U.S. Department
of Transportation
Federal Transit Administration

Regional Transportation Commission of Washoe County Transit Intelligent Transportation System Implementation Evaluation

Report No. FTA-NV-26-7005-2010.1

May 2010

http://www.fta.dot.gov/research

REPORT DOCUMENTATION PAGE			Form Approved *OMB No. 0704-0188*
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE May 2010	3. REPORT TYPE AND DATES COVERED 2002 – 2007	
4. TITLE AND SUBTITLE Regional Transportation Commission of Washoe County Intelligent Transportation System Implementation Evaluation Study			5. FUNDING/GRANT NUMBER NV-26-7005
6. AUTHOR(S) Tina Wu, Matt Weatherford, Ancila Kaiparambil, Linna Zhang			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Regional Transportation Commission, Washoe County 2050 Villanova Drive Reno, NV 89502			8. PERFORMING ORGANIZATION REPORT NUMBER FTA-NV-26-7005
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Charlene Wilder, charlene.wilder@dot.gov, 202-366-1077 Federal Transit Administration U.S. Department of Transportation 1200 New Jersey Avenue, SE Washington, DC 20590 Website [http://www.fta.dot.gov/research]			10. SPONSORING/ MONITORING AGENCY REPORT NUMBER FTA- NV-26-7005-2010.1
11. SUPPLEMENTARY NOTES.			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Available From: National Technical Information Service/NTIS, 5285 Port Royal Road, Springfield, Virginia 22161. Phone 703.605.6000, Fax 703.605.6900, Email [orders@ntis.d.gov]			12b. DISTRIBUTION CODE TRI-11
13. ABSTRACT (Maximum 200 words) This report documents the evaluation of the procurement, implementation and operation of Transit Intelligent Transportation Systems (ITS) in Washoe County, Nevada, from the perspective of the deploying agency. The purpose of the document is to provide insight and lessons learned to other agencies considering the deployment of Transit ITS to improve system efficiency, customer service and safety.			
14. SUBJECT TERMS Intelligent Transportation Systems, Advanced Public Transportation Systems, System Evaluation, Automated Vehicle Location			15. NUMBER OF PAGES 105 16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500 Prescribed by ANSI Std. 239-18298-102 Standard Form 298 (Rev.02-89)

U.S. Department of Transportation

Federal Transit Administration

Regional Transportation Commission of Washoe County
Transit Intelligent Transportation System
Implementation Evaluation Study

May 2010

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Report No. FTA- NV-26-7005-2010.1

Sponsored by:

Federal Transit Administration
Office of Research, Demonstration and Innovation
U.S. Department of Transportation
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Washington, DC 20590
Available Online
[http://www.fta.dot.gov/research]

FOREWORD

In 2000, the Regional Transportation Commission (RTC) of Washoe County, Nevada, began planning and designing a comprehensive Intelligent Transportation System (ITS) for its transit services. RTC sought a system that could meet the following goals:

1. Make public transit more attractive to the general population
2. Maximize passenger movements
3. Reduce operational costs
4. Reduce emission/energy use
5. Improve transit system safety
6. Increase awareness of ITS benefits

RTC completed the installation, testing and acceptance of its transit ITS in 2007. The system was deployed for fixed-route and paratransit operations. The transit ITS included the following major features:

- Automatic Vehicle Location (AVL) on approximately 147 fixed-route, paratransit and supervisor vehicles
- Transit Signal Priority (TSP) installed on at least 56 fixed-route vehicles, but not yet operational at the signals
- Automatic Passenger Counters
- Computer-Aided Dispatch
- Transit Signal Priority
- Real-time traveler information

This report provides an evaluation of the RTC transit ITS. It describes the transit ITS as it was planned and as it was deployed, the planned and existing system interactions, the functions of the system components and how RTC staff use them. The report evaluates how well transit ITS meets RTC's goals, both in quantifiable terms and in the perception of RTC staff. It also describes the lessons learned by RTC and analyzes the deployment and operation in an instructive way for agencies considering similar Transit ITS deployment.

