Chattanooga SmartBus Project
Final Phase II Evaluation Report

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16. Abstract This report presents the results of Phase II of the national evaluation of the Chattanooga Area Regional Transportation Authority's (CARTA's) 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 to accumulate data from different CARTA applications and provide reports to support CARTA operations; 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 smart card 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 to date of the technologies that have been in place for at least 1 year. It is important to note that the full impacts of many of the technologies are not expected to be realized until the onboard systems are in place and integrated with the existing technologies, and that those later impacts will be documented in the Phase III report. The evaluation involved a series of interviews with various CARTA staff, as well as gathering data on various performance measures including transit ridership, on-time performance, and on the road failures. The results of the study indicate that the ticket vending machines for the Incline Railway have helped CARTA access to make better business decisions about the Incline service; the data warehousing and reporting software has allowed for more rapid preparation of a variety of reports, has resulted in efficiencies in operations, and has made it possible to answer complex business decisions more quickly; the fixed route scheduling software has allowed CARTA to provide the same level of service with lower operating costs; and the paratransit scheduling and dispatch management software has increased efficiency in terms of passengers per vehicle-hour while it has not reduced the time required to issue invoices or improved the on-time performance.			
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GLOSSARY OF ACRONYMS

AAS	Automated Announcement System
ADA	Americans with Disabilities Act
APC	Automatic Passenger Counter
ATIS	Advanced Traveler Information Systems
ATTRP	Advanced Technology Transportation Research Program
AVL	Automatic Vehicle Location
CAD	Computer-Aided Dispatch
CARTA	Chattanooga Area Regional Transportation Authority
EPS	Electronic Payment System
FTA	Federal Transit Administration
DVR	Digital Video Recorder
GPS	Global Positioning System
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
LED	Light-Emitting Diode
MAC-ITS	Multi-Agency Coordinated ITS Initiative
MDC	Mobile Data Computer
MOE	Measure of Effectiveness
NTD	National Transit Database
TSP	Transit Signal Priority
TVM	Ticket Vending Machine
USDOT	United States Department of Transportation
UTC	University of Tennessee - Chattanooga

EXECUTIVE SUMMARY

The purpose of this document is to present the Phase II 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 being deployed. Because several of these new technologies were already deployed at the time Phase II of the evaluation began, this document reports on both this "before" data analysis and on the "before" and "after" analysis of all fully deployed systems.

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).
- 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 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 2009).
- New fareboxes, a revenue management system, and a multi-modal transit/parking smart card electronic fare payment system (scheduled for 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 for at least 1 year as of January 2008. 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 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. Those later impacts will be documented in the Phase III report.

Conclusions of the Evaluation

At the start of the evaluation, the evaluation team identified a number of hypotheses regarding the impact that the SmartBus project might have on CARTA operations. Most of these hypotheses related to direct impacts of the deployed technology, such as ticket vending machines improving revenue, and paratransit and dispatch management software reducing the time required to book trips for the Care-A-Van service. While not all of the planned technologies were deployed at the time of this report, enough of them were deployed to begin to see their impacts. Preliminary results related to eight of the evaluation hypotheses are summarized below. In interpreting these results, it is important to note that they are preliminary in nature since CARTA is continuing to deploy additional technologies and is gaining experience in how to best use the technologies that have already been deployed.

Below is a list of each of the hypotheses that have been tested to date. A full list of the hypotheses for the evaluation can be found in Section 2.3.2.

- *Hypothesis: The addition of the TVMs will result in a revenue improvement.* This hypothesis is inconclusive at this time. It is not evident from the data whether there has been an improvement in revenue. However, anecdotal evidence indicates that the TVMs have been a success. A few months after the TVMs were installed, the Marketing Manager at the time reported that ridership was up over the previous year while the number of visitors at other partner attractions remained level. Beyond any revenue goals, the most important benefit of the TVMs is that they provide CARTA access to a wealth of information about ridership that was not previously available. CARTA feels that this information will allow the agency to make better business decisions that should lead to increased profitability for the Incline Railway in the long run.
- *Hypothesis: The addition of the data warehousing and reporting software will allow for more rapid preparation of a variety of reports.* This hypothesis is supported based on findings of interviews with a variety of CARTA staff. Staff report that they can now easily look at the cost per mile for each bus and use that information to make decisions about future fleet purchase. They can also look at the average fuel or oil usage for each bus and pull buses out of service to examine them for maintenance problems when noticing that a particular vehicle is using more fuel or oil than expected.
- *Hypothesis: The addition of the data warehousing and reporting software will result in efficiencies in operations, and will make it possible to answer complex business decisions quickly.* This hypothesis is supported based on findings of interviews with a variety of CARTA staff. CARTA staff report that they now spend time using data to improve operations rather than generating data. They are now able to spend more time managing CARTA operations. They now have immediate access to reports that would have cost approximately $60,000 to create before the Data Warehouse. The Data

Warehouse has saved time for the CARTA staff member who does purchasing for the agency. This has expanded her effectiveness as a purchaser in that she now has time to assist more in CARTA's storeroom and to spend time in negotiations with vendors to obtain more competitive prices. The Data Warehouse has also assisted the agency in providing reports and backup information required for periodic agency audits.

- *Hypothesis: The addition of fixed route scheduling software will allow CARTA to provide the same level of service with lower operating costs.* This hypothesis is supported based on agency interviews. Even before integration with CAD/AVL, the fixed-route scheduling software has enabled CARTA to lower agency operating costs. CARTA estimates that by using the new scheduling software for runcutting, the agency has saved approximately 60 hours per week in operator labor, or approximately $62,000 per year. In terms of operating costs, the software has drastically cut down on the time required to perform runcutting and in general, created equivalent or better runcutting results. The runcutting process used to take up to 2 weeks to perform; with the new software, it now takes about 5 minutes. The time savings allows the Director of Planning to run multiple scenarios through the software and to select the optimum set of cuts based on various factors such as cost or route schedule. The software enables CARTA to produce runcuts that minimize operating costs while ensuring compliance with labor laws and CARTA policies. The software also automates the production of headway sheets and paddles, a process that used to be manual.
- *Hypothesis: The addition of paratransit scheduling and dispatch management software will increase efficiency in terms of passenger trips per vehicle revenue-hour.* This hypothesis is supported based on data providing information on the passenger trips per vehicle revenue-hour. Based on the data it appears that the software has improved efficiency for Care-A-Van operations. The number of passenger trips per vehicle revenue-hour increased significantly (with no increase in the number of vehicles being used to provide service) when the new scheduling software was added in April 2006, and this measure has continued to climb steadily since that time, with no direct correlation to the total number of passengers served by Care-A-Van. Although it is unknown whether the system could have handled the service increase without the new scheduling software (i.e., it is possible that there was some excess capacity in the system), if one assumes that the increase in efficiency would not have been possible without the software, CARTA would have had to increase Care-A-Van service by 20 percent to accommodate the increased demand at a cost of approximately $89,000.
- *Hypothesis: The addition of paratransit scheduling and dispatch management software will reduce the average trip booking time.* This hypothesis is inconclusive at this time based on agency interviews. Overall, it does not appear that the addition of paratransit scheduling and dispatch management software has increased the efficiency in average booking time, but it may have saved the agency some time. The reservationist reported that it is possible that the new software makes booking a reservation slightly faster. The Care-A-Van scheduler reported that using the new software to prepare daily schedules does take her less time as compared with the previous software. She particularly notices the improvement during the process of "matching and batching" or mixing together the reservations taken by the reservationist with the standing orders to develop routes for the day.
- *Hypothesis: The addition of paratransit scheduling and dispatch management software will reduce the time required to issue invoices.* This hypothesis is not supported based on agency interviews. Since the amount of time that it took the biller to generate the

invoices before the new software was such a small part of the overall process, he reports that there has not yet been any time savings.

- *Hypothesis: The addition of paratransit scheduling and dispatch management software will improve on-time performance.* This hypothesis was not testable due to challenges in obtaining and analyzing the required data. Based on the small data set of manifests that were converted to a usable format, it is not apparent whether on-time performance has improved or decreased. Furthermore, it is possible that a range of unrelated factors could affect on-time performance for the Care-A-Van service. For example, if the number of passengers increases while the same level of service is provided, the on-time performance would decrease. If this measure is pursued further in Phase III, ridership will be included in this analysis. It is important to note that the Care-A-Van scheduler noted that on-time performance has never been much of an issue for Care-A-Van, so this hypothesis may not make sense moving forward. Also, it has yet to be decided whether the evaluation team will fully pursue the customer satisfaction study. Once the CAD/AVL has been integrated with the software, the evaluation team will discuss the project with CARTA staff to determine if any elements of the project were deployed in such a way that should positively affect riders' perceptions of the service. If so, the team will proceed with undertaking customer satisfaction surveys to determine whether these improvements have positively impacted customer satisfaction.

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 their 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. First, they were time-consuming for CARTA personnel. Some staff reported that the time required to manage and maintain data limited the time they had available to improve CARTA operations. Second, the resulting data included limited detail and was prone to errors and inconsistencies due to the manual methods used to collect and maintain it. Several performance metrics the evaluation team considered could not be produced from available CARTA data, and the team noted several errors in the archived data received to support the evaluation. Third, the data was often difficult to access and costly to analyze. Several of the sources of data used during the evaluation were paper logs, some of which were boxed and archived in a warehouse. Analyzing the data to produce performance metrics required finding the appropriate paper archives and transcribing the data before an analysis could begin. Overall CARTA believes that they have seen a return on investment from the data warehousing and scheduling software in just 1.65 years.[1]

As CARTA began automating and integrating their data collection and management processes, it began to open up new possibilities for available data to support CARTA decision making. For example, CARTA was able to review Incline Rail ticket sales by time of day when they considered whether to change their hours of operation (previously, only daily tickets sales were available). The newly automated process also freed up staff time once spent on manual data management activities. For example, one staff member reported that saving time previously

[1] The combined purchase price of the software package and the data warehouse was $266,000. The annual cost for licensing fees is approximately $50,000 and CARTA estimates that they have experienced an annual cost savings of $211,000 since purchase of the software and data warehouse. Therefore CARTA estimates that the net annual benefit is $161,000 ($211,000 - $50,000) and the breakeven time period is 1.65 years ($266,000 / $161,000).

spent maintaining fuel usage data allowed them to contact more vendors when purchasing equipment, which allowed them to reduce equipment purchase costs at CARTA.

As this phase of the evaluation draws to a close, it appears that CARTA will be entering an exciting time in the SmartBus deployment. They have already deployed a number of the technologies that are part of the SmartBus plans, and are beginning to use the resulting improvements in their data management and access processes to improve their decision-making processes. As they complete the next steps in the deployment – deploying onboard systems – they will obtain real-time access to operational performance data for their transit vehicles and archives of this operational data. It is expected that this will result in continued improvements in CARTA's operational performance and their decision making processes, expectations that will be assessed during Phase III of this evaluation.

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 II 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 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, and 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 II evaluation reports, this document presents a summary of current data analyzed in preparation for later before/after analysis to be performed in Phase III of the evaluation once later technologies are deployed. However, it also presents a before/after analysis of the technologies that are already in place since several of the SmartBus project technologies were already deployed at the time that Phase II of the evaluation began.

The remainder of this document is organized as follows:

- **Section 2 – Background on CARTA and the SmartBus Evaluation.** This section provides background information on CARTA, on the project being evaluated, and on the overall evaluation approach for the national evaluation.
- **Section 3 - Impact of Scheduling Software.** This section provides background information about CARTA's current fixed route and paratransit operations, information about the perceived impacts of the scheduling software to date, as well as information about the expected impacts of the scheduling software once it is integrated with CAD/AVL, and information about how the impacts will be measured.
- **Section 4 – Impact of Incline Railway Ticket Vending Machines.** This section provides background information about CARTA's Incline Railway as well as information about the impacts of ticket vending machines.
- **Section 5 – Impact of CARTA Reporting Capabilities.** This section provides background information about CARTA's Data Warehouse capabilities as well as information about the impacts of the data warehousing to date.
- **Section 6 – Anticipated Impacts of Planned Deployments.** This section provides information about the other onboard technologies that CARTA has planned for deployment in early 2009 as well as information about the expected impacts of the technologies and about how the impact of these technologies will be measured once they are in place.
- **Section 7 – Conclusions and Recommendations.** This section provides conclusions and recommendations for the overall evaluation.

2 BACKGROUND ON CARTA AND THE SMARTBUS EVALUATION

2.1 CARTA OPERATIONS

CARTA provides transit services for the City of Chattanooga in southeastern Tennessee.[2] 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 is also authorized to provide service in portions of Dade, Walker and Catoosa counties in Georgia.

Figure 1 shows a system map of CARTA's main line and neighborhood fixed routes.[3] CARTA operates 13 main line routes, 3 neighborhood routes, and the Care-A-Van demand responsive service. In addition, CARTA operates a free shuttle service in downtown Chattanooga that connects the Shuttle Park North and Shuttle Park South parking/terminal facilities. Main line routes provide frequent fixed route service between downtown Chattanooga and areas within the City of Chattanooga and Hamilton County.

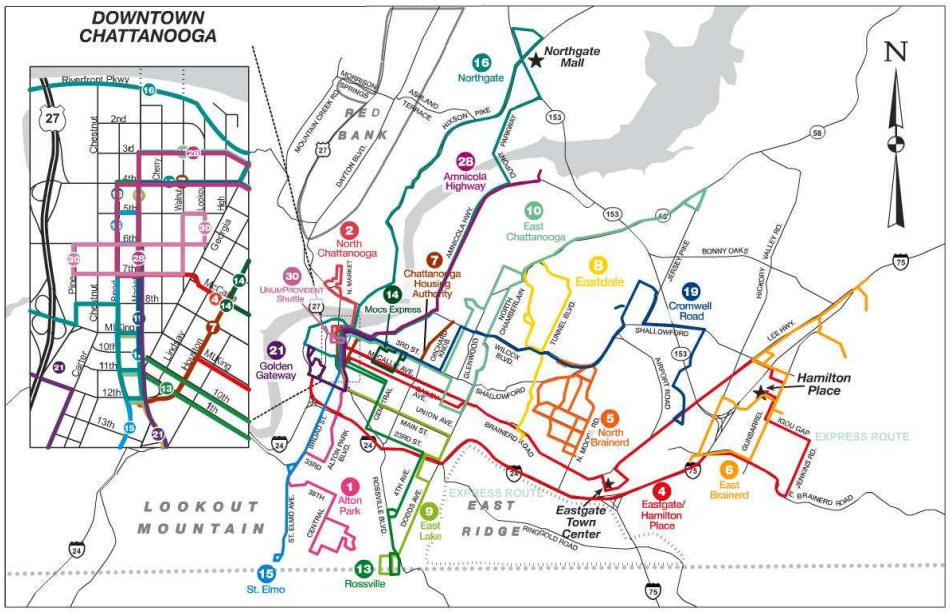

Figure 1. System Map of CARTA's Fixed Routes.

CARTA's fixed route and paratransit services operate out of their headquarters complex, which includes facilities for administration, operations, and vehicle storage and maintenance. CARTA operates with a mix of conventional diesel buses and electric shuttle buses. Peak operation requires 41 fixed route vehicles and 5 electric shuttle buses. Dispatch hours of operation from CARTA headquarters are between 4:00 a.m. and 8:00 p.m., Monday through Saturday. Main line route service hours are between 4:40 a.m. and 12:45 a.m. Monday through Friday, 5:35 a.m. and 12:25 a.m. on Saturday, and 10:20 a.m. and 8:15 p.m. on Sundays. The neighborhood routes operate Monday through Saturday.

[2] Information derived from CARTA staff and from CARTA website (www.carta-bus.org), accessed January 2007.
[3] Map Source: CARTA website (www.carta-bus.org), accessed January 2007.

CARTA's flexible route service operates on two of the neighborhood routes. These flexible routes provide more frequent service within a neighborhood service area, with connections to mainline routes. A flexible route has scheduled stops at a connection point with a mainline route, and circulates to make additional stops within the defined service area on a demand-responsive basis (as directed by the flexible routes dispatcher). To request a demand-response pick-up, passengers simply call the flexible routes dispatcher to indicate their desired pick-up and drop-off locations within the service area. Passengers can also board without calling first, in this case indicating their desired drop-off location within the service area as they board. Passengers of this service do not need to be pre-registered and therefore remain anonymous.

CARTA Care-A-Van demand response service, for clients eligible under the provisions of the Americans with Disabilities Act (ADA), operates primarily within the City of Chattanooga with hours of operation between 4:40 a.m. and 12:45 a.m. Monday through Friday, between 5:30 a.m. and 12:25 a.m. on Saturday, and between 10:20 a.m. and 8:25 p.m. on Sunday. Normal office hours are 8:00 a.m. to 5:00 p.m. Care-A-Van has a total of 14 transportation vehicles (3 vans and 11 cut-aways), and peak transportation load is supported by 12 vehicles. Passengers of this service must be pre-registered with CARTA as Care-A-Van clients, and must book trips in advance.

Table 1 lists some of the key events in CARTA's history, up through 2003, when the Chattanooga SmartBus project began.

