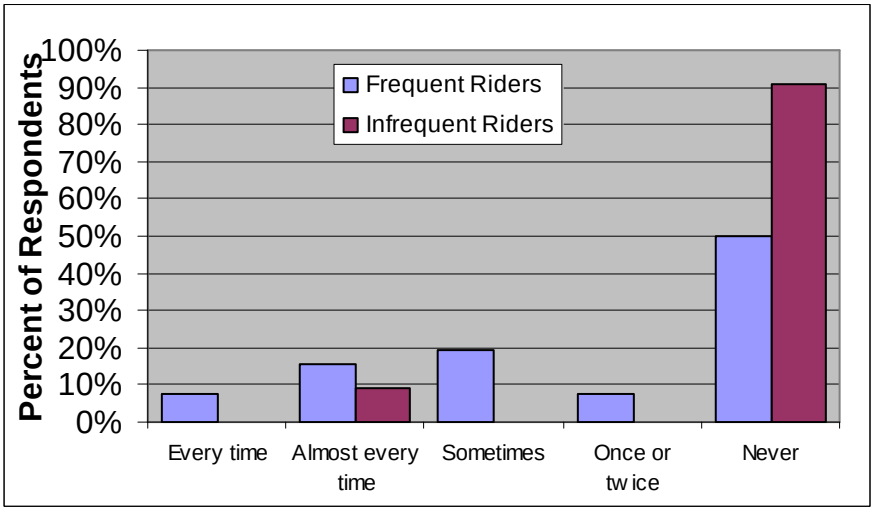


30 percent of respondents did not have a car available for their use.

RESPONSES FOR FREQUENT BUS RIDERS

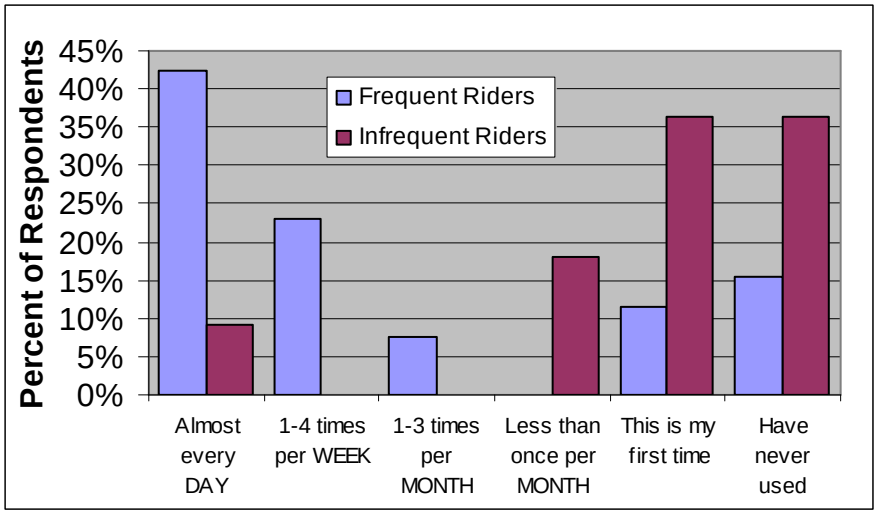
The following charts compare the responses of frequent bus riders (i.e., those how indicated they ride the bus almost every day or one to four times per week) with those of less frequent bus riders. (Note that only 11 less frequent bus riders participated in the survey.)

How often do you use the free WiFi service offered on CARTA's buses?



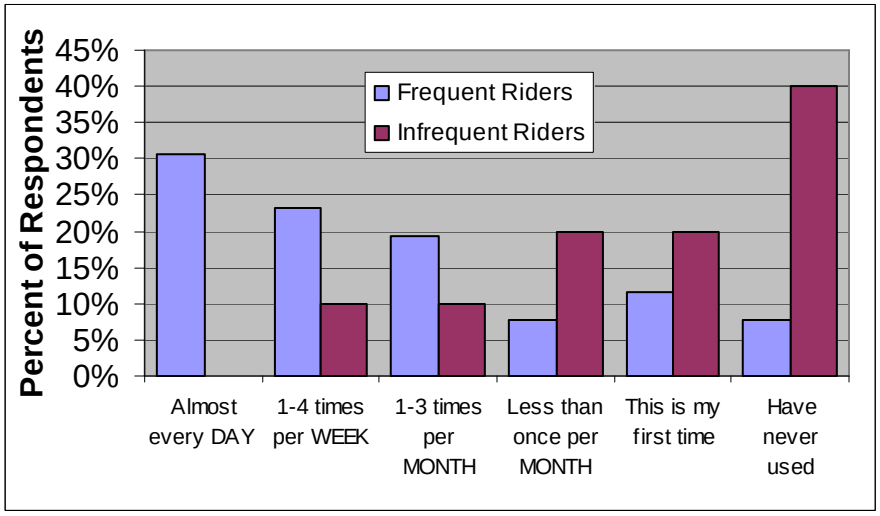
Respondents that were infrequent riders were much less likely to use the WiFi service.

How OFTEN do you use the Bus Arrival Time System available on CARTA's website?



Frequent riders used the bus arrival time system more frequently than infrequent riders.

How OFTEN do you use the Bus Location Map available on CARTA's website?



Frequent riders used the bus location map more frequently than infrequent riders.