The target audience for this document is public transportation agencies who are considering the procurement of transit ITS. It is written to emphasize the information that may be most valuable to those planning future deployments.

DISCLAIMER/NOTICE

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List of Acronyms

ADA	Americans with Disabilities Act
AED	Automated Engine Diagnostic
APC	Automated Passenger Counter
APTA	American Public Transportation Association
ASA	Automated Stop Announcement
AVL	Automatic Vehicle Location
CAD	Computer-Aided Dispatch
CO_2	Carbon Dioxide
DB	Database
DOS	Disk Operating System
FTA	Federal Transit Administration
FTE	Full Time Employee
FY	Fiscal Year – July 1 to June 30 for RTC
GPS	Geographic Positioning System
GTFS	Google Transit™ Feed Specification
IEEE	Institute for Electrical and Electronics Engineer
ISP	Information Service Provider
ISTEA	Intermodal Surface Transportation Efficiency Act
IT	Information Technology
ITS	Intelligent Transportation System
IVLU	Integrated Vehicle Logic Unit
IVR	Interactive Voice Response
LCD	Liquid Crystal Diode
LED	Light Emitting Diode
MDT	Mobile Data Terminal
OEM	Original Equipment Manufacturer
PC	Personal Computer
PRTT	Priority Request to Talk
RFP	Request for Proposals
RTC	Regional Transportation Commission – Washoe County
RTC ACCESS	RTC’s paratransit service
RTC RIDE	RTC’s fixed-route service
RTT	Request to Talk
TSP	Transit Signal Priority
WLAN	Wireless Local Area Network

ACKNOWLEDGEMENTS

This report presents the results of an evaluation effort undertaken by the Regional Transportation Commission of Washoe County and Iteris, Inc. with sponsorship and funding from the United States Department of Transportation (USDOT) Federal Transit Administration (FTA).

The people who participated directly in this evaluation include the following:
Regional Transportation Commission of Washoe County: Tina Wu, Vonnie Burkhead, RTC Public Transportation, RTC Information Technology, RTC RIDE and RTC ACCESS.
Iteris, Inc.: Matt Weatherford, Ancila Kaiparambil, Linna Zhang.

Project management was provided by Tina Wu of Regional Transportation Commission of Washoe County. Technical and project management support was provided by Matt Weatherford of Iteris, Inc. USDOT project management and direction was provided by Charlene Wilder of the FTA. Local funding match was provided by the Regional Transportation Commission of Washoe County.

SUMMARY

In 1999, the Regional Transportation Commission (RTC) of Washoe County entered into a cooperative agreement with the Federal Transit Administration (FTA) to procure and implement Intelligent Transportation Systems (ITS) for its fixed-route and paratransit services. RTC's Transit ITS project was a multi-year funding project. The total cost agreed to was $4,750,000, with a funding split of 80% federal and 20% local. The objective of the agreement was to achieve the FTA’s Goal #2 at the time: *Improve mobility and accessibility*, through outcome. Goal F: *Employ the latest technology to meet increased needs of mobility and accessibility*.

In 2000, RTC began the procurement process for transit ITS. In 2002, RTC contracted with Trapeze ITS (formerly Siemens VDO and Continental Corporation) to install TransitMaster™, a comprehensive transit ITS. The system was designed for fixed-route and paratransit operations. RTC and Trapeze ITS began implementation in 2002, and fully completed implementation and acceptance testing in 2007. RTC staff and its passengers have become accustomed to the system and its functionality. This independent evaluation compares baseline pre-transit ITS data and post-transit ITS data to measure the quantitative and qualitative impacts the system has had on operational efficiency and how RTC staff perform their responsibilities.