Table 1. Key Events in CARTA History

Year	Event in CARTA History
1973	Founded CARTA.
1990's	Deployed and refined the downtown electric shuttle system.
1996	Began using maintenance planning and tracking software for vehicles and facilities.
1997	Completed strategic plan for public transportation.
1998	Began using GIS-based software to manage demand-response operations.
1999	Began using network accounting program.
1999	Began off-site computer training for CARTA staff.
2001	Completed major rearrangement of existing services.
2001	Implemented new service.
1992	Deployed use of City 800 MHz radio system at CARTA.
2001	Established system-wide network for CARTA fixed facilities.
2001	Integrated CARTA network with City IT network.
2001	Deployed parking garage security system.
2003	Deployed signal priority system for buses on routes near Hamilton Place Mall.
2003	Began using Ridecheck™ software to monitoring passenger activities twice per year.

2.2 THE CHATTANOOGA SMARTBUS PROJECT[4]

Like many other transit agencies, CARTA was faced with challenges in keeping track of its fleet and personnel and monitoring the performance of its services. CARTA is undertaking the SmartBus Project to meet these needs. The project is a comprehensive transit ITS program for

[4] Taken from various documents prepared by TranSystems for CARTA: "Project-Specific Deployment Plans", May 12, 2005, and October 26, 2005.

the city of Chattanooga, Tennessee that involves deployment of a wide array of transit ITS technologies. The project elements and the deployment status of each are shown in Table 2.[5]

Table 2. ITS Subsystem and Deployment Status

ITS Subsystem	Deployment Status
Data Warehousing and Reporting Software	Deployed in 2004
Remote Diagnostics Maintenance System	In-vehicle components deployed in 2006; Communications planned for 2009
Ticket Vending Machines	Deployed in 2006
Operations Software	Deployed in 2006 on demand-responsive service and fixed route service
CAD/AVL Software and other Onboard Systems	Planned for 2009
Fareboxes and Revenue Management System	Planned for 2009
Next Arrival Dynamic Message Signs at Bus Stops	Planned for 2010
Real-Time Traveler Information through Website	Planned for 2011
Onboard Surveillance Cameras	Planned for 2011
Transit Signal Priority	Planned for 2012

The national evaluation is focused on the ITS subsystems that are planned for completion through 2009. However, if any other subsystems become available before that time, they will also be considered for evaluation. For example, CARTA is exploring a potential opportunity to collaborate with Advanced Technology Transportation Research Program (ATTRP) at the University of Tennessee - Chattanooga (UTC) to accelerate the deployment of the Next Bus Arrival Dynamic Message Signs at Bus Stops forward into 2009.

The following sections provide more detailed descriptions of the ITS subsystems included in this evaluation. More detail about each of these technologies is provided in Sections 3 through 7.

2.2.1 Data Warehousing and Reporting Software

CARTA's overall vision for this project involves comprehensive integration between all of the individual applications. Each software application will both use data from other applications and provide data for use by other applications. This sharing of information will be facilitated through the data warehousing and reporting software that CARTA has had in place since late 2004, which provides the capability for detailed reporting on a periodic or as-needed basis through this central "warehouse" repository of data. The data warehouse is already supporting analysis and reporting for several existing applications and will be integrated with other onboard systems that are planned for a later date.

2.2.2 Remote Diagnostics Maintenance System

CARTA currently has a multiplex system on ten of its buses that combines data from several subsystems to produce a single stream of system performance data. This system was installed on ten of CARTA's buses that were purchased in 2006, and will be required on all future bus purchases. It is a precursor to the full remote diagnostics maintenance system expected to be in place by 2009. The planned remote diagnostics maintenance system will monitor engine

[5] Per information gathered during meetings with Kirk Shore (CARTA) and Doug Parker (TranSystems) on November 17, 2006, January 8, 2007, and November 11, 2007.

temperature, oil pressure, and other elements of the bus, and will alert maintenance staff whenever the performance status of a subsystem exceeds a pre-determined threshold.

2.2.3 Ticket Vending Machines

In the spring of 2006, CARTA deployed five ticket vending machines (TVMs) along with a central TVM management server application to support the Incline Railway operation. The TVMs accept both cash and credit cards, and are equipped with a contactless smart card reader to enable eventual payment using smart cards.

2.2.4 Operations Software

CARTA completed the deployment of new scheduling software in April 2006. Although the new software is already providing some benefit, the full benefit 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 (this is currently expected to occur in early 2009).

The fixed route scheduling software supports more efficient development of fixed route schedules, blocks, runs and rosters, and allows the user to explore various alternative scenarios. The paratransit scheduling and dispatch management software supports paratransit booking, scheduling, manifest generation, same day manifest changes, completed trip validation, invoicing, and reporting.

The same software that is being used for the paratransit services is expected to be configured to also support the operation of the flexible neighborhood routes using real-time scheduling and manifest updating in response to telephone requests from passengers. The software is not currently being used to support this service as CAD/AVL is required.

2.2.5 Fareboxes and Revenue Management System

CARTA's fareboxes will be replaced with newer models that support a transactional database (i.e., a time-stamped record will be created for each fare transaction indicating the amount collected and the fare type) and contactless smart card readers.

2.2.6 Onboard Systems

CARTA is also planning to procure several onboard systems as shown below. These technologies are currently slated for deployment by early 2009. It is important to note that the full impacts of many of the technologies already discussed are not expected to be fully realized until the onboard systems are in place and integrated with the operations software. An example of this is the mobile data computers (MDCs). The MDCs are expected to enhance the paratransit software by providing features such as paperless manifests, real-time manifest updates, automated reporting of date/time/location for pick-up/drop-off trip events, and location-enhanced same day scheduling.

- *Mobile data computers.* Mobile data computers (MDCs) on the vehicles will provide operators with text messaging capabilities, voice radio call management, and navigational assistance, and will also provide feedback to the operator regarding route/schedule adherence and remote diagnostics.
- *Computer-aided dispatch / automated vehicle location software.* The CAD/AVL software will receive location and schedule adherence data from the onboard MDCs and will

provide dispatchers, customer service, and maintenance management staff with a map and tabular display of the vehicle locations/status for the entire fleet including fixed route, paratransit, and non-revenue vehicles.

- *Covert alarm.* A covert alarm switch will be incorporated into the MDCs to allow operators to send an emergency alarm message to dispatch through the CAD/AVL system.
- *Automated passenger counters.* Automated passenger counters (APCs) will count the number of passengers boarding and alighting at each stop and will display this information on the operator's MDC. This data will be archived onboard and uploaded using the bulk data transfer system when the vehicles return to the garage.
- *Next stop automated announcement system.* An automated announcement system (AAS) will announce each bus stop as the vehicle approaches (e.g., stop name, cross street, landmark). An LED display inside the vehicle will simultaneously display a corresponding text message.

2.3 EVALUATION OVERVIEW

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/after analysis in a Phase III Report. 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[6]. Therefore, this evaluation is being conducted in the following manner, which will enable the timely publication of evaluation results for the technologies already deployed:

- **Phase II:** This phase was initiated immediately following approval of the Detailed Test Plan document. During this phase a before/after analysis was performed for those technologies that are fully deployed and that have 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 out here are those that resulted from interviews regarding experiences "before" deployment of that particular technology).
- **Phase III:** This phase will consist of evaluating the technologies that are to be deployed after publication of the Phase II Report, performing an "update analysis" for the technologies that were already evaluated during Phase II (i.e., for each of the technologies that were already evaluated in Phase II, the team will gather and analyze additional data for the time period between publication of the Phase II report and the Phase III report), and gathering the information for the systems engineering case study.

During Phase II the evaluation team performed in-person interviews with CARTA staff and collected and analyzed before/after data. After approval from USDOT to continue to Phase III, the evaluation team will perform the following activities:

[6] Final Detailed Test Plans, prepared by SAIC for USDOT, September 10, 2007.

- Work with CARTA to determine whether customer satisfaction measures are worth pursuing during Phase III and make recommendations to USDOT.
- Collect data for the "after" analysis following the implementation of the new technologies.
- Perform data analysis and test the hypotheses associated with Phase III technologies.
- Develop the Draft Systems Engineering Case Study and Draft Phase III Evaluation Report and provide the report to USDOT for review and comment.
- Incorporate USDOT comments, revise, and finalize the Systems Engineering Case Study and Phase III Evaluation Report and submit to USDOT for final review and approval.

2.3.2 Evaluation Approach

The hypotheses and measures of effectiveness (MOEs) that guided this evaluation were presented in the Detailed Test Plans Document.[7] 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.[8] The hypotheses for this evaluation have been divided into "key" and "secondary" based on the likelihood of successfully being able to measure the hypothesis, and based on the relevance of the hypothesis to the USDOT goals.

Key hypotheses identified for this evaluation are as follows:

- The addition of scheduling software and CAD/AVL will allow dispatchers to improve headway/ schedule control among particular "problem" routes real-time, and will allow for tighter scheduling of demand responsive routes.
- 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.
- 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.
- 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.
- 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.
- The addition of CAD/AVL and its integration with the scheduling software will result in an improvement in customer satisfaction among riders.

Secondary hypotheses are as follows:

- The addition of the ticket vending machines will result in a revenue improvement for the Incline Railway service.

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[7] Final Detailed Test Plans, prepared by SAIC for USDOT, September 10, 2007.

[8] Taken from documents prepared by TranSystems for CARTA: "CARTA ITS: Preliminary Monitoring and Evaluation Plans Summary for Projects in Procurement, Implementation, or Completed" and "Project-Specific Deployment Plans", May 12, 2005 and October 26, 2005.

- The addition of data warehousing and reporting software will allow for more rapid preparation of a variety of reports.
- The addition of data warehousing and reporting software will result in efficiencies in operations; will make it possible to answer complex business decisions quickly.
- The addition of fixed route scheduling software will allow CARTA to provide the same level of service with lower operating costs.
- The addition of paratransit scheduling and dispatch management software will increase efficiency in terms of trips per vehicle-hour.
- The addition of paratransit scheduling and dispatch management software will reduce the average trip booking time.
- The addition of paratransit scheduling and dispatch management software will reduce the time required to issue invoices.
- The addition of paratransit scheduling and dispatch management software will improve on-time performance.
- The addition of flexible route scheduling and dispatch management software will result in increased efficiency in terms of trips per vehicle-hour.
- The addition of flexible route scheduling and dispatch management software will improve on-time performance.
- The addition of a bus stop audio and visual automated announcement system (AAS) on the buses will result in improved customer satisfaction among riders.

Sections 3 through 6 describe the details of the approach that the evaluation team took to gathering data and information for the evaluation, and also describe the findings from these activities. The data collection approach and the findings are presented as follows: Section 3 presents the impacts of the scheduling software, Section 4 presents the impacts of the Incline ticket vending machines, Section 5 presents the impacts of CARTA reporting capabilities, and Section 6 presents information about the anticipated impacts of the planned deployments.

It has yet to be decided whether the evaluation team will fully pursue the customer satisfaction study. Once the CAD/AVL has been integrated with the software, the evaluation team will discuss the project with CARTA staff to determine if any elements of the project were deployed in such a way that should positively affect riders' perceptions of the service. If so, the team will proceed with undertaking customer satisfaction surveys to determine whether these improvements have positively impacted customer satisfaction. The hypotheses and corresponding MOEs and data sources that would be employed for the customer satisfaction evaluation were specified in the Detailed Test Plans.[9]

[9] Final Detailed Test Plans, prepared by SAIC for USDOT, September 10, 2007.

3 IMPACT OF SCHEDULING SOFTWARE

3.1 FIXED ROUTE SERVICE

3.1.1 Background

CARTA provides fixed route service on 13 routes that operate within the City of Chattanooga and Hamilton County. Peak operation requires 41 fixed route vehicles and 5 electric shuttle buses (both are shown in Figure 2). Main line route service hours are between 4:40 a.m. and 12:45 a.m. Monday through Friday, 5:35 a.m. and 12:25 a.m. on Saturday, and 10:20 a.m. and 8:15 p.m. on Sundays. The neighborhood routes operate Monday through Saturday.

In addition to fixed-route transit, CARTA provides flex-route service within two fixed geographic areas. Each area is served by one to two buses that make a scheduled stop every 30 minutes at the Hamilton Place Mall, a high-demand location. During the scheduled stop, the bus picks up riders and then drops them off at any requested location within the specified service area. The bus operators also respond to ride requests from individuals who call CARTA and request a pick-up. The requests are permitted as long as the bus can make its scheduled stop.

Figure 2. CARTA Electric Shuttle Buses and Fixed Route Buses.

CARTA implemented new fixed-route scheduling software in April of 2006, and will be integrating this software with the CAD/AVL system once in place. This is expected to occur in 2009. This section presents information about the impacts of the scheduling software to date. It also reports on the anticipated impacts of the planned deployments. Phase III of the evaluation will report on impacts of the scheduling software once integrated with CAD/AVL.

3.1.2 Impacts

The evaluation team hypothesized that the fixed-route scheduling software would enable CARTA to lower its operating costs while providing the same level of service. Combined with CAD/AVL, the scheduling software is expected to facilitate greater control of headway times and schedules among routes that are particularly problematic.

To determine the impacts CARTA has already experienced from the fixed-route scheduling software, and to determine the anticipated effects of CAD/AVL integration with the scheduling software, the evaluation team interviewed CARTA's Director of Planning and CARTA's Manager of Scheduling. The Director of Planning has 20 years of experience with runcutting, the process of developing operator assignments from service schedules, and formerly served as a bus

driver and dispatcher. The Manager of Scheduling also has experience as a bus driver, which provides a perspective that has been particularly useful in planning and scheduling.

3.1.2.1 Current Impacts

In the year and a half since the new scheduling software has been in place, CARTA reports that there have been several significant benefits to CARTA in terms of efficiency and increased capabilities.

It is CARTA's practice to conduct runcutting on a semi-annual basis, approximately at Memorial Day and Labor Day. Prior to adopting their current scheduling software in April of 2006, the runcutting process would take up to 2 weeks to perform; with the new software, it now takes about 5 minutes. The time savings allows the Director of Planning to run multiple scenarios through the software and to select the optimum set of cuts based on various factors such as cost or route schedule. The ability to run several different scenarios quickly has been the greatest benefit of the new software according to the Director of Planning.

In addition, the new scheduling software is able to produce runcuts that minimize operating costs while ensuring compliance with labor laws and CARTA policies. This is possible since human resources data is integrated into the system and CARTA staff can input pertinent information such as hourly rates, overtime rates, overtime policies, and driver break policies. CARTA's Director of Planning, an expert runcutter, even admits that there are occasions in which the software produces a better runcut than what she is able to develop based on her experience (for example, she finds herself trying to force every shift into 8 hours while the software will sometimes find that it is more optimal for an operator to work 8 hours and 15 minutes). She adds that the software does a good job of identifying cuts, but that she does occasionally have to make an adjustment because the software developed a scenario with an error.

CARTA has made highly-skilled runcutting capabilities more permanent within the organization because of this software. This helps to protect CARTA when inevitable turnovers or retirements occur with staff who are heavily relied upon for their runcutting expertise.

By using the new scheduling software for runcutting, CARTA was able to save the costs associated with one bus operator; savings that CARTA then used to increase bus service.

Another benefit that CARTA has realized from the new software is the automated production of headway sheets and paddles (headway sheets list the schedule for each block within each line, and paddles list all of the details for one particular line – these are distributed to bus operators at the start of the day and list their schedule including all scheduled arrival and departure times). Previously, CARTA staff had to create both of these sheets in a spreadsheet program, and this was a time-consuming process.

In summary, the fixed-route scheduling software has enabled CARTA to lower its operating costs. CARTA's Director of Planning estimates that by using the new scheduling software for runcutting, the agency has saved approximately 60 hours per week in operator labor, or approximately $62,000 per year. The software has also drastically cut down on the time to perform runcutting and in general, created equivalent or better runcutting results.

3.1.2.2 Anticipated Impacts after Integration with CAD/AVL

The evaluation team interviewed CARTA's Director of Planning, Manager of Scheduling, General Manager, and Head of Maintenance to gauge their expectations for the integration of CAD/AVL with CARTA's recently acquired scheduling and dispatch management software for fixed-route.

In talking with the Director of Planning and Manager of Scheduling, it was clear that they are very excited about the upcoming infusion of information anticipated from the CAD/AVL system. When asked about it, they responded "We can't wait for CAD/AVL!" They expect the data from the CAD/AVL system to improve customer service by providing them information that will allow them to make more informed runcutting, planning, and scheduling decisions. The data should allow them to examine patterns emerging over time of performance by time of day. For example, if they see that a route is consistently slower than expected in certain areas of town, CARTA can decide to adjust stop times, adjust the route itself, or add buses to improve performance. In other words, the CAD/AVL system will provide a complete set of data that CARTA will be able to use to determine whether the scheduled run times are consistent with the actual run times made by buses in the field, and so that they can make adjustments when discrepancies do exist.

The current relationship between scheduled and observed run times for CARTA's fixed routes is depicted in Figure 3. This chart is based on 2,748 run-time measurements collected by CARTA staff across all routes between July 1, 2006 and June 25, 2007 as part of their RideCheck data collection. In this context, a run-time measurement refers to a run-time measurement for a segment of a route, where each route is broken up into four to eight segments. The values in the chart represent the percentage of run-time observations that were ahead of schedule (i.e., the actual run time was less than the scheduled run time) or behind schedule. These observations are well represented by a normal distribution with a mean of -0.3 minutes and standard deviation of 3.9 minutes, which indicates that the scheduled and observed run times are quite close on average.