<u>Components of the Planned ITS</u>

The planned ITS deployment included the following major components:

- Automatic Vehicle Location (AVL) on fixed-route, paratransit and supervisor vehicles
- Computer-Aided Dispatch
- Paratransit Scheduling and Reservation Software
- Fixed-Route Scheduling Software
- DataMart™
- Automated Passenger Counters
- Real-Time Traveler Information for Fixed-Route Vehicles
- Remote Engine Diagnostics
- Automated Stop Announcements
- Transit Signal Priority
- Mobile Supervisor

At the time of RTC’s transit ITS deployment a new radio system was also implemented. The new system is used for communicating voice and text from the fixed-route and paratransit transit management centers to vehicles. The following summarizes the descriptions of the system components in **Section 4** of the report.

<u>Automatic Vehicle Location</u>
The AVL installed on each vehicle consists of three major components: a Geographic Positioning System (GPS) antenna, an Integrated Vehicle Logic Unit (IVLU), and a Mobile Data Terminal (MDT). AVL is described in more detail in **Section 4.1**. RTC RIDE vehicle operators believe the AVL system has improved their ability to provide customer service. The ability to text message has made tracking messages easier and reduced voice traffic. RTC ACCESS vehicle operators believe the AVL has greatly improved their ability to do their jobs. The MDT allows them to receive, acknowledge and send messages, including the manifest of scheduled trips. It has greatly reduced voice communications and provided them with a more accurate and updateable means for tracking trips than paper manifests. Until

recently, on-street supervisors used the MDT to track vehicles in service. They believed the system was useful, but provided limited information for their purpose. They have recently transitioned to mobile laptops running a modified version of the dispatch center Computer-Aided Dispatch (CAD) application.

Computer-Aided Dispatch

CAD provides the RTC RIDE and RTC ACCESS dispatch centers with fleet management, real-time display of AVL, schedule adherence, event playback, emergency alarm monitoring, text messaging, transfer coordination, work-force automation, incident reporting, vehicle monitoring, and off-line report generation. The CAD primarily consists of a mapping tool, fleet management tools, and playback functions for reviewing past events. It is described in more detail in **Section 4.2**. RTC RIDE dispatchers are very satisfied with the CAD and believe it gives them much more control over on-street activities. The most appreciated functions are the ability to see real-time vehicle locations and exchange messages with vehicle operators via text. RTC ACCESS dispatchers are also very satisfied with the CAD. They use it to track vehicles and exchange messages. They also use it to provide instructions to drivers. RTC RIDE customer service uses the CAD to track vehicle locations upon customer request, review customer complaints, and to exchange messages with vehicle operators regarding items left on vehicles. RTC RIDE supervisors believe the CAD has significantly improved their ability to manage the fixed-route fleet. They are able to track vehicles, check schedule adherence and exchange messages regarding schedule and route adherence. RTC RIDE administration uses the CAD to review schedule adherence, complaints and grievances. Due to labor rules, the CAD cannot be used as evidence in a disciplinary review of an operator.

Paratransit Scheduling and Reservation Software

RTC ACCESS uses Trapeze™ for paratransit reservation and scheduling. The software provides the following scheduling and dispatch functions:

- Automatically generate and optimize schedules
- View detailed itineraries including pick-ups, drop-offs and times for each run
- Calculate accurate times of arrival
- Monitor and adjust service in real-time
- Estimates trip distances
- Track incidents, cancellations and no-shows instantly

The Trapeze™ software is described in more detail in **Section 4.3**. Both RTC ACCESS reservationists and dispatchers are generally satisfied with the Trapeze™ software. They were using a previous version of Trapeze™ prior to this implementation, and the upgrade did not significantly impact how they perform their jobs. When directions are needed, they use the TransitMaster™ CAD workstation to get them, and then enter them into the trip manifest for the operator through Trapeze™. The ability of Trapeze™ to automatically generate trip manifests is considered very good by the reservationists.

Fixed-Route Scheduling Software

RTC RIDE uses the HASTUS™ software package by GIRO Inc. for fixed-route scheduling and operations. It contains a routing, scheduling, vehicle assignment, bus stop and bid database. The HASTUS™ software is described in more detail in **Section 4.4**. While the HASTUS™ fixed-route scheduling software is capable of developing and optimizing schedules, RTC RIDE continues to manually develop schedules using a spreadsheet. Because RTC RIDE staff are satisfied with their current scheduling process, they do not expect to transition to fully using HASTUS™ for scheduling in the near future.

DataMart™

DataMart™ is the AVL/CAD reporting database, which is populated with real-time data from the system using a Data Staging Service. The automated service extracts, transforms and loads transit data into the system database in a way that can be easily extracted for analysis and reporting. It is used by RTC to generate data on operations performance, route and run data. Passenger counts are also reported through the DataMart™. It is described in more detail in **Section 4.5**.

RTC scheduling staff believe DataMart™ saved them "vast amounts of time" in performing data analysis. However, the "canned" Crystal Reports queries that were provided with the system have been found to be inadequate. As a result, RTC has hired a contractor to develop customized reports using Crystal Reports to make better use of DataMart™.

Automated Passenger Counters

The Automated Passenger Counter (APC) is a device that automatically counts passenger boarding and alighting at stops. The APC core components are the APC module, infrared receivers and transmitters, and the standard integrated mobile equipment including the IVLU and the MDT. APC is described in more detail in **Section 4.6**. RTC planning and scheduling staff have been slow to adapt to the data collected through the ITS into its processes; however, the APC data has been used and is considered very valuable for planning facilities. By having passenger boarding and alighting counts for each stop on each route, the planning staff are better able to determine where benches, shelters, trash cans and other facilities should be placed.

Real-Time Traveler Information for Fixed-Route Vehicles

Traveler information display signs are available at RTC CITICENTER to inform bus riders of scheduled bus departure time and the operational status of RTC RIDE services. These signs are dynamic and report the time until the next bus arrives or departs in minutes, based on the actual bus schedule performance. The display configuration consists of two screens and a personal computer (PC). The Real-Time Traveler Information system is described in more detail in **Section 4.7**. Before implementation of the system, passengers often asked customer service about bus schedules. Customer Service staff used the printed schedule book to estimate when a bus would arrive. Customer Service staff state the real-time signs reduce the number of questions and provide more accurate information.

Remote Engine Diagnostics

The Remote Bus Engine Diagnostic System is a test and diagnostic tool that provides automatic inspection and detection of bus health status. It reports to the RTC RIDE staff when a vehicle engine sensor detects a problem. The system is described in more detail in **Section 4.8**. RTC RIDE Maintenance staff are very satisfied with the system. They use the information to determine whether a vehicle should be taken out of service, receive immediate repair on street, let the fault be addressed at the end of a run, or be resolved by the vehicle operator. The RTC RIDE Maintenance staff are very satisfied with the system. They indicated the system is always correct when sending an error code. Knowing the exact nature of an engine failure has resulted in Maintenance staff being able to keep 50% to 60% of vehicles on the street that would have been brought into the maintenance yard before remote engine diagnostics.

Automated Stop Announcement

RTC RIDE vehicles are equipped with the American with Disabilities Act (ADA) compliant Trapeze ITS Automated Stop Announcement (ASA) system. The system provides passengers with vehicle route and stop information and other information, such as rules and rider instructions. Messages are delivered visually through interior Light Emitting Diode (LED) signs, and audibly through announcements broadcasted through the vehicle speakers. The system is described in more detail in **Section 4.9**. RTC RIDE vehicle operators are generally satisfied with the automated stop annunciation system. They believe it has helped them perform their jobs better by providing audible and visual displays of stop locations.

Transit Signal Priority

RTC planned for Transit Signal Priority (TSP) in its ITS procurement and has equipped 56 of its fixed-route vehicles with the Opticom Infrared TSP hardware. The agency has not deployed TSP at any intersections in the Reno-Sparks area and, therefore, RTC's TSP is not currently operational. The planned TSP is described in more detail in **Section 4.10**.