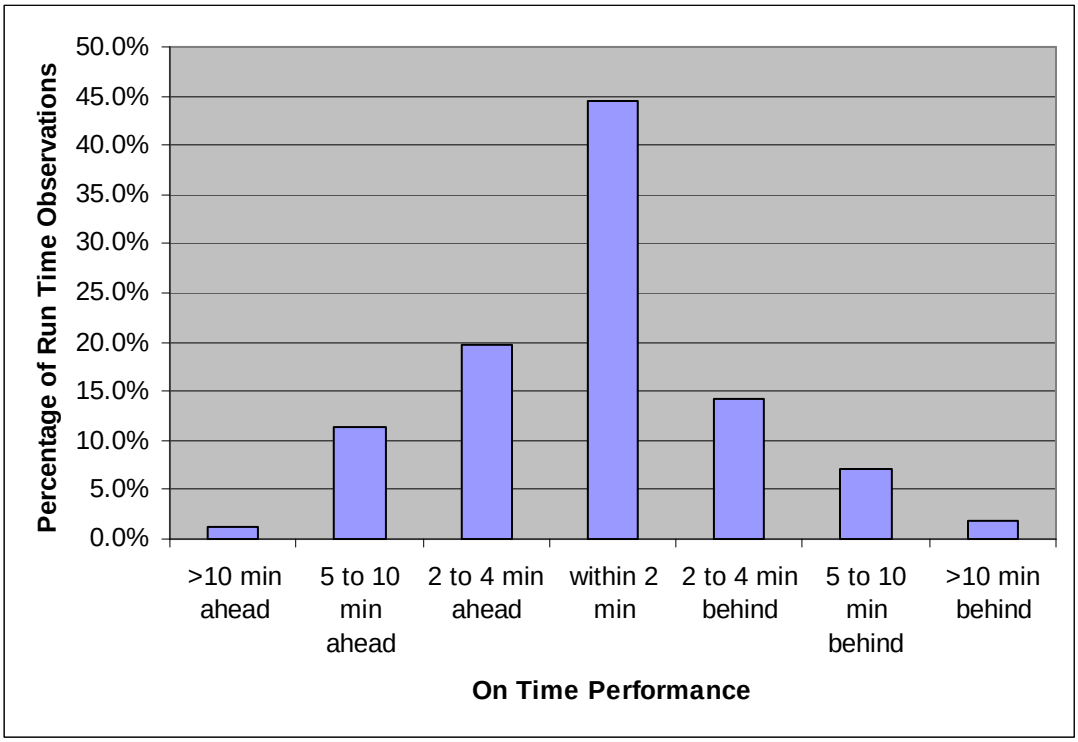

Figure 3. Difference between Scheduled and Actual Run Times for Fixed Route Service.

Surprisingly the data show that CARTA buses are more likely to be running ahead of schedule than behind schedule. Of the 21 segments, there are 5 for which the bus was running 5 or more minutes ahead of schedule 20 percent of the time or more (in fact, it was as high as 50 percent in the case of Line 6, the East Brainard route, and as high as 40 percent of the time on Line 14,

the Mocs Express). In contrast, there is only 1 segment for which the bus was running 5 or more minutes behind schedule 20 percent of the time or more (Line 30, UnumProvident). In Phase III of the evaluation, the evaluation team will focus in particular on those routes that CARTA perceives as "problem routes" when comparing before and after data to see if the integration of CAD/AVL with the scheduling software has had an impact on the on-time performance of these routes. The routes running ahead of schedule will receive particular scrutiny in this analysis as a bus running ahead of schedule can be more of an inconvenience for customers than a late bus.

Another way that CARTA expects to benefit from the CAD/AVL is that, with CAD/AVL, the system will collect run time information on every segment for every route, providing CARTA with approximately 800,000 travel time measurements per year for their fixed-route service – more than 300 times the measurements than they are currently able to collect through their manual run-time data collection which supplied the 2,748 run-time measurements discussed and presented above. CARTA hopes to mine this rich source of run time data to develop a more detailed understanding of the travel conditions that affect their on-time performance. Additionally CARTA expects to save money. The 2,748 run-time measurements discussed above required 630 hours of labor, and this labor intensive effort will no longer be required after the technologies are in place and automatically archiving on-time performance.

CARTA anticipates that the visibility of bus operations afforded by CAD/AVL to dispatchers and operations managers will enable them to address problems in the field in real-time and direct bus operators to make appropriate responses. For example, this visibility will allow managers to better control headways between buses by examining the positions of the buses and communicating with the operators. In the event of severe and unexpected congestion, managers potentially could direct operators to reroute to avoid significant delays.

The ability for increased oversight of field operations will be particularly helpful with flex-routes where it is difficult to track the buses that operate within an assigned area but not a specific route. This will help to ensure that the buses sharing a given area are distributing ride requests in a way that provides the best customer service.

CARTA staff anticipate that the introduction of CAD/AVL will significantly reduce the time necessary to track schedule adherence. In order to meet the Federal reporting requirement,[10] CARTA currently tracks 11 trips per week, which equates to up to 10 hours a week in which staff trail buses to verify stop times. (The archived run time data used to produce Figure 3 represents more than 500 man-hours of time spent following buses to collect run-time data, not including any time spent driving to/from the start and end locations for the run-time data collection.) This is a task shared by the Director of Planning and Manager of Scheduling, both of which have many other responsibilities demanding their attention. In addition to regular schedule tracking, CARTA checks adherence any time it gets a complaint from a customer or a driver. With CAD/AVL this information will be available without going into the field saving significant staff time and decreasing human error involved in data collection.

The General Manager and Head of Maintenance noted that equipping buses with AVL will also benefit drivers who can more easily refute complaints that have no actual merit (and to ensure that CARTA is responding appropriately to those complaints that *do* have merit). These

[10]Section 15 of the Federal Transit Act provides for establishment of two information-gathering analytic systems: A Uniform System of Accounts and Records, and a Reporting System for the collection and dissemination of public mass transportation financial and operating data by uniform categories. The purpose of these two Systems is to provide information on which to base public transportation planning and public sector investment decisions. The Section 15 system is administered by the Federal Transit Administration (FTA).

complaints could range from a claim that a bus caused property damage at a certain time to a complaint from a rider who feels he or she missed a bus because the bus left the stop too early.

3.2 PARATRANSIT SERVICE (CARE-A-VAN)

3.2.1 Background

CARTA's Care-A-Van demand response service, which serves clients eligible under the provisions of the Americans with Disabilities Act (ADA), operates primarily within the City of Chattanooga. Service is provided between 4:40 a.m. and 12:45 a.m. Monday through Friday, between 5:30 a.m. and 12:25 a.m. on Saturdays, and between 10:20 a.m. and 8:25 p.m. on Sundays. Normal dispatch hours are 8:00 a.m. to 5:00 p.m. Care-A-Van has a total of 14 transportation vehicles (3 vans and 11 cut-aways), and peak transportation load is supported by 12 vehicles. Passengers of this service must be pre-registered with CARTA as Care-A-Van clients, and must book trips in advance. A Care-A-Van shuttle is shown in Figure 4.

Figure 4. CARTA Care-A-Van Shuttle.

Seventy (70) percent of CARTA's paratransit trips are standing order, meaning that a client travels at the same time and between the same origin and destination on a regular basis, generally every week or every month. However, the other 30 percent of trips are those that are one-time trips. To request a one-time trip, clients call CARTA and speak with a dispatcher who takes their trip request (date, requested pick-up time and location, requested drop-off time and location), and enters the information into the paratransit scheduling software. By close of business each day, all requests for the following day are scheduled along with any standing order trips (a process termed "match and batch"), and driver manifests are printed, listing the trips scheduled for each driver.

At the start of each day, each driver picks up their manifest and begins making their scheduled trips. With each pick-up and drop-off, the driver records on the paper manifest the time, the number, and the type of passengers picked up or dropped off, as well as any payments received. At the end of the day, each driver returns to CARTA their updated manifest, copies of fare-payment receipts, and collected fares. Dispatchers later reconcile the fare receipts and collected fares, and enter payment information into the paratransit scheduling software.

Three activities can occur that would require a driver to change their manifest: a client calls in and cancels a trip, a client calls in with a last-minute trip request, or a client is dropped off for an appointment with an indeterminate pick-up time following the appointment (termed a "will-call" trip). In each of these cases, the client calls a Care-A-Van dispatcher, who identifies the changes that should be made to the driver manifest. The dispatcher then radios the driver to inform them of the change.

3.2.2 Impacts

The evaluation team hypothesized that the addition of paratransit scheduling and dispatch management software would increase productivity in terms of the number of trips completed per vehicle run and in terms of the number of trips per hour of service. It was also expected that the

addition of paratransit scheduling and dispatch management software would reduce the average trip booking time and the time required to issue invoices.

As part of gathering information on the impacts of the scheduling software on CARTA's Care-A-Van operations, the evaluation team interviewed the Manager of Care-A-Van who has been with the operation for the past 16 years. The team also interviewed the CARTA staff member who provides scheduling and administration for Care-A-Van. She prepares the final schedules for the day, assigns drivers to routes, and schedules all recurring reservations or clients' standing orders. Finally the evaluation team spoke with Care-A-Van's reservationist and back-up dispatcher who makes reservations for clients calling in one-time requests for rides. With the exception of standing orders, Care-A-Van only accepts reservations for trips occurring within the next 2 weeks; in general Care-A-Van requires at least 24-hour advance notice for trips.

The Care-A-Van scheduler (shown at work in Figure 5) prepares the schedule for the day about 2 days in advance by combining the standing orders with the reservations that reservationist has made. Care-A-Van dispatchers are responsible for handling same-day requests for rides (although Care-A-Van generally requires 24-hour advance notice, they do make exceptions), which Care-A-Van tries to accommodate if at all possible. Care-A-Van has an extremely low turn-down rate for ride requests (only 0.8 percent), although the rate at which clients cancel reservations is fairly high at 20 percent. CARTA views this as one area in which new technology can help them increase efficiency by taking advantage of the unexpected gaps in operator schedules to accommodate more riders as demand for Care-A-Van services has grown over the recent years.

Figure 5. CARTA Scheduler at Work.

3.2.2.1 Current Impacts

Feelings about the current impacts from the use of new paratransit and dispatch management software are mixed.

Trip Booking Time

Changes in average trip booking time were gauged through interviews with Care-A-Van's reservationist and scheduler.

When the reservationist takes a request for a ride over the phone, she enters several pieces of information into the scheduling software about the request such as pick-up and drop-off location and client name. The scheduling software then gives her one or more options in ranked order to select from to meet the ride request. The reservationist estimates that the scheduling software recommends what she judges to be the best option about 50 to 60 percent of the time (however, she added that what she would consider to be the "best" option is generally one of the top choices listed by the software). She then negotiates a suitable time with the client over the phone and enters in the reservation. The dispatchers follow a similar process for requests made with less than 24 hours' notice. They also scan the list of options to find the best one and sometimes consult the drivers' schedules to find an appropriate place to accommodate the ride request.

The reservationist reported that it is possible that the new software makes booking a reservation slightly faster, but she is not sure. According to the reservationist, the scheduler, and the manager of Care-A-Van, it is helpful that the new system provides a list of recommendations from which to choose, but in general they have not found the new software to be user-friendly or intuitive, and consequently, they report that it has a steep learning curve.

The Care-A-Van scheduler reports that using the new software to prepare daily schedules does take her less time as compared with the previous software. She particularly notices the improvement during the process of "matching and batching" or mixing together the reservations taken by the reservationist with the standing orders to develop routes for the day. After "matching and batching," she will examine the resulting schedule and typically has to rearrange about 20 to 25 percent of the entries. Overall, though, the scheduler reports that the new software does not save a lot of time.

Care-A-Van has taken all of their business policies and entered them into the new scheduling software so that it will only offer ride recommendations and routes that follow those policies. Additionally, the software is designed to schedule routes to minimize operator costs. Frequently, the scheduler and the other users of the new software must override the recommendations made by the system because it does not take into account all of Care-A-Van's customer service priorities or is not able to make exceptions to policies programmed into the system. When small exceptions to those policies need to be made to accommodate clients, the software users have to go into the system and force a reservation or route sequence to be accepted by the system. Additionally, it will not utilize a driver scheduled to work during a given day if it is able to divide all of the ride requests among fewer drivers. For example, the software may stop recommending bus #6 for pick ups after 10:30 a.m. if it calculates that from 10:30 a.m. on, the rides can be accommodated with fewer buses. Since it is not CARTA's practice to send a driver home for half a day, the Care-A-Van schedulers must work against the software's recommendations to evenly distribute the ride requests among all available drivers. This enables Care-A-Van to maintain a high level of customer service.

One final issue is that staff members have noticed that rides that they believed to have been cancelled will unexpectedly appear in the system again. As a result, Care-A-Van schedulers and reservationists must also keep track of their cancellations manually.

Overall, the addition of paratransit scheduling and dispatch management software does not appear to have increased the efficiency in average booking time.

Passenger Trips per Vehicle Revenue-Hour

It was also expected that the software would increase efficiency of operations through an increase in the number of passenger trips per vehicle revenue-hour. One reason for this is that the new scheduling software selects routes using turn-by-turn navigation instead of triangulation or "as-the-crow-flies" estimation that was used by the previous scheduling software. This was expected to result in more efficient route creation.

However, CARTA faces several challenges that could limit the efficiency gains of the new scheduling software. First, since Care-A-Van prioritizes customer service over trip throughput, Care-A-Van may not actually be experiencing an increase in passenger trips per vehicle revenue-hour. As one example, Care-A-Van works to minimize the amount of excess time that a client is on-board a vehicle (what they term "hold hostage time"), which limits the number of additional passengers the driver can pick up and the number of trips that can be completed per vehicle revenue-hour. Another example of this is the fact that CARTA handles a large number of "will call" return trips, primarily for medical trips. Obviously scheduling efficiency would be much easier to achieve if no "will call" returns were permitted and every passenger needed to commit to a pick-up time when they booked. However, CARTA does not intend to do away with

"will calls" since they provide customers with flexibility and freedom. As the Care-A-Van manager described, "…there is a fine line between customer service and efficiency, and we like to lean more towards the customer service side of the business".

Finally, operating any paratransit service means many "same day" changes (e.g., bookings, changes, cancellations, traffic delays, no-shows) that occur after the scheduling software has already batched the trips, so some inefficiencies are unavoidable no matter how efficient the schedule is at the start of the day.

Despite these challenges, the evaluation team reviewed 6 years of archived performance data for the Care-A-Van service to determine if any changes due to the new software were evident. It should be noted that for the Care-A-Van service, CARTA defines "revenue-hours" to begin when the first passenger is picked up, and to end when the last passenger is dropped off (i.e., they are not including the "dead head" hours at the start and end of the day, but they are including any down-time that may occur between pick-ups and drop-offs when there are no passengers on the vehicle).

As can be seen in Figure 6, the number of passenger trips per vehicle revenue-hour did increase significantly when the new software was added in April 2006, and this measure has continued to climb since that time (it is important to note that the number of vehicles providing the Care-a-Van service has remained the same and that the overall hours of operation of Care-A-Van did not change). Prior to April 2006, the number of passenger trips per vehicle revenue-hour was fairly consistent, fluctuating between 1.0 and 1.3. Since that time it has steadily climbed, reaching more than 1.5 at its highest point in early 2008. One reason for the climb in passenger trips per vehicle revenue-hour could be due to an overall increase in passengers. As Figure 7 shows, the number of Care-A-Van passengers did increase around the time that the new software was put into place, but it has recently dropped while the passengers per vehicle revenue-hour continued to climb. From the data it appears that the software has improved efficiency for Care-A-Van operations. Although it is unknown whether the system could have handled the service increase without the new scheduling software (i.e., it is possible that there was some excess capacity in the system), if one assumes that the increase in efficiency would not have been possible without the software, CARTA would have had to increase Care-A-Van service by 20 percent to accommodate the increased demand. CARTA estimates that this increase in service would have cost the agency approximately $89,000.[11]

[11] Per conversation with Kirk Shore on April 18, 2008. This number is based on the total operating costs that CARTA experienced over the time period April 1, 2007 - April 1, 2008. Care-A-Van shuttles traveled a total of 519,247 miles over this timeframe at an average operating cost of $0.48 per mile. To arrive at the total estimated value of $89,000, this cost, which includes the cost of maintenance, was added to the cost of paying one years' salary to two additional Care-A-Van operators.