Mobile Supervisor

The Mobile Supervisor is a module that serves as a mini-dispatch suite running on a laptop computer mounted within the supervisor vehicle. It is connected to the AVL/CAD system through a high-speed wireless connection. The Mobile Supervisor Module displays a digital map with vehicle locations, very similar to the CAD workstation used by the off-street supervisors and dispatchers. The purpose is to allow field supervisors to monitor vehicles in real-time. At the time of this evaluation, the Mobile Supervisor was not operational. RTC has since enabled some mobile supervisor functionality, but it is not discussed in this report. The planned Mobile Supervisor system is described in detail in **Section 4.11**.

ITS Implementation Goals

The following summarizes the ITS implementation goals and the findings in **Section 6** of the report that document how RTC achieved those goals through transit ITS.

1. Make public transportation more attractive to the general public.
   - Since AVL data has been used to track fixed-route schedule adherence, on-time performance is documented between 86% and 88%.
   - Since FY2006, fixed-route vehicles have experienced a 50% decrease in missed trips due to mechanical reasons.
2. Maximize passenger movements.
   - Ridership on fixed-route services rose between FY2002[1] and FY2008 by 10.8%.
   - From 2002 to 2007, paratransit ridership has increased by 5.1%.
   - Paratransit trip "no-shows" have dropped 45% between FY2005 and FY2008.
3. Reduce operational costs.
   - The size of the planning, administrative and management staffs at RTC ACCESS and RTC RIDE have stayed constant, despite the increase in passenger trips provided.
   - Fixed-route operating costs increased by 64% between 2002 and 2007, and operating cost per passenger trip increased 48%.
   - Paratransit operating costs have increased by 30% between 2002 and 2007, and operating cost per passenger trip have increased by 23%.
   - Overtime operating hours dropped 30% between FY2005 and FY2008.
4. Reduce emissions/energy use.

[1] The RTC Fiscal Year is from July 1 to June 30. FY2002 is July 1, 2001 to June 30, 2002.

- The increased transit usage in Washoe County between 2002 and 2007 potentially saved 9.37 million personal vehicle miles, and the resulting estimated total fuel cost savings for this period is estimated be as high as $1.37 million.
- The potential total CO_2 emission reduction in the Reno-Sparks area from increased transit usage is estimated to be as high as 4,252 metric tons.

5. Improve public transportation safety.
   - Since FY2006, RTC RIDE has experienced a 50% decrease in missed trips for mechanical reasons.
6. Increase the awareness of ITS benefits.
   - Since FY2002, customer complaints per 1,000 passengers for paratransit service has decreased by 45%.
   - Calls requesting traveler information have increased by approximately 15% since 2006.

In some cases, the above findings are mitigated by other factors that are described in the full Evaluation Report; however, the findings represent the quantitative findings of the study that may be a result in full or in part of transit ITS.

Lessons Learned

During the planning, procurement, implementation and operation phases of RTC's transit ITS project, the agency gathered considerable knowledge and lessons learned. A brief summary of the lessons described in **Section 7** of the report are:

- **Planning**
  - Select an Agency Project Manager with the Right Skill Set.
  - Identify Champions to Represent Each User Group in the Agency.
  - Know the Limitations of Your Agency's Labor Contracts.
  - Conduct a Review of Your Existing Technologies.
- **Procurement**
  - The Agency Project Manager Should be a Single Point of Contact for the Contractor.
  - Demand Consistent Support from the Contractor.
  - Review Your Requirements One Last Time Before Requesting Proposals.
  - Independently Procure Computer and Network Hardware When Feasible.
  - Procure the Right-Sized Systems.
  - Plan for Operations and Maintenance Costs.
- **Implementation**
  - Require the Contractor to Remain On-site After Installation.
  - Prepare Agency Staff for the Implementation Process.
  - Involve Maintenance and IT Staff in the Installation Process.
  - Seek a Contractor who Supports an Original Equipment Manufacturer (OEM) Process for Equipping New Vehicles.
  - Maintain an Asset Management List That Details New IT Inventory.
  - Implementation Can Be Simplified by Procuring All New Hardware and Software.
- **Ongoing Operations**
  - Do Not Expect to Observe Staff Reductions.
  - Have or Obtain the Ability to Customize Reports.
  - Have an Independent Dialog with Other Agencies Using the Same Contractor.
  - Encourage Creative Uses of Transit ITS.
  - Allow Supervisors to Use the AVL System.
  - Continue Learning and Training.
  - Ensure Your System's Critical Components Can Be Maintained Locally.

- Purchase Monitoring Software to Track the Health and Activities of the Transit ITS Servers.
- Expect the Agency's IT Budget to Increase.
- Budget for Onboard ITS Hardware Component Upgrades.

All groups of RTC staff that were interviewed for this report expressed satisfaction with the transit ITS. While the system has shown limited success in achieving RTC's goals, the technology positions RTC to effectively manage its fleet and efficiently increase and improve its service as transit demand grows. It is expected that RTC will experience significant benefits and further achieve its goals from transit ITS in the future.

1. REPORT CHAPTER SEQUENCE

The Regional Transportation Commission (RTC) of Washoe County Transit Intelligent Transportation System (ITS) Implementation Evaluation Report is comprised of eight chapters in addition to this chapter describing the Report contents.

Chapter 2 provides an overview of the operations of RTC. It discusses the vehicle fleets, facilities and services provided by RTC. The chapter also provides a brief overview of the agency's transit ITS project.

Chapter 3 discusses RTC's transit ITS planning, procurement, implementation and operations process. It provides a timeline of RTC's process from initial planning to full deployment, and discusses the actions taken and decisions made by the agency, consultants and system vendor that resulted in the as-built system.

Chapter 4 summarizes the transit ITS system as planned and as actually operated by RTC. A summary of each ITS component is provided that includes a description of the planned and actual components, a graphical depiction of the component elements and their planned and actual data flows, a mapping of the component to the national ITS architecture, a description of how the component addresses RTC's ITS goals, and a summary of how RTC uses the component.

Chapter 5 discusses the architecture of RTC's transit ITS. It summarizes the components of the system in terms of ITS architecture, including data flows and ITS market packages.

Chapter 6 evaluates how the ITS implementation has helped RTC achieve its goals. The evaluation includes a summary of key trends and discusses factors that may mitigate the findings.

Chapter 7 summarizes the key lessons learned by RTC through the ITS planning, procurement, implementation, and operations phases. The lessons learned focus on sharing the knowledge gathered by RTC with other agencies who have deployed, or are considering deploying, transit ITS.

Chapter 8 concludes the evaluation. It looks forward to how RTC may use the transit ITS in the future and discusses the overall impact of transit ITS on RTC and its customers.

2. INTRODUCTION

RTC is responsible for the planning of public transportation services in Washoe County. Public transportation services provide critical mobility to many transit-dependent and transportation-disadvantaged in the community. In addition, public transportation provides an alternative to the private vehicle, thus potentially reducing traffic congestion and air pollution.

RTC provides public transportation service to the greater Reno/Sparks area with RTC RIDE fixed-route service and RTC ACCESS paratransit service. Currently, RTC RIDE and RTC ACCESS have separate dispatch facilities and operations. The subsections below provide a detailed description of each service.

2.1 RTC RIDE

Figure 2.1 RTC RIDE Bus

RTC RIDE is a public fixed-route transit service owned and operated by the RTC. Today, the system encompasses the cities of Reno and Sparks, and other areas of Washoe County, using a fleet of 75 buses on 32 routes. It services approximately 58 square miles.