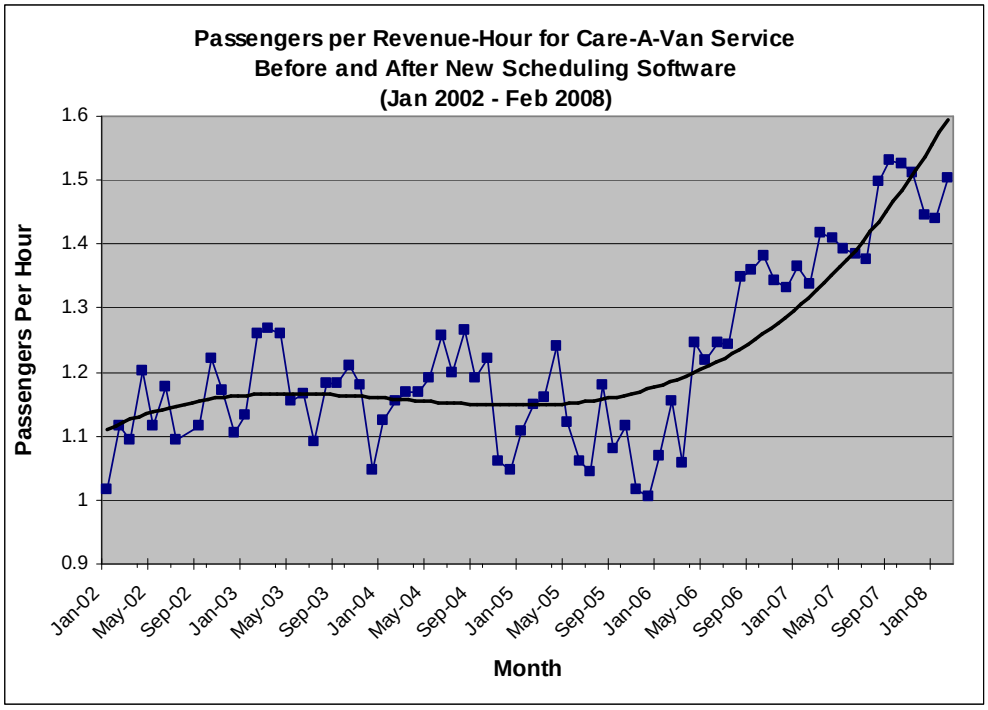

Figure 6. Passengers per Vehicle Revenue-Hour for Care-A-Van Service.

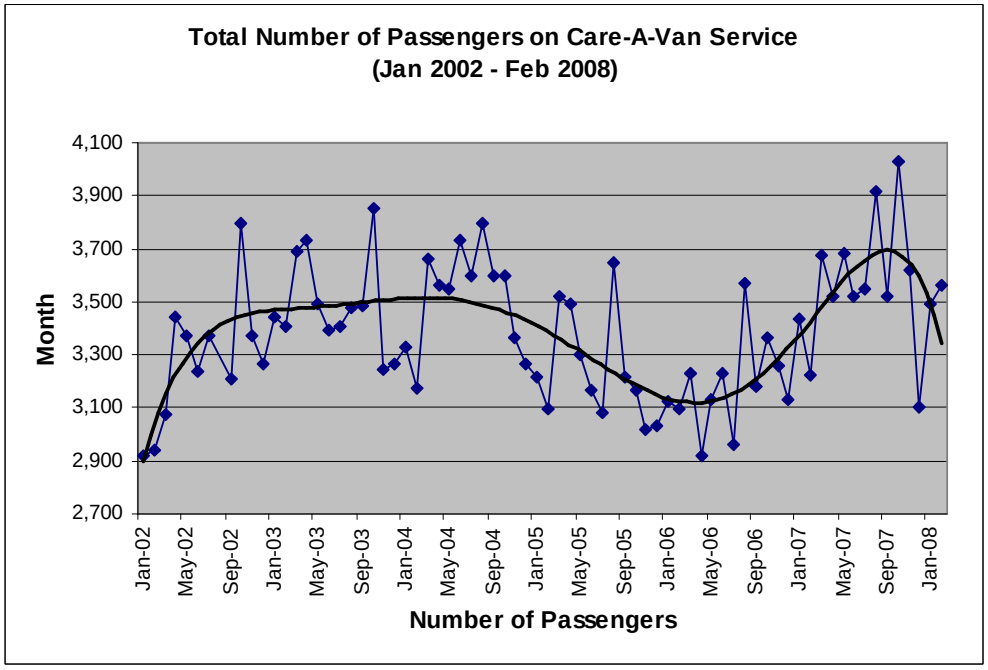

Figure 7. Total Number of Passengers Served by Care-A-Van.

On-Time Performance

The evaluation team initially expected that the scheduling and dispatch management software would improve on-time performance. However, through discussions with the Care-A-Van scheduler, the team learned that on-time performance has never been much of an issue for Care-A-Van, so this hypothesis may not make sense moving forward. Furthermore, on-time performance can be a difficult metric to look at when it comes to paratransit operations. Typically clients are scheduled to an arrival window given the level of available vehicle-hours. The service is therefore scheduled to be "on-time" by adjusting the level of service offered (within constraints) to manage demand. Therefore, days with unusually low on-time performance are more likely the result of factors that are occurring independently of the scheduling software such as unusual weather or traffic.

In order to measure on-time performance for the Care-A-Van service, it was necessary to obtain raw data from CARTA and to then convert this data into a useable format. The "raw data" consists of manifests that are maintained in paper format with handwritten notes about actual pick-up and drop-off times. Since obtaining and converting the data is an extremely labor-intensive process, and one that may not be a worthwhile use of time for the evaluation moving forward, the evaluation team converted only 12 days of data into a usable format for the purposes of reporting for Phase II, with the thought that more "before" data could be converted during Phase III if desired. The data set included 6 days of "before" data from the week of August 3, 2003, and 6 days of "after" data from the weeks of February 17 and February 25, 2008 (note that although it is not ideal to compare August data to February data, data were used from these time periods since obtaining the raw data is labor intensive for CARTA; as a result, the evaluation team accepted data that was readily accessible without regard to date).

By examining this small sample of on-time performance data for Care-A-Van, the evaluation team found that there is no evidence of improvement. Based on data from these 12 days (see Figure 8), it appears that on-time performance may have actually declined with the use of the new scheduling software. On both weekdays and Saturdays vehicles were previously more than 15 minutes early 14 percent of the time, while this number climbed to 17 percent after the software. On weekdays the vehicles arrived right on time for the scheduled pick-up approximately 17 to 29 percent of the time before the software, but only 5 to 20 percent of the time after the software. On weekends the vehicles arrived right on time for the scheduled pick-up 7 percent of the time before the software and 17 percent of the time after the software.

However, this is clearly not a large enough data set to make conclusions. In addition, the data is inherently flawed as it relies on operator-recorded data which is not likely consistent from operator to operator, and could very well be inaccurate due to the incentive that operators would have to record pick-up and drop-off times that make them appear to be more on-time than they perhaps are. Furthermore, there are unrelated factors that could affect on-time performance for the Care-A-Van service. One example is the number of passengers served. If the number of passengers increases while the same level of service is provided, the on-time performance would decrease. If on-time performance for Care-A-Van is pursued further in Phase III, ridership will be included in this analysis.

It should be noted that the evaluation team may also pursue a customer satisfaction study in Phase III. Once the CAD/AVL has been integrated with the software, the evaluation team will discuss the project with CARTA staff to determine if any elements of the project were deployed in such a way that should positively affect riders' perceptions of the service. If so, the team will proceed with undertaking customer satisfaction surveys to determine whether these improvements have positively impacted customer satisfaction.

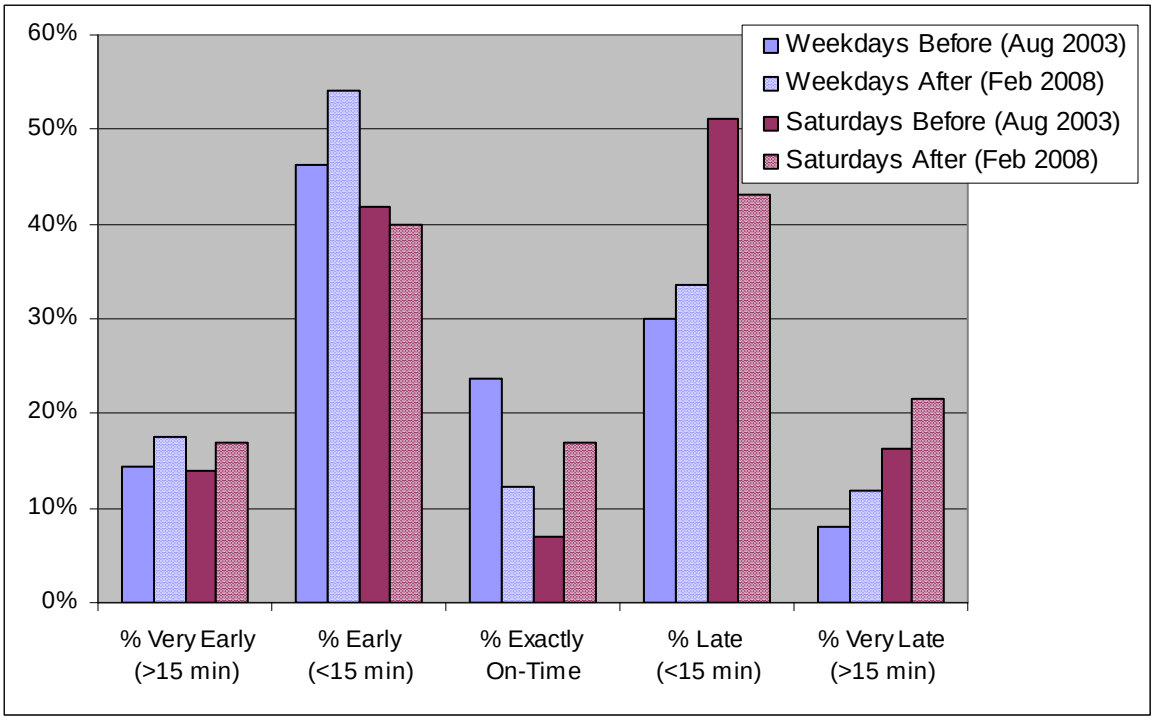

Figure 8. Care-A-Van On-Time Performance Before/After Scheduling Software.

Time Required to Issue Invoices

The evaluation team spoke with the staff member who performs invoicing for Care-A-Van to determine if the addition of the paratransit scheduling and dispatch management software decreased the time required to issue invoices. Prior to the new software, Care-A-Van prepared all invoices on a monthly basis by hand. With the new system, the invoices are automatically generated and include pertinent information such as an itemized list of all the trips taken by the client during that month.

There are several elements of the invoicing process that have not been changed by the new software. Care-A-Van operators write up receipts and record on their paper manifests during the day the trip purpose for each client, the amount of the client's payment, and the amount that still needs to be paid by the client or a supporting organization. Many of the clients' trips are funded through social service agencies and foundations such as the American Kidney Foundation and TennCare, Tennessee's Medicaid managed care program. On a daily basis, Care-A-Van dispatchers collect and compile the receipts in preparation for the monthly invoicing performed by CARTA's biller. The person responsible for invoicing then enters payment information into the software from the compiled receipts and manifests. The software then generates invoices for each client or organization, which is printed out, labeled, and either mailed or faxed to the appropriate party. Since the amount of time that it took the biller to generate the invoices before the new software was such a small part of the overall process, he reports that there has not been any time savings.

3.2.2.2 Anticipated Impacts after Integration with CAD/AVL and MDT

It is expected that the integration of CAD/AVL into the paratransit scheduling and dispatching system will allow for tighter scheduling and result in improved customer satisfaction among Care-A-Van riders.

During the interviews with the Care-A-Van manager, scheduler, and reservationist, the evaluation team inquired about their expectations for the introduction of CAD/AVL. Like the fixed-route staff, the Care-A-Van staff were enthusiastic about the new system that will allow them to know where each vehicle is at any time. Care-A-Van's manager expressed that "AVL will be the best thing we've ever done!" The reservationist reported that AVL will give them an advantage when trying to handle medical emergency situations on the van. When the need arises for an ambulance, the dispatcher will know exactly where the vehicle is and can easily direct emergency services to it. Care-A-Van's scheduler cited the benefit of assisting dispatchers in knowing where all the vehicles are when they need to assign an operator to pick up a passenger returning home from an appointment or fulfill a same-day request. Many of the ride requests received by Care-A-Van involve a return trip at an unknown time. This often happens when a client needs a ride to the doctor but does not know when the appointment will be finished. In these cases, Care-A-Van will schedule the first leg of the trip and then assign the return trip (also referred to as a will-call) to a driver who is close by and can accommodate the trip into his or her schedule. AVL "will save us a lot of time when we can see where the vehicles are at all times," Care-A-Van's scheduler anticipates.

Another expected benefit comes from observations made by the evaluation team while performing the analyses to support the charts and figures presented in this section. Much of the Care-A-Van ridership data presented in Figure 6 and Figure 7 came from copies of paper reports. Preparing these charts required transcribing data from those reports into a database for analysis. Similarly, the on-time performance data reported in Figure 8 came from the paper manifests filled in by vehicle operators as they complete their trips, again requiring transcription before these performance metrics could be computed. The difficulty of producing such performance metrics often prevented CARTA from using them in their decision-making processes. With the new systems CARTA is deploying, most key performance data will be automatically collected and archived in a data warehouse. This should give CARTA the opportunity to consider a broader range of performance metrics while managing their transit operations.

4 IMPACT OF INCLINE RAILWAY TICKET VENDING MACHINES

4.1 BACKGROUND

Beyond fixed route and paratransit services, CARTA also operates the Lookout Mountain Incline Railway (known as "the Incline"). The Incline, shown in Figure 9, has been in operation since 1895 and has the distinction of being the steepest passenger railway in the world as well as a National Historic Site and National Historic Mechanical Engineering Landmark. It also provides access to a state park at the site of a key Civil War battle and to a scenic overlook of the Great Smoky Mountains.[12] It is primarily used by tourists, and many patrons actually purchase a multi-pass ticket that allows them to visit Ruby Falls and Rock City along with the Incline. The Incline is open daily except for Thanksgiving Day and Christmas Day. Operating hours are: 8:30 a.m. to 9:30 p.m. Memorial Day through Labor Day; 9:00 a.m. to 6:00 p.m. in April, May, September, and October; and 10:00 a.m. to 6:00 p.m. November through March.

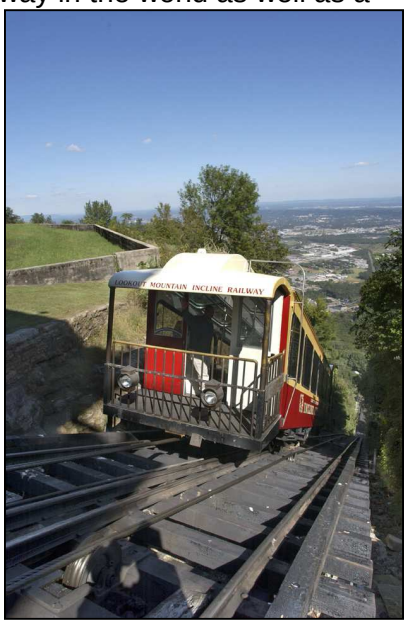

Figure 9. Chattanooga's Incline Railway.

In January 2006 CARTA installed five ticket vending machines (TVMs) to support ticket sales for the Incline Railway (see Figure 10). It was expected that the TVMs would result in a revenue improvement for the Incline Railway service. 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. The same employees who operated the ticket counter also managed the Incline and operated the passenger cars. Instead of tending a ticket counter, these employees are now responsible for replenishing the stock of tickets and receipts in the TVMs and for helping customers with any problems they may have with the TVMs. 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.

Figure 10. Patron using Incline Ticket Vending Machines.

4.2 IMPACTS

One of the primary benefits that CARTA expected to result from the addition of the TVMs was better quality control over revenue stream of the Incline and better quality control of ridership data. Another benefit of the TVMs is that they improve security for employees by eliminating the need for money handling by employees who were previously required to transport cash. Previously all revenue-recording lay in the hands of the employees. At the end of the day employees were responsible for counting their receipts to determine the amount of revenue collected and for tallying up the number of passengers served by the Incline that day. Any reports had to

[12] Information from http://ridetheincline.com

be created based on manual logs of recorded ticket sales, and the level of detail possible in the analysis was severely limited since only daily sales totals were recorded in the log book.

Since all revenue is now collected in an automated fashion it was thought that the TVMs would provide for more aggressive loss prevention with funds handling. It was initially thought that this improvement might be evident in the ridership data, but in looking at ticket sales for the Incline Railway over the time period August 2003 – February 2008,[13] it is apparent that any benefit is not discernable in the data. As shown in Figure 11, ridership appears to follow the same trend both before and after installation of the TVMs with ridership consistently at its lowest in January and at its peak in July. Considering the pure volume of ticket sales and the variability in ticket sales by year, it is not surprising that the change is not apparent (when comparing any given month, the variability in the number of tickets sold in that month from year to year fluctuates anywhere from as little as 477 tickets in the winter months to as many as 10,000 tickets in the summer months). Note that ticket sales were compared, rather than revenue from ticket sales, since ticket prices increased during this timeframe.

Anecdotal evidence, however, indicates that the TVMs have been successful. A few months after the TVMs were installed, the Marketing Manager at the time reported that ridership was up over the previous year while the number of visitors at other partner attractions Rock City and Ruby Falls (both tourist attractions at the top of Lookout Mountain near the Incline Railway) remained level.

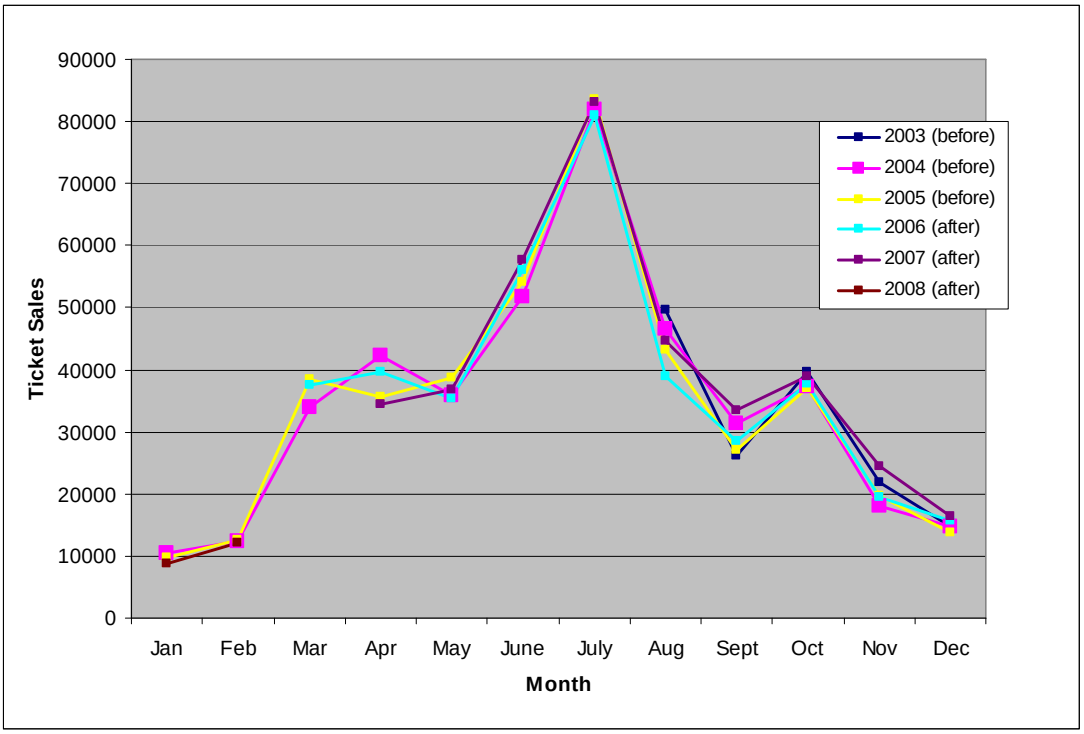

Figure 11. Ticket Sales for Incline Railway Before and After TVMs.

Beyond any revenue goals, the most important benefit of the TVMs is that they provide CARTA access to a wealth of information not previously available. CARTA feels that this information will

[13] Note that data for the months of January-February 2006 and January-March 2007 are not included in this analysis since data for these months was incomplete.

allow the agency to make better business decisions that should lead to increased profitability for the Incline Railway in the long run. As an example, CARTA now has access to the exact time of each ticket sale, allowing ridership to be tracked by hour while it could previously only be tracked by day. CARTA used this data to identify the times of the day when Incline ridership was at its lowest and, based on this information, proposed that service hours be cut to increase profitability of the service. However, after presenting this proposal to partnering vendors for consideration (e.g., staff for Rock City and Ruby Falls), it was decided that rail hours would not be cut since this would negatively affect business for the partner vendors, and in turn, for the Incline (according to CARTA staff, approximately 60 percent of the rides served on the Incline are all-in-one tickets, meaning that the tickets were purchased in conjunction with other tourist attractions).

The importance of this example is not whether or not a change was made in the hours of service. The importance is that, for the first time, CARTA could easily analyze archived data to estimate the potential impact of such a change on Incline Rail revenue.

Another example of where the TVMs have benefited CARTA is in responding to occasional disputes over credit card payments. Prior to the TVMs, identifying information about credit card purchases required manual review of paper credit card receipts. To simplify this process, CARTA tied the TVM data into the Data Warehouse and created a report that allows select staff to review details on TVM credit card transactions when the need arises.

A final way that the TVMs have helped CARTA is that they provide data that ensure that appropriate policies are followed regarding the issuance of reduced fares that are offered to some patrons such as large groups. The railway attendants now use a smart card to request these special rates, allowing CARTA to track tickets by ticket type.

These are just a few examples of ways in which CARTA has already benefited from the TVMs. Other benefits may arise as CARTA realizes other ways to use the TVM data to make key business decisions about the Incline Railway service.

5 IMPACT OF CARTA REPORTING CAPABILITIES

The CARTA Data Warehouse integrates data from different CARTA applications, such as the maintenance and accounting systems, and provides tools for querying that data and generating reports based on the query results. The evaluation team expected that the addition of data warehousing and reporting software at CARTA would result in more rapid preparation of a variety of reports, increased efficiencies in operations and the ability to make complex business decisions more quickly. This section of this report describes the CARTA Data Warehouse, provides examples of how it is used, and the impacts of deploying and using it.

5.1 SOURCES OF CARTA DATA

There are a number of different operational activities that occur within CARTA that generate data, and each of these sources of data is a candidate for inclusion in the CARTA Data Warehouse. The following describes each of these operational activities and the data produced by them.

Care-A-Van Operations. There are three main sources of data related to Care-A-Van operations: paratransit scheduling software, driver manifests, and employee timecards. These data sources and their content are depicted in Figure 12.

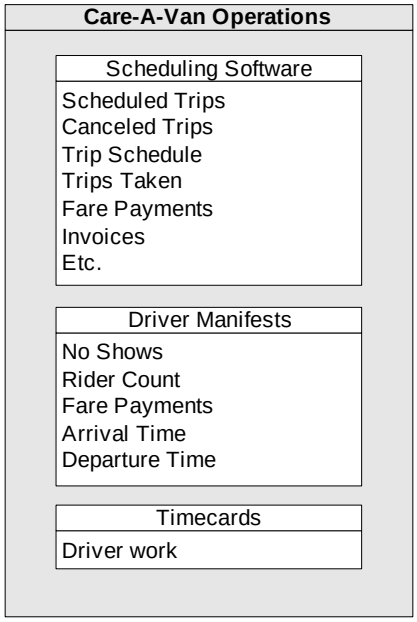

Figure 12. Care-A-Van Operations Data.

CARTA uses its paratransit scheduling software to schedule Care-A-Van service. This system maintains all data related to providing demand response service, including scheduled trips, cancellations, trips taken, fare payment, on-time performance, etc. Clients call in to schedule trips, and the trip request information is entered into the paratransit scheduling software. By close of business each day, these requests are scheduled and driver manifests are printed listing the trips scheduled for each driver.

At the start of each day, each driver picks up their manifest and begins making their scheduled trips. With each pick-up and drop-off , the driver records on the paper manifest the time, the number, and the type of passengers picked up or dropped off, as well as any payments made.

Three activities could occur that would require a driver to change their manifest: a client could call in and cancel a trip, a client could call with a last-minute trip request, or a client could be dropped off for an appointment with an indeterminate pick-up time following the appointment (termed a “will-call” trip). In each of these cases, the client calls a Care-A-Van dispatcher, who identifies the changes that should be made to the driver manifest. The dispatcher then radios the driver to inform them of the change.

At the end of the day, each driver returns to CARTA their updated manifest, copies of fare-payment receipts, and collected fares. Dispatchers later reconcile the fare receipts and collected fares, and enter payment information into the paratransit scheduling software.

Each month, the paratransit scheduling software is used to generate invoices from the trip and fare payment information, and the invoices are printed and distributed to clients. Throughout the month, payments are recorded as they are received and any billing disputes are resolved.

Monthly reports are provided to accounting and to other CARTA management.

Fixed-Route Operations. There are five main sources of data related to CARTA fixed-route operations: the fixed route scheduling software, farebox data, Ridecheck data, run-time check data, and employee timecards. These data sources and their content are depicted in Figure 13.

CARTA revises routes and route schedules and performs run cuts twice per year. Route locations and headways are determined manually based on estimated demand, and the fixed route scheduling software is used to perform the run cuts, produce paddles, etc. These activities set the route and driver schedules.

While on a route, drivers collect fares, check fare passes, and enter passenger and fare information into the onboard farebox system. Each night workers download data from the farebox and collect the fares from each bus. CARTA accounting staff then reconcile the fares collected with the farebox data.

To verify passenger and fare information, CARTA performs Ridecheck surveys on each route twice per year. During a Ridecheck survey, a CARTA employee rides the bus, and at each stop they record the time that the bus arrived and left the stop, as well as information about passengers boarding and alighting the vehicle. These results validate passenger counts.

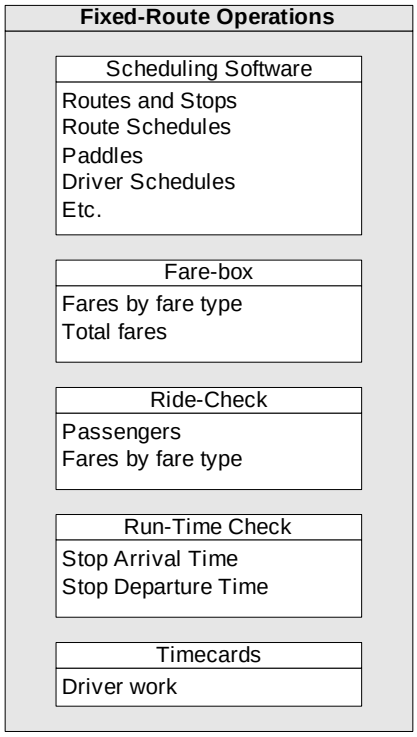

Figure 13. Fixed-Route Operations Data.

To verify run-times, CARTA staff periodically follow behind a bus and record the travel time between specified stops. This data is used to address complaints from passengers regarding on-time performance and as input when CARTA revises route schedules.

Flex-Route Operations. There are three main sources of data related to CARTA flex-route operations: farebox data, Ridecheck data, and employee timecards. (Because the flex-route service does not have a fixed schedule, other than being at the Hamilton Place Mall stop every 30 minutes, run-time check data is not collected. CARTA uses Excel spreadsheets to manage pick-up requests for the flex-routes.)

CARTA's flex-route service provides transportation between Hamilton Place Mall and the surrounding neighborhoods. Each bus provides service between that mall and a specific neighborhood, making pick-ups and drop-offs in that neighborhood and returning to Hamilton Place Mall at 30-minute intervals. The only regularly scheduled stops for these buses are at Hamilton Place Mall. Other stops are made as needed to pick-up and drop-off passengers in the neighborhood serviced by each bus.

To schedule a pick-up at a neighborhood location, a passenger calls CARTA to request a pick-up at a specific location. CARTA provides the passenger with a time window during which the pick-up will occur and informs the driver of the pick-up request. Typically, CARTA will accumulate pick-up requests while the bus is making neighborhood pick-ups and drop-offs and provide the pick-up requests to the driver when the bus next stops at Hamilton Place Mall. When bus usage or congestion is high, a pick-up request might be scheduled for a future run to help ensure that the bus can compute each run during the allotted schedule. Pick-ups at the

mall do not have to be pre-scheduled as the bus makes regularly scheduled stops there.

Drop-off locations are specified when passengers board the bus. The driver records the requested drop-off locations and the pick-up requests received from CARTA and determines a route for completing the requested drop-offs and pick-ups. The driver also collects fares and records fare data in the farebox system. At the scheduled departure time for the mall stop, the driver leaves to service the drop-off and pick-up requests before returning to the mall to repeat the cycle.

Excel spreadsheets are used to maintain information about the passenger pick-up requests and other information related to flex-route operations. The farebox system maintains information about the number of passengers, the type of fare for these passengers, and the fare paid. Ridechecks are performed periodically to validate the farebox data. Employees use timecards to record their hours worked. These data sources and their content are depicted in Figure 14.

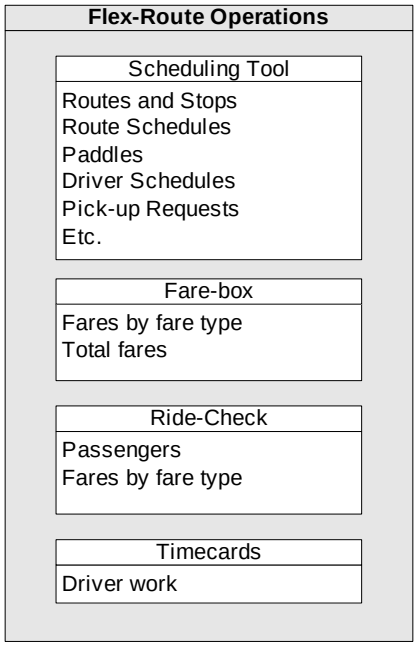

Figure 14. Flex-Route Operations Data.

Fleet Maintenance Operations. CARTA uses fleet maintenance system software to support fleet maintenance activities. The system includes vehicle inventory information, work order management, tire inventory and tracking, parts inventory and purchasing, fuel inventory and usage tracking, vehicle repair records, etc. It is the central repository of all maintenance-related data at CARTA. These data sources and their content are depicted in Figure 15.

Each bus begins its day at the maintenance garage, clean and ready for service. As the driver uses the vehicle during the day, they report any problems to maintenance personnel. For new CARTA buses, driver observations are supplemented by a Vehicle Performance Monitoring system, which monitors key vehicle performance parameters, such as engine temperature and oil pressure. As the bus is used, the system archives the performance data. In the future, the Remote Vehicle Monitoring System will transmit this data to CARTA in real-time.

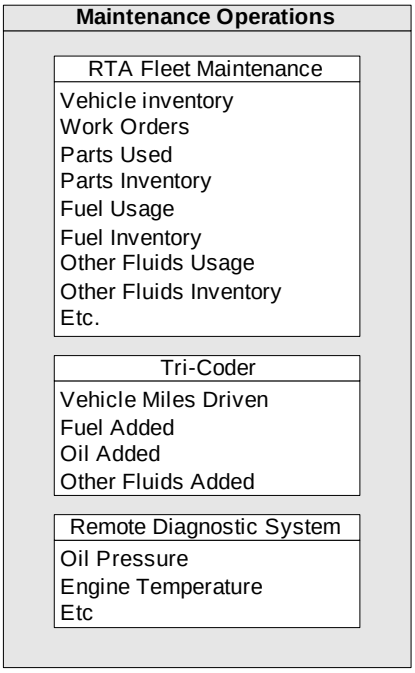

Figure 15. Maintenance Operation Data.

At the end of the day, each bus returns to the maintenance garage, where the vehicles are cleaned and inspected. All fluid levels are checked and topped off, and the amount of each fluid used, as well as the vehicle mileage, is recorded on a handheld device referred to as a Tri-Coder. This data is uploaded to a spreadsheet and reviewed before it is loaded into the fleet maintenance system. (Before CARTA began using the Tri-coder, this data was recorded manually and later transcribed into the fleet maintenance system.)

The fleet maintenance system tracks vehicle usage and indicates when regularly scheduled maintenance

is required. Repairs and maintenance are also being performed when the operator reports a problem, when a problem is detected during nightly inspections, or when an accident occurs and damages a vehicle. All such maintenance activities are performed under work orders maintained by the fleet management system. This system also tracks all parts used for repairs and maintains information about current parts and fluid inventories.

Incline Rail Operations. Operational data (e.g., revenue, receipts) regarding the Incline Railway are kept separate from other CARTA operations. Prior to recent automation efforts, Incline Railway ticket sales data was maintained in paper log books that were manually summarized to produce monthly reports for CARTA management. In conjunction with the installation of Incline Railway Ticket Vending Machines (TVM), CARTA began maintaining a database that archives information about each TVM transaction.

Parking Meter Operations. CARTA manages paid parking in the North Shore region of Chattanooga and in the Riverfront Special Parking Management District in downtown Chattanooga. CARTA uses revenue from these parking facilities to support its parking management operations and to pay for the expenses of the North Shore and Downtown Shuttle operations.

Human Resources. CARTA uses a workforce management software tool that tracks timecard, salary, and payroll data and supports activities related to employee management.

Accounting. CARTA uses an accounting software tool. Other CARTA systems produce monthly reports, and data from those reports is entered into this accounting software to support accounting activities.

5.2 THE CARTA DATA WAREHOUSE

The CARTA Data Warehouse combines data from different CARTA database systems to create a combined data resource that provides functionality that cannot be provided by the individual systems. The Data Warehouse itself is a SQL Server database combined with the data integration software tool used to integrate data into the Data Warehouse and generate reports based on Data Warehouse data. This provides three types of capabilities to CARTA:

- Data is imported from other CARTA databases into the Data Warehouse.
- Data contained in other CARTA databases can be accessed through the Data Warehouse tools.
- Data imported into or accessible from the Data Warehouse can be queried and formatted into reports.

The following three sections describe these capabilities in more detail.

5.2.1 Imported Data

The data integration features of the data integration software allow CARTA to define and schedule periodic data import operations to obtain data from one of the CARTA operations databases listed in the previous section and reorganize it to better support queries in the CARTA Data Warehouse. These import operations are automatically performed each night and include most key operational characteristics related to CARTA operations.

For example, the load plan depicted in Figure 16 is used to import data from the maintenance system into the Data Warehouse each month.