There are three major transfer stations within the RTC RIDE system: RTC CITICENTER, RTC CENTENNIAL PLAZA, and the Meadowood Mall. RTC CITICENTER transit center is located at the southwest corner of Fourth Street and Center Street in downtown Reno. It can accommodate up to 16 buses at any given time and is served by 19 RTC RIDE routes. Approximately 88% of all passenger transfers occur at RTC CITICENTER. Passenger amenities include two enclosed buildings with information services, passenger waiting areas, restrooms and telephones. RTC CENTENNIAL PLAZA transit center is located in downtown Sparks. It is served by seven RTC RIDE routes. The Meadowood Mall transfer station is located approximately 4.5 mile south of RTC CITICENTER along Virginia Street at the Meadowood Mall. It is also serviced by seven RTC RIDE routes.

The new transfer center, RTC CENTENNIAL PLAZA in Sparks, opened in October, 2008. RTC is also developing a new transit center for downtown Reno (RTC 4TH STREET STATION). The new center will be relocated and expanded from the current transit facility in order to improve bus operations, prepare for future growth, and support and enhance the transit experience. Both locations will have joint development retail opportunities for passengers and passerbys.

RTC RIDE service is provided on most routes between 5:30 am and 7:30 pm, seven days a week, with peak headways (frequencies) ranging from ten minutes to sixty minutes. RTC RIDE currently provides four types of fixed-route service:

- Radial routes serve major passenger generators. RTC RIDE currently has 19 radial routes originating at the RTC CITICENTER transfer station in downtown Reno.
- Collector routes provide service between transfer points and outlying areas. RTC RIDE currently operates three collector routes.
- Cross-town routes are designed to minimize the need to transfer and save on travel time. RTC RIDE currently operates one cross-town route.
- Special temporary service is provided for special or seasonal events or activities such as the Great Reno Balloon Race in September and Hot August Nights.

RTC RIDE fares can be paid with cash or passes through the bus onboard farebox. **Table 2-1** below summarizes the type of fares of the RTC RIDE service. As shown in the table, transfers are free and discounted fares are provided to youth, seniors, and people with disabilities. Pass vending machines are available at the transit stations for the purchase of passes with cash, debit or credit cards. The 24-hour passes can also be purchased onboard on all RTC RIDE buses at the time of boarding.

Table 2-1: Summary of RTC RIDE Service Fare

	Adult	Youth (6-18)*	Senior (60+)*	Disabled/ Medicare*	ACCESS on RIDE	Children age 5 and under	Transfers
Cash Fare	$2.00	$1.25	$1.00	$1.00	50¢	FREE	FREE
Passes							
24-Hour	$5.00	$3.00	$2.50	$2.50	N/A	N/A	N/A
7-Day	$21.00	$13.00	$10.50	$10.50	N/A	N/A	N/A
31-Day	$70.00	$44.00	$35.00	$26.00	N/A	N/A	N/A
10-Ride	$17.00	$10.50	$8.50	$8.50	$5.00	N/A	FREE

In the 12-month period ending July 2008, RTC RIDE carried over 9 million passenger trips. On an average weekday, RTC RIDE handled over 26,000 passenger trips. Approximately 24% of these trips are made by senior citizens or people with disabilities; and 13% of the trips are made by youth. More than half of the trips on RTC RIDE are people going to or from work. According to 2000 Census data and the RTC forecasting tool, RTC RIDE carried approximately 3.5% of the total work trips in the region. This percentage is higher to downtown Reno and Sparks, where transfer centers (RTC CITICENTER and RTC CENTENNIAL PLAZA) are an effective and convenient hub for downtown employees and visitors. **Table 2-2** summarizes key system performance indicators for RTC RIDE for FY2008.