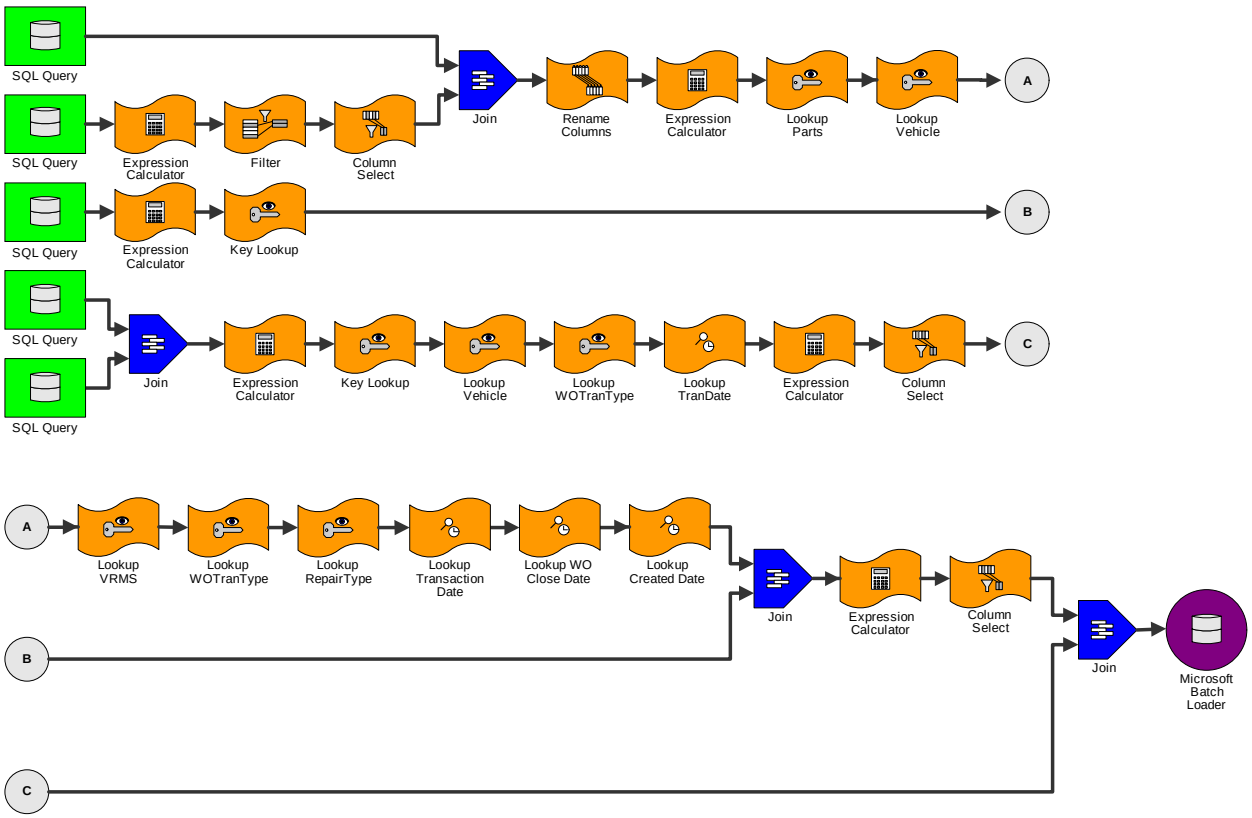

Figure 16. The Load Plan for Maintenance Work Orders

This load plan imports information related to each work order that has been created and/or modified during the month. Although the load plan itself is complicated, the data integration software user interface allows CARTA to break the load process into a series of easy-to-understand steps.

The SQL Query and Lookup steps extract data from the maintenance system, and expression calculations compute derived values. Join steps then merge data streams together. The Microsoft Batch Loader automatically runs the loader each night, allowing CARTA to create and maintain the load plans without the help of an outside contractor. This is important because whenever a vendor changes data structures in one of the other CARTA applications, CARTA has to modify any load plans affected by the database changes. Hiring an outside contractor to make these changes would significantly increase the cost of maintaining the Data Warehouse.

Once this data is in the Data Warehouse, it can be related to other Data Warehouse information, such as information about the type of fuel used by each vehicle. This is reflected in Figure 17, which depicts the tables associated with the maintenance data in the Data Warehouse.

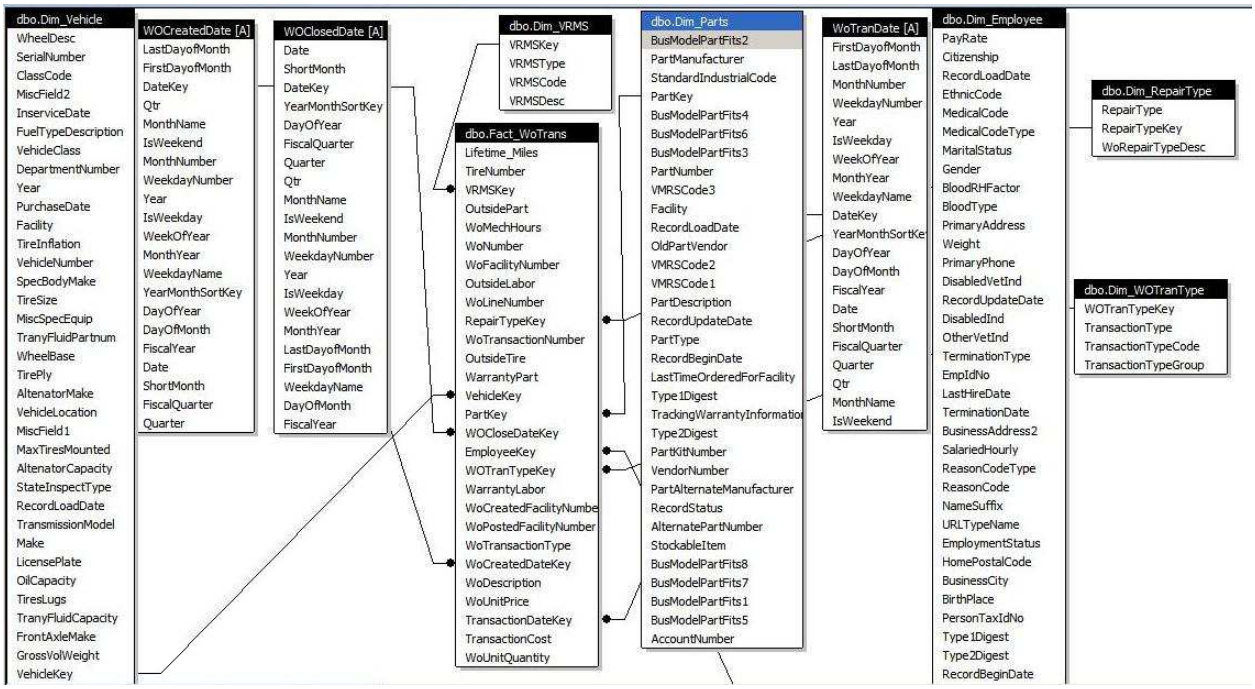

Figure 17. Data Warehouse Tables for Maintenance Data

Note that data from the maintenance system (e.g., work orders, parts, person performing the work), once in the data warehouse, is related to other data not from the maintenance system, such as information about employees and detailed information about each vehicle.

At the time of this report, the Data Warehouse included the following types of data:

- *Vehicle inventory.* This includes a list of all of the CARTA vehicles along with information about each vehicle (e.g., vehicle make and model, purchase date, type of transmission).
- *Employees.* This includes a list of all CARTA employees along with information about each employee (e.g., name, address, phone number).
- *Vehicle maintenance and repairs.* This includes information about each work order for vehicle maintenance or repairs (e.g., repair type, parts used, labor used).
- *Fuel usage.* This includes information about each fueling and recharging operation (e.g., date, gallons or kilowatts used, type of fuel used, cost of fuel used, odometer reading).

In general, CARTA migrates data into the Data Warehouse as needed to support specific operational needs. For example, fuel usage is brought into the Data Warehouse to automate monthly fuel mileage reports that were previously produced using a special reporting tool that gathered information from a non-relational database. Maintenance data is brought into the Data Warehouse to produce reports of historical parts inventories that are needed to support audits. Previously, producing these inventories required manual review of work orders. Bringing data into the Data Warehouse to automate existing reporting processes helps to justify the cost of doing so.

As of February 2008, CARTA expects this process of migrating data into the Data Warehouse to continue for some time. As the potential to automate existing CARTA processes were revealed, additional data have been imported into the Data Warehouse to support that automation. As the

Data Warehouse becomes a richer reservoir of CARTA operational data, new uses will be found for the data.

5.2.2 Accessible Data

In addition to the data that is imported into it, the Data Warehouse also has access to data that resides in the CARTA operations databases. This access was provided by defining direct links between the Data Warehouse database and other CARTA database. This allows CARTA to use the sophisticated query and reporting tools available through the data integration software to query data in other CARTA databases. For example, little data was imported from the fixed route scheduling software system into the Data Warehouse, though this data could be queried through the Data Warehouse, if necessary.

One example of this approach is access to the Incline Railway TVM data. A database is used to record each TVM transaction, and this database is linked with the CARTA Data Warehouse. This allows CARTA to use the Data Warehouse reporting tools to automate a number of monthly reports summarizing Incline Railway operations. (See the next section for more information on these reports.)

Linking the separate CARTA databases to the Data Warehouse was made simpler by the fact that each database uses the same database engine. Using the same database engine for all the CARTA databases allows one CARTA staff member, familiar with a single database engine, to support database management requirements for all CARTA applications.

5.2.3 Data Warehouse Reports

The final major feature of the Data Warehouse is a reporting tool that allows CARTA to build custom reports based on the data available through the Data Warehouse. This tool combines features from the query tool used to move data into the Data Warehouse with a tool for formatting data sets obtained with the query tool. The following list describes some of the reports developed by CARTA:

- *Monthly Reporting.* Each month, CARTA produces a number of reports for management that summarize CARTA's monthly performance. While a variety of different methods were used to produce these reports, many of them required a considerable amount of manual effort. This manual processing was not only time-consuming, it also introduced the potential for error during the manual steps and for inconsistencies when different staff produced the reports. Some of the reports required accessing data in archaic systems, and CARTA commonly brought in an outside consultant for two days to help with the end-of-month reporting. With the introduction of the Data Warehouse, many of these reports are now automatically produced each month.
  - *Fuel Inventory for all Fuel Types by Month, Fuel Mileage Reports.* Prior to recent automation efforts, these reports were produced from data maintained by an archaic COBOL system. Some manual calculations were required, and correcting errors in the data was particularly difficult. The Data Warehouse produces these reports automatically at the end of each month.
  - *Incline Rail Ticket Sales Reports.* Previously, these reports were produced from manual logs of recorded ticket sales. Producing the reports required manual calculations based on the log book entries, and the level of detail was limited because only daily sales totals were recorded in the log book. The Data Warehouse produces these reports automatically at the end of each month from TVM sales data.
  - *Leased Tire Usage Report*. CARTA leased tires and was required to make monthly payments based on tire usage. Previously, CARTA computed tire usage by

manually reviewing vehicle mileage reports and cross-referencing those reports with information about the tires on each vehicle. The CARTA Data Warehouse automatically produces this report at the end of each month.

- *Lookout Mountain Sales Tax Report*. Because the CARTA TVMs at the top of the Incline Railway are in the City of Lookout Mountain, a different sales tax is due for ticket sales made from that location. The CARTA Data Warehouse automates the production of a report on monthly ticket sales from that TVM.

- *Annual Reporting.* Each year, CARTA produces a number of annual reports. Some of these reports are required to support FTA funding. Others are required submissions to the National Transit Database (NTD). Others are used internally at CARTA to access CARTA operations. As with the monthly reports, a variety of different methods were used to produce these reports, and manual steps were often required. The Data Warehouse allows CARTA to automate production of many of the agency's required annual reports.
  - *Annual Parts Inventory Audit Report.* Annually, CARTA conducts audits of their maintenance part inventories, and these audits require information about part inventories at previous points in time. Because the maintenance system used by CARTA was not capable of producing this information, CARTA produced them manually by reviewing parts transaction records. This report now uses inventory transactions (e.g., parts used for maintenance and repairs, parts purchased) from the Data Warehouse along with current inventory data to produce the required parts inventory data.
  - *Maintenance Work Hours by PM Code Report.* One submission requirement for the NTD is reporting on the number maintenance labor hours spent according to the type of activity being performed (e.g., repairing a mechanical failure, performing inspection or maintenance). Prior to the Data Warehouse, this report was produced by reviewing maintenance work order logs from the maintenance database. The Data Warehouse automates the production of this report.
  - *Human Resource Reports.* The software system used by CARTA to manage human resources data was not specifically designed for transit and could not generate some reports in the format needed by CARTA. A number of such reports were produced manually at the end of each fiscal year. The Data Warehouse automates the production of these reports.
- *Other Reports.* As CARTA staff have become more familiar with the data available in the Data Warehouse, they were able to identify many other reports to help them with their operations. Some of these reports were used during a brief period of time to help with a specific operational decision. Others helped address needs that arose occasionally. In some cases, CARTA produced similar reports manually. In other cases, the fact that the Data Warehouse provides access to detailed data from several different CARTA systems has made it feasible to produce some reports for the first time.
  - *Total Cost per Vehicle Mile.* CARTA had been using different types of bio-diesel fuels and was interested in determining whether the bio-diesel provided for a more cost-effective operation. The Data Warehouse allowed CARTA to combine information about the fuel cost per vehicle mile with information about maintenance costs related to the fuel system repairs. This assessment helped CARTA determine that the bio-diesels they had been using had higher total costs and were correlated with more frequent fuel system maintenance activities as compared to traditional diesel fuel. Over the 2 years and 8 months of the test period (from August 2005 to

March 2008), bio-diesel represented approximately 5 percent of all diesel purchased at CARTA, and the test fleet represented approximately 5 percent of the CARTA fleet. The average cost per mile for the bio-diesel test fleet was $1.23 per mile, while the average cost per mile for the rest of the fleet was only $0.55 per mile (the average cost of bio-diesel during the test was $2.45 per gallon on average while traditional diesel was only $2.08 per gallon on average). In addition to the higher fuel cost, the bio-diesel test fleet also required a higher number of fuel system repairs.[14]

- *TVM Sales by Hour.* When CARTA considered reducing the hours of operation for the Incline Railway, a report from the Data Warehouse detailed the number of tickets sold by time of day. This allowed CARTA to estimate the potential revenue impact of decreasing the hours of operation. Previously, hourly sales information for the Incline Railway was not available.
- *TVM Credit Card Detail Report.* At times, CARTA is contacted regarding disputes over credit card payments made to the Incline Railway. Before deploying the TVMs and making TVM data available in the Data Warehouse, identifying information about credit card purchases required manual review of paper credit card receipts. To simplify this process, CARTA developed Data Warehouse reports that allow selected CARTA staff to review details on all TVM credit card transactions.
- *TVM Attendant Transaction Reports.* Incline Railway attendants use a smart card to request special rates for some patrons, such as reduced fares for large groups. This Data Warehouse report allows CARTA to review all such transactions for each attendant to ensure that appropriate policies are followed regarding the use of reduced fares.
- *Alternator Mileage Report.* At one point, CARTA maintenance staff noted a large number of on-the-road failures due to failed alternators. This report allowed CARTA to review the frequency with which different types of alternators were failing on different types of vehicles. From this report, CARTA identified that one specific brand of alternator was failing more frequently than the scheduled replacement time for that part. CARTA increased the frequency of inspection and replacement for that brand of alternator, which helped reduce the frequency of on-the-road failures for the affected vehicles.

While this list only describes a few of the reports produced by CARTA through the Data Warehouse, it does exemplify the two main types of reports that are produced. One type of report is produced to support existing CARTA operations (e.g., the Auditors Parts Inventory Time Machine Report, the TVM Reports). The Data Warehouse provides a more efficient method for producing these reports.

The second type of report is produced for one-time use to support specific CARTA decision-making activities (e.g., the Total Cost per Mile reports, the TVM Sales by Hour report). These reports would have been so difficult for CARTA to produce without the Data Warehouse that decisions would have been made without the support of these reports.

5.3 IMPACTS OF THE DATA WAREHOUSE

The Data Warehouse allows CARTA to merge data from existing applications into a single database. This improves CARTA operations in several ways, such as automating the process for producing a number of monthly reports. More importantly, CARTA staff can spend more

[14] Per analysis presented in April 2008 memo from Kirk Shore to Ron Sweeney and Don Watson, all of CARTA.

time using data to improve operations rather than generating data needed in order to perform basic operations. The Data Warehouse is particularly useful for a transit agency because the cost of transit operations is a compilation of many small costs and the Warehouse has been critically important in helping CARTA to monitor and control those costs. Information was gathered on the impacts from interviews with CARTA's Director of Transportation, Director of Technology, Head of Maintenance, General Manager, and purchasing staff member.

This combined data resource and the tools for generating reports from it have two immediate benefits: staff time and money savings from streamlined reporting and increased support for CARTA operations decision making.

The Data Warehouse reports help streamline the production of monthly and other reports already required by CARTA, allowing CARTA staff to spend less time producing those reports and more time managing CARTA operations. 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. With the Data Warehouse, CARTA now has 103 custom reports automatically generated on a regular basis and used by a variety of departments within CARTA. They now have easy access to reports that would have cost approximately $60,000 to create before the Data Warehouse.

During an interview with the CARTA staff member who performs purchasing, the evaluation team learned that the Data Warehouse and its reporting capability has enabled her to save time performing routine tasks and has expanded her effectiveness as a purchaser for CARTA. The automated inventory reports save her time in performing inventory and other month-end tasks and allow her to take more time in negotiations with vendors for more competitive prices and assist in CARTA's storeroom.

The Data Warehouse has also facilitated the year-end inventory with reports that specify items by department, provided data on a more granular level, and assisted with spending summaries. The reports have been highly useful during CARTA's annual audit. The agency can now easily provide reports and backup information requested by the auditors.

The Data Warehouse reports help CARTA analyze their operational data in new ways, providing better support for CARTA operations decision making. They can now easily look at the cost per mile for each bus and use that information to make decisions about future fleet purchases. CARTA uses the Data Warehouse reporting feature to quickly look at the average fuel or oil usage for each bus and when staff notice a bus that is using more fuel that expected, the maintenance staff pulls that bus out of service and examines it for maintenance problems. Fuel is a major cost for the agency and being able to closely manage fuel usage by bus saves CARTA money.

As different types of data became available in the Data Warehouse, new opportunities are created for CARTA to make use of the data. For example, once both fuel usage and maintenance work order data were in the Data Warehouse, it became possible for CARTA to produce reports on the total operating costs for different fuels. In one case, this helped CARTA to identify that one type of fuel they were using was associated with higher maintenance costs because it tended to clog the fuel filter more frequently. This relationship would have been difficult for CARTA to detect before creating the Data Warehouse because the maintenance and fuel usage data were maintained separately.

Several years ago CARTA purchased several electric buses from a company that is now going out of business. The buses require repeat repairs, and replacement parts are hard to find. CARTA is using their new warehousing capabilities to track the costs to maintain these buses as compared to other buses in their fleet, and plan to use this data to justify an early retirement

for those buses.

The Data Warehouse allowed CARTA to examine the usage of free passes on their incline railway and discover that the high use of free passes was having a significant impact on their revenue. With this information, they took steps to better manage the distribution of their free passes.

Automating the reporting process also helps reduce two problems that sometimes occurred with manually produced reports – reporting errors and inconsistent results that were a consequence of the manual process. Migrating data out of proprietary databases into the Data Warehouse also means that CARTA has much more control over the reporting process. CARTA can export data into many different formats, and can refine and reorganize reports using internal staff rather than requiring the services of outside consultants. Going forward, CARTA expects to migrate additional data into the Data Warehouse as new opportunities to streamline reporting processes or otherwise support CARTA operational decision making are identified.

One factor that is beginning to limit the expansion of the Data Warehouse is the availability of CARTA's one-person technical staff to support the expansion. The limited number of technical staff available at CARTA is one reason that the steps taken to reduce the demands made on this staff were so important — steps such as using a single database technology for all of the CARTA databases and purchasing the data integration software tool to simplify management of the Data Warehouse data and reports. The next several years may prove challenging as CARTA works to maintain and expand the Data Warehouse while pursuing the wide array of other technology enhancements that they are currently pursuing.

Once data from automated passenger counters, fareboxes, and AVL are incorporated into the warehouse, CARTA expects to be able to make better transit service planning decisions in addition to the improved purchasing and maintenance decisions that CARTA is already experiencing.

In summary, during the first 2 years of use, CARTA has gained several important benefits from the data warehouse and its reporting software. Impacts include the ability to make more informed complex business decisions and improve efficiency in business operations.

6 ANTICIPATED IMPACTS OF PLANNED DEPLOYMENTS

6.1 REMOTE DIAGNOSTICS MAINTENANCE SYSTEM

The introduction of the remote diagnostics maintenance system is expected to reduce annual maintenance costs and reduce the number of on-road vehicle failures due to maintenance issues. To gain an understanding of what benefits CARTA anticipates from the system, the evaluation team spoke with CARTA's Director of Transportation, Director of Technology, Head of Maintenance, and General Manager.

Figure 18 shows a CARTA bus undergoing maintenance work. CARTA currently has a multiplex system on ten of its buses that combines data from several subsystems on the bus to produce a single stream of system performance data. Future plans call for more extensive diagnostic data to be archived onboard, with some stored for bulk data transfer when the bus returns to the garage at the end of the day and with time-sensitive data transmitted back to the central system in real-time via the mobile data communications system (including appropriate staff notifications to trigger immediate action). This capability is scheduled for completion in 2009 and will be achieved once additional enabling onboard systems are deployed as part of the CAD/AVL software and onboard systems project.

Figure 18. CARTA Bus Undergoing Maintenance Work.

The CARTA staff who were interviewed envision the remote maintenance system to save CARTA both material and labor costs, to improve customer service, and to help CARTA maintain a positive reputation with the public.

The remote diagnostics maintenance system will monitor engine temperature, oil pressure, and other elements of the bus, and will alert maintenance staff whenever the performance status of a bus subsystem exceeds a threshold pre-determined by CARTA staff. The alerts will enable CARTA's maintenance supervisors to take the appropriate action to address whatever maintenance issue exists. Based on the data viewed 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. As the Head of Maintenance explained, the cost of an engine is typically between $30,000 and $40,000. He 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 estimates that they spend nearly $100 responding to a typical road call (this does not include the cost of repair as the repair would have been needed regardless of whether it was

detected in time to prevent a road call or not).[15] Although the remote diagnostics system will not eliminate the need for those repairs that currently result in road calls, it will hopefully allow CARTA maintenance staff to proactively identify and make needed repairs, resulting in fewer road calls. Fewer road calls will mean a cost savings as well as reduced inconvenience to customers. The resulting cost savings could be significant. In 2007 alone CARTA experienced nearly 250 road calls; if the system eliminated half of these, it would result in an annual cost savings of about $13,000.

As shown in Figure 19, over the past 2 ½ years, the number of on-the-road failures that CARTA has experienced varies in any given month, with the electric shuttle and Care-A-Van vehicles typically experiencing anywhere from 0 to 10 failures. The fixed route fleet has experienced more failures, with anywhere from 3 to 30 occurring in a given month. Over this time the electric shuttle vehicles traveled an average of 10,594 miles between road failures while the Care-A-Van vehicles traveled 17,442 miles and the fixed route vehicles traveled 9,202 miles. As a whole, the Care-A-Van vehicles have been performing better, typically traveling nearly twice as far between road calls as the fixed route buses and electric shuttles. This is not surprising since the Care-A-Van fleet is newer as a whole (only 4 of the 14 vehicles are at the end of their useful life) while all of the electric shuttles are beyond their useful life, and 4 of the 49 fixed route vehicles are over 20 years old and have exceeded 1 million miles.

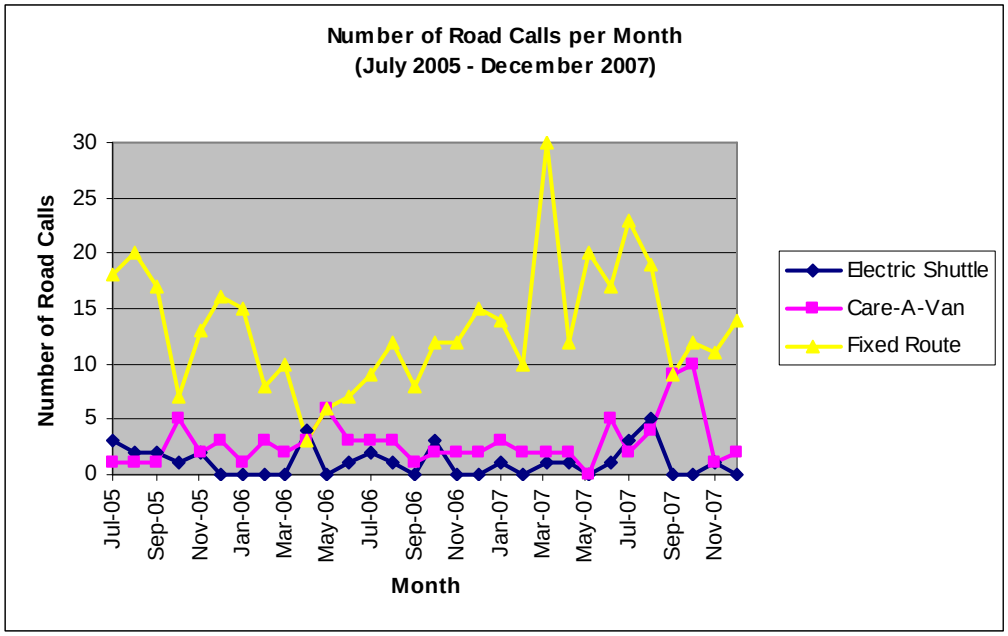

Figure 19. Number of Road Calls Occurring per Month for CARTA Services.

Figures 20 and 21 show how CARTA's overall average compares to the average of other agencies across the country (CARTA's value is represented by the CARTA icon).[16] For both

[15] Based on information from Kirk Shore, CARTA, received by e-mail on May 16, 2008. This estimate includes the cost of 1 hour of a mechanic's time, 1 hour of a bus driver's time (including overtime), and the cost of towing the bus back to the maintenance shop in approximately one-third of the road calls.

[16] 2006 National Transit Database.

fixed route service and demand response service, CARTA was at the 61st percentile (i.e, 61 percent of agencies had a measure for miles between road calls that was lower than that of CARTA).[17]

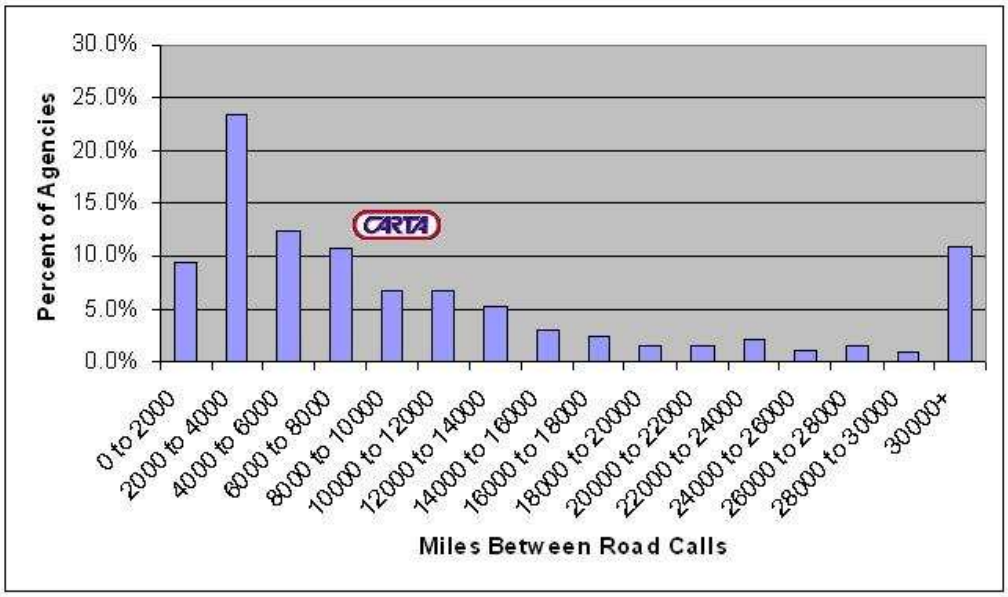

Figure 20. National Average for Number of Miles between Road Calls, Fixed Route Service.

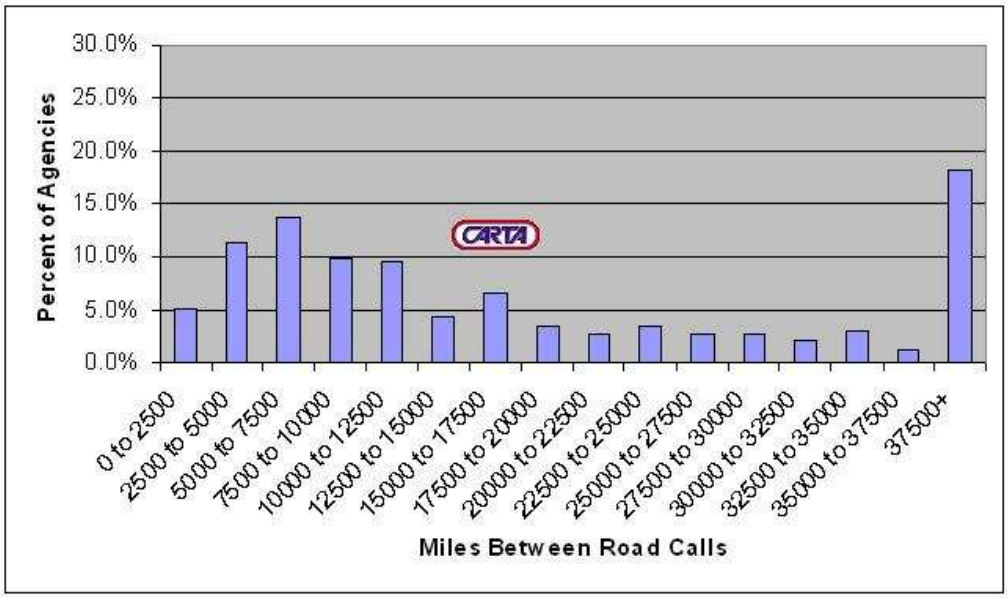

Figure 21. National Average for Number of Miles between Road Calls, Demand Response Service.

[17] The evaluation team noted that the variation in the number of miles per road call was very broad, as indicated in the two figures. For example, the most likely value for the number of miles per road call was between 2,000 and 4,000, with values nearly ten times this large occurring frequently – about 11 percent of the time. A review of the 2002 through 2006 NTD data indicated that, although the variation in these values from agency to agency is very large, the variation from year to year at the same agency is relatively small. This would seem to indicate that the large variation was due to differences in either maintenance practices or reporting practices. If the latter is an important factor, then comparisons to national averages should be treated with care.

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 it potentially damages the reputation of CARTA as a reliable, customer-friendly transit service. By preventing or limiting failures on the road, CARTA can not only provide more reliable customer service, but can 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 delays for passengers.

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 enable the maintenance supervisor to send out a mechanic with the skill set and tools necessary for the in-field repair.

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.

6.2 ONBOARD TECHNOLOGIES

Interviews with the Director of Planning, Manager of Scheduling, General Manager, and Head of Maintenance gave the evaluation team an opportunity to gather their impressions on the expected impacts of future planned technologies. These technologies, which are all planned for deployment in 2009, include new fareboxes and a revenue management system, automated passenger counters, an automated announcement system, mobile data computers, and a covert alarm.

6.2.1 Wireless Internet

An added benefit of the SmartBus project is that CARTA has been able to take advantage of the communication network needed to support communications for the Remote Diagnostics Maintenance System and the CAD/AVL onboard systems to provide free wireless Internet access (Wi-Fi) to their transit riders (Figure 22). They are able to do this at no additional cost beyond what they already had to invest to support onboard systems since they realized that the data bandwidth needed to support the real-time communication needed for these onboard systems was sufficient to also support Wi-Fi. They are one of the first regional transit authorities to roll out Wi-Fi fleetwide.

Figure 22. Customers using Free Wireless Internet on CARTA Bus.

Although the Wi-Fi service has only been in place since October 2007, CARTA has been monitoring the usage of the network and they have already noticed that there are often many simultaneous users. CARTA hopes that providing Wi-Fi will improve customer satisfaction among some transit

riders who will want to take advantage of the network while commuting.[18] Although this technology was not included in the original evaluation (since it was not part of the original SmartBus project), during Phase III the evaluation team plans to review usage data to determine how widely used the Wi-Fi service actually is among CARTA riders. In addition to this, if customer satisfaction surveys are included in Phase III of the evaluation, the survey will include questions about the Wi-Fi service.

6.2.2 Fareboxes and Revenue Management System

CARTA plans to replace their current fareboxes with newer models that will support a transactional database (i.e., a time-stamped record will be created for each fare transaction indicating the amount collected and the fare type) and contactless smart card readers. This system will replace CARTA's current fareboxes, which are 15 years old. CARTA's current and future fareboxes are shown in Figure 23. It is expected that the newer fareboxes and the new revenue management system will give CARTA access to less expensive, more frequent, and more accurate farebox data that will be useful in planning and scheduling.

Figure 23. CARTA's Current and Future Fareboxes.

CARTA staff expect the new farebox system to be a significant improvement over the existing fareboxes. The data collected is expected to be far more accurate than the data coming from the current system, which should be helpful in CARTA's planning. Currently, the fareboxes only consistently track cash payments whereas the new fareboxes will track all types of fares. The existing fareboxes also require the bus operator to flip the direction indicator on the farebox at the beginning and end of each run. If the operator forgets, the fare and ridership data is attributed to the wrong leg of the route. The new fareboxes will be integrated with the mobile data terminals (MDCs), and the MDCs will automatically inform the farebox when each trip ends. As stated previously, the new fareboxes will also create time-stamped records for each transaction, showing the amount collected and the fare type. Overall, the new farebox system is expected to be less susceptible to operator error.

6.2.3 Automated Passenger Counters

Automated passenger counters (APCs) will count the number of passengers boarding and alighting at each stop and will display this information on the operator's mobile data computer. This data will be archived onboard and uploaded using the bulk data transfer system when the vehicles return to the garage.

The evaluation team expects that the addition of APCs will result in access to less expensive, more frequent, and more accurate ridership data that will be useful in planning and scheduling. Through an interview with the Director of Planning, the evaluation team learned that CARTA currently obtains ridership data by month from farebox reports but that this data is significantly

[18] Obtained from http://www.eschoolnews.com/news/top-news/index.cfm?i=45975&CFID=603769&CFTOKEN=86797666, accessed February 2008.

limited since the farebox only consistently tracks riders paying with cash. As a result, systemwide ridership counts are conducted once a year. These counts are conducted manually by CARTA employees on-board buses, a process that is quite labor-intensive (CARTA reports that staff spend approximately 900 hours each year on this activity, or the equivalent of approximately $8,000 each year without even considering the cost of employee benefits packages). Although the agency will likely want to continue to collect some data for validation purposes,[19] there should still be a cost savings due to the APCs.

The General Manager reported that they are looking forward to having consistent and accurate data on passenger counts with the introduction of APCs. The current level of detail in the data is low and he is not confident in the accuracy of the ridership data currently coming from the fareboxes. The automated passenger counters will provide access to consistent data across all buses and all routes whereas currently bus operators may differ in their counting practices. The General Manager expects that the APCs will enable CARTA to improve its alignment of stops by passenger volume, and that in general the data will enable them to make better business policies and to improve planning.

6.2.4 Automated Announcement System

An automated announcement system (AAS) will announce each bus stop as the vehicle approaches the stop (e.g., stop name, cross street, landmark). A light-emitting diode (LED) display inside the vehicle will simultaneously display a corresponding text message.

The evaluation team hypothesizes that the automated announcement system and the LED display indicating the next stop will result in greater customer satisfaction among CARTA riders. During the interviews, CARTA staff did not comment on their expectations for the announcement system although the Manager of Scheduling is currently working to define the stop announcement sequences for the buses.

6.2.5 Mobile Data Computers

Mobile data computers (MDCs) on the vehicles will provide operators with text messaging capabilities, voice radio call management, and navigational assistance, and will also provide feedback to the operator regarding route/schedule adherence and remote diagnostics.

The introduction of mobile data computers (MDCs) on paratransit vehicles is expected to improve the efficiency and effectiveness of communication between drivers and dispatchers and to reduce the need for radio communication. Additionally, the introduction of MDCs – and thereby the elimination of paper manifests - should save time for both bus operator and dispatchers. Finally, the MDCs are expected to increase safety during emergency situations by providing the capability for drivers and dispatchers to communicate silently.

During an interview, the General Manager reported that he anticipates the MDCs will reduce the high number of exchanges that occur over the radio and will shift the majority of communication from audio to visual. CARTA also anticipates that freeing up the radio of routine, non-critical communications (such as general announcements to operators) will help to ensure that the critical communications (such as emergencies) are effectively conveyed.

The MDCs are expected to help in particular with the Care-A-Van service. The evaluation team

[19] According to CARTA's consultant, many agencies report that they continue to conduct at least 100 randomly selected Ridechecks each year for the purposes of validating APC data for reporting to the National Transit Database (NTD). He reports that he has heard this from several agencies of varying size, despite the fact that from a statistical perspective one would think that the number of such parallel validation would vary based on the overall number of trips operated annually.

spoke with Care-A-Van's manager, reservationist, and billing staff member about the changes they anticipate as a result of the upcoming mobile data terminals on the Care-A-Van vehicles.

It is known that the van operators will have 10-inch, full color LCD terminals, but the details on the design and function are still being developed. The display will show the driver's manifest for the day and this will allow dispatchers to rearrange the manifest in real-time to adjust the drivers' assignments to accommodate will-calls and same-day requests.

As mentioned previously, one opportunity for improved efficiency and increased service involves rider cancellations. Approximately 20 percent of Care-A-Van reservations are cancelled by the client and sometimes that cancellation occurs on the same day of the scheduled trip. The ability to reassign operators in real-time using the electronic manifest opens up the possibility of making better use of the gaps left in an operator's schedule after a cancellation. One drawback of the ability to reshuffle schedules, involves the introduction of errors. The new manifest will need to be reviewed prior to transmission to the driver's terminal on the bus. The ability to electronically update a driver's manifest may also have safety benefits, as noted by Care-A-Van's manager. Currently, when a driver receives a change to his or her manifest over the radio, the driver has to manually write the change on the paper manifest. Updates via MDC will help to eliminate these distractions while the operator is on the road.

Care-A-Van's reservationist mentioned that the text messaging function of the MDC will definitely reduce the amount of excess radio traffic between drivers and dispatchers. Additionally, the text communication will provide a back up for drivers if their radio battery dies.

The staff member who prepare invoices for Care-A-Van expects that the MDCs will increase accuracy of billing and save him time manually entering in the data that drivers currently hand-write on manifests and receipts. When picking up each client, the driver will be able to enter into the MDC the amount paid. This will reduce transcribing errors and eliminate the need for him to enter in payment information into the software to generate monthly invoices.

In addition to these benefits, the MDCs should save a significant amount of time for both paratransit operators and dispatchers. Currently, operators manually record pickup/dropoff times on their manifests by hand, and dispatch staff later transcribe these markups into the system. This is a labor-intensive process that will be eliminated by the addition of the MDCs.

Also Care-A-Van operators are currently responsible for writing receipts and recording on their paper manifests the trip purpose for each client, the amount of the client's payment, and the amount that still needs to be paid by the client or a supporting organization. The MDCs will certainly help the operators in this effort.

6.2.6 Covert Alarm

The addition of a covert alarm will provide the capability for bus operators to silently signal to dispatchers in the event of an emergency. It is expected that the alarm will result in increased safety during critical situations. Although no CARTA staff could recall an instance where the covert alarm would have been needed, it is possible that a situation may arise at any time. The evaluation team will explore the use of the covert alarm through interviews during Phase III of the evaluation.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Based on the results of this evaluation to date, eight of the hypotheses stated up front either have been supported by the results of the evaluation, have not been supported by the results of the evaluation, or are inconclusive at this time. A summary of the conclusions are presented below.

It is important to note that the conclusions presented here are based on CARTA's experiences to date with these technologies and that these same hypotheses will be revisited in Phase III, at which point there may be different conclusions as CARTA will have had more time to experience and make use of these technologies.

- *Hypothesis: The addition of the TVMs will result in a revenue improvement* for the Incline Railway service. This hypothesis is inconclusive at this time. It is not evident from the data whether there has been an improvement in revenue. However, anecdotal evidence indicates that the TVMs have been a success. A few months after the TVMs were installed, the Marketing Manager at the time reported that ridership was up over the previous year while the number of visitors at other partner attractions remained level. Beyond any revenue goals, the most important benefit of the TVMs is that they provide CARTA access to a wealth of information about ridership that was not previously available. CARTA feels that this information will allow the agency to make better business decisions that should lead to increased profitability for the Incline Railway in the long run.
- *Hypothesis: The addition of the data warehousing and reporting software will allow for more rapid preparation of a variety of reports.* This hypothesis is supported based on findings of interviews with a variety of CARTA staff. Staff report that they can now easily look at the cost per mile for each bus and use that information to make decisions about future fleet purchase. They can also look at the average fuel or oil usage for each bus and pull buses out of service to examine them for maintenance problems when noticing that a particular vehicle is using more fuel or oil than expected.
- *Hypothesis: The addition of the data warehousing and reporting software will result in efficiencies in operations, and will make it possible to answer complex business decisions quickly.* This hypothesis is supported based on findings of interviews with a variety of CARTA staff. CARTA staff report that they now spend time using data to improve operations rather than generating data. They are now able to spend more time managing CARTA operations. They now have immediate access to reports that would have cost approximately $60,000 to create before the Data Warehouse. The Data Warehouse has saved time for the CARTA staff member who does purchasing for the agency. This has expanded her effectiveness as a purchaser in that she now has time to assist more in CARTA's storeroom and to spend time in negotiations with vendors to obtain more competitive prices. The Data Warehouse has also assisted the agency in providing reports and backup information required for periodic agency audits.
- *Hypothesis: The addition of fixed route scheduling software will allow CARTA to provide the same level of service with lower operating costs.* This hypothesis is supported based on agency interviews. Even before integration with CAD/AVL, the fixed-route scheduling software has enabled CARTA to lower agency operating costs. CARTA estimates that by using the new scheduling software for runcutting, the agency has saved approximately 60 hours per week in operator labor, or approximately $62,000 per

year. In terms of operating costs, the software has drastically cut down on the time required to perform runcutting and in general, created equivalent or better runcutting results. The runcutting process used to take up to 2 weeks to perform; with the new software, it now takes about 5 minutes. The time savings allows the Director of Planning to run multiple scenarios through the software and to select the optimum set of cuts based on various factors such as cost or route schedule. The software enables CARTA to produce runcuts that minimize operating costs while ensuring compliance with labor laws and CARTA policies. The software also automates the production of headway sheets and paddles, a process that used to be manual.

- *Hypothesis: The addition of paratransit scheduling and dispatch management software will increase efficiency in terms of passenger trips per vehicle revenue-hour.* This hypothesis is supported based on data providing information on the passenger trips per vehicle revenue-hour. Based on the data it appears that the software has improved efficiency for Care-A-Van operations. The number of passenger trips per vehicle revenue-hour increased significantly (with no increase in the number of vehicles being used to provide service) when the new scheduling software was added in April 2006, and this measure has continued to climb steadily since that time, with no direct correlation to the total number of passengers served by Care-A-Van.
- *Hypothesis: The addition of paratransit scheduling and dispatch management software will reduce the average trip booking time.* This hypothesis is inconclusive at this time based on agency interviews. Overall it does not appear that the addition of paratransit scheduling and dispatch management software has increased the efficiency in average booking time, but it may have saved the agency some time. The reservationist reported that it is possible that the new software makes booking a reservation slightly faster. The Care-A-Van scheduler reported that using the new software to prepare daily schedules does take her less time as compared with the previous software. She particularly notices the improvement during the process of "matching and batching" or mixing together the reservations taken by the reservationist with the standing orders to develop routes for the day. Although it is unknown whether the system could have handled the service increase without the new scheduling software (i.e., it is possible that there was some excess capacity in the system), if one assumes that the increase in efficiency would not have been possible without the software, CARTA would have had to increase Care-A-Van service by 20 percent to accommodate the increased demand at a cost of approximately $89,000.
- *Hypothesis: The addition of paratransit scheduling and dispatch management software will reduce the time required to issue invoices.* This hypothesis is not supported based on agency interviews. Since the amount of time that it took the biller to generate the invoices before the new software was such a small part of the overall process, he reports that there has not yet been any time savings.
- *Hypothesis: The addition of paratransit scheduling and dispatch management software will improve on-time performance.* This hypothesis was not testable due to challenges in obtaining and analyzing the required data. Based on the small data set of manifests that were converted to a usable format, it is not apparent whether on-time performance has improved or decreased. Furthermore, it is possible that a range of unrelated factors could affect on-time performance for the Care-A-Van service. For example, if the number of passengers increases while the same level of service is provided, the on-time performance would decrease. If this measure is pursued further in Phase III, ridership will be included in this analysis. It is important to note that the Care-A-Van scheduler noted that on-time performance has never been much of an issue for Care-A-Van, so

this hypothesis may not make sense moving forward. Also, it has yet to be decided whether the evaluation team will fully pursue the customer satisfaction study. Once the CAD/AVL has been integrated with the software, the evaluation team will discuss the project with CARTA staff to determine if any elements of the project were deployed in such a way that should positively affect riders' perceptions of the service. If so, the team will proceed with undertaking customer satisfaction surveys to determine whether these improvements have positively impacted customer satisfaction.

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 their 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. First, they were time-consuming for CARTA personnel. Some staff reported that the time required to manage and maintain data limited the time they had available to improve CARTA operations. Second, the resulting data included limited detail and was prone to errors and inconsistencies due to the manual methods used to collect and maintain it. Several performance metrics the evaluation team considered could not be produced from available CARTA data, and the team noted several errors in the archived data received to support the evaluation. Third, the data was often difficult to access and costly to analyze. Several of the sources of data used during the evaluation were paper logs, some of which were boxed and archived in a warehouse. Analyzing the data to produce performance metrics required finding the appropriate paper archives and transcribing the data before an analysis could begin. Overall CARTA believes that they have seen a return on investment from the data warehousing and scheduling software in just 1.65 years.[20]

As CARTA began automating and integrating their data collection and management processes, it began to open up new possibilities for available data to support CARTA decision making. For example, CARTA was able to review Incline Rail ticket sales by time of day when they considered whether to change their hours of operation (previously, only daily tickets sales were available). The newly automated process also freed up staff time once spent on manual data management activities. For example, one staff member reported that saving time previously spent maintaining fuel usage data allowed them to contact more vendors when purchasing equipment, which allowed them to reduce equipment purchase costs at CARTA.

As this phase of the evaluation draws to a close, it appears that CARTA will be entering an exciting time in the SmartBus deployment. They have already deployed a number of the technologies that are part of the SmartBus plans, and are beginning to use the resulting improvements in their data management and access processes to improve their decision-making processes. As they complete the next steps in the deployment – deploying onboard systems – they will obtain real-time access to operational performance data for their transit vehicles and archives of this operational data. It is expected that this will result in continued improvements in CARTA's operational performance and their decision making processes, expectations that will be assessed during Phase III of this evaluation.

[20] The combined purchase price of the software package and the data warehouse was $266,000. The annual cost for licensing fees is approximately $50,000 and CARTA estimates that they have experienced an annual cost savings of $211,000 since purchase of the software and data warehouse. Therefore CARTA estimates that the net annual benefit is $161,000 ($211,000 - $50,000) and the breakeven time period is 1.65 years ($266,000 / $161,000).

7.2 PROJECT STATUS UPDATE

To date the deployment team has not faced any significant delays or challenges with regard to the deployment as a whole or with regard to any of the specific technologies that they are implementing. As of now the project is on-schedule and all of the project elements to be included in the evaluation are planned to be in place by early 2009, which is in line with the current schedule for Phase III of the national evaluation.

7.3 EVALUATION RISK ASSESSMENT AND RECOMMENDATIONS

The SmartBus project appears to be well on its way to a successful implementation. CARTA has already selected a vendor for the GPS-based AVL/CAD and the ATIS (Advanced Traveler Information Systems) applications. CARTA has installed all of the on-vehicle hardware with the exception of the MDCs, which will be installed in April 2008. Preliminary design review has been completed for the GPS/AVL/CAD and ATIS deployment. Fareboxes have also been ordered and delivered. In addition, CARTA is currently involved in a marketing effort, which includes public meetings to develop a schedule for installation of the new fare systems that is within the context of the other ITS technologies that are coming on line.

The evaluation team recommends that Phase III of the evaluation be funded with the bulk of the post-implementation data collection activities taking place beginning in early 2009 when the remaining key project elements are expected to be in place. It is recommended, however, that Phase III activities be authorized to begin upon acceptance of the Phase II Report so that the evaluation team can begin working with CARTA to ensure that the Data Warehouse provides access to all data required to support the evaluation and to document lessons learned throughout the deployment and operation of the project elements that are already in place. In addition to this, the evaluation team has noted that many of the performance measures needed to support the evaluation would also be useful for supporting CARTA decision-making. As a result, it would be beneficial for the evaluation team to begin working with CARTA now to identify the performance measure tools that CARTA will be developing. This will allow the team to focus on computing other performance measures that CARTA is not planning to use. This approach will allow the evaluation team to gain access to measures that CARTA is collecting and allow CARTA to benefit from any additional performance measures that are computed by the evaluation team.

The evaluation team also expected that the scheduling and dispatch management software would improve customer satisfaction due to an increase in on-time performance. It is important to note that the Care-A-Van scheduler noted that on-time performance has never been much of an issue for Care-A-Van, so this hypothesis may not make sense moving forward. Also, it has yet to be decided whether the evaluation team will fully pursue the customer satisfaction study. Once the CAD/AVL has been integrated with the software, the evaluation team will discuss the project with CARTA staff to determine if any elements of the project were deployed in such a way that should positively affect riders' perceptions of the service. If so, the team will proceed with undertaking customer satisfaction surveys to determine whether these improvements have positively impacted customer satisfaction. However, for the purposes of Phase II reporting, the evaluation team analyzed data to determine if any improvements in on-time performance are already evident.

Another hypothesis that may not be worthwhile to pursue into Phase III is the on-time performance of Care-A-Van. First, the Care-A-Van scheduler noted that on-time performance has never been much of an issue for Care-A-Van, so this hypothesis may not make sense moving forward. Second, the process of converting the data required for this analysis into a useable format is extremely labor-intensive, and may not be a worthwhile use of time for the

evaluation moving forward. In addition, the data is inherently flawed as it relies on operator-recorded data which is not likely consistent from operator to operator, and could very well be inaccurate due to the incentive that operators would have to record pick-up and drop-off times that make them appear to be more on-time than they perhaps are. Finally, based on a very limited data set it appears that there is no evidence of improvement (in fact, it appears that on-time performance actually declined with the use of the new scheduling software), and there are a number of unrelated factors that could affect on-time performance for the Care-A-Van service (e.g., the number of passengers served). The evaluation team recommends a discussion of this hypothesis with USDOT.

The schedule shown in Table 3 details the current planned schedule for Phase III of the evaluation. Given CARTA's current deployment schedule, which plans for all "short-term deployments" to be in place by early 2009, this schedule allows for one full year of post-deployment data collection. In the event that the project is delayed, the evaluation team recommends revising these dates to ensure that they still accommodate one full year of post-deployment data collection.

Table 3. Current Schedule for Phase III of the Evaluation

Phase III Milestones	***Schedule***
Draft Systems Engineering Case Study	6/25/10
Comments due to SAIC	7/16/10
Final Systems Engineering Case Study	7/30/10
Draft Phase III Report	10/22/10
Comments due to SAIC	11/12/10
Phase III Results Briefing	Nov 2010
Final Phase III Report	12/3/10