Table 2-2: RTC RIDE System Performance Indicators

Performance Measure	Jul '07-Jul '08
Annual Ridership	9,056,533
Revenue Hours	288,661
Revenue Miles	3,613,707
Passengers/Revenue Hour	31.4
Passengers/Revenue Mile	2.5
Total Operating Cost	$ 28,332,423
Cost/Revenue Hour	$98.15
Cost/Revenue Mile	$7.84
Total Revenue	$6,027,247
Farebox Recovery Ratio	21.3%

Source: RTC Transit Operating Statistics, July 2008

2.2 RTC ACCESS

Figure 2.2 RTC ACCESS Van

RTC ACCESS provides prescheduled, demand-responsive, door-to-door transportation for all individuals with disabilities who are certified as eligible under the provision of the Americans with Disabilities Act (ADA). RTC ACCESS has been in operation since 1988. RTC ACCESS currently has a fleet of approximately 50 paratransit vans servicing a 250 square mile area, including the Reno-Sparks area of Washoe County. Within that is an area of approximately 100 square miles known as the "ADA Service Area" that is within ¾-mile of the RTC RIDE bus routes. RTC ACCESS administrative offices and operations are located at 600 Sutro Street in Reno.

RTC ACCESS operates 24 hours a day, 365 days a year, in compliance with ADA regulations. Trips within the ADA Service Area have priority and may be scheduled one to three days in advance. Passengers requiring fixed-schedule service may request subscription service, which has limited availability.

RTC ACCESS fare is paid by ticket only. RTC ACCESS fares are summarized in **Table 2-3** below. Tickets are also sold in books of 10 with a price of $17.50. Tickets may be purchased at more than 30 outlets or by mail.

Table 2-3. Summary of RTC ACCESS Service Fare

RTC ACCESS	ADA Zone	Non-ADA Zone
Base Fare	$1.75	$3.50
Will-Call Fare	$3.50	$7.00
Companion Fare	$1.75	$3.50
Authorized Attendant	FREE	FREE

RTC ACCESS provides approximately 237,000 annual trips to eligible residents in Washoe County. RTC ACCESS is generally in compliance with all the ADA requirements, with the exception of trip denials. **Table 2-4** summarizes key system performance indicators for RTC RIDE for FY2007.

Table 2-4: RTC ACESS System Performance Indicators

Performance Measure	Jul '06-Jul '07
Annual Ridership	247,218
Revenue Vehicle Hours	88,320
Passengers/Revenue Hour	2.63
Complaints per 1,000 Passengers	0.80
ADA Capacity Denials	8*
Other Denials	2,661
Accidents per 100,000 Miles	2.31
On-Time Performance	95.3%
Net Operating Cost/Passenger Trip	$24.80
Net Operating Cost/Passenger Mile	$3.56
Total Operating Cost	$6,131,006

* - *RTC ACCESS has had no additional denials since September 2007.*

The RTC ACCESS service is currently supported by a private contractor, MV Transportation, through a federally-funded project which is re-solicited every five years. MV transportation has been RTC's contractor for RTC ACCESS since 2004.

2.3 Washoe County Demographics

The demographics of Washoe County play a significant role in the evaluation of data. Changes in population, employment, geographic distribution of population and income may be variables in determining the reasons for changes in transit use. This section provides a brief summary of the demographics of the area served by RTC.

2.3.1 Population

Per the U. S. Census Bureau, Washoe County had a population of 396,428 as of 2006. Over 50% of the County's population lives in the City of Reno. **Table 2-5** summarizes the change in overall population for the County and for the City of Reno.

Table 2-5: Population Demographics for Washoe County

Location	Population			People per Square Mile	
	2000	2006	% Change	2000	2006
Washoe County	339,486	396,428	16.8%	53.5	62.5
Reno	180,480	210,255	14.8%	2612	3047
Sparks	66,346	83,959	26.6%	2774	3651

Washoe County is a largely rural county. Reno and Sparks comprise 1.5% of the area and are home to 74% of the County's residents.

2.3.2 Employment and Economics

Compared to national statistics, Washoe County has experienced average to better-than-average employment over the past decade. **Table 2-6** summarizes the employment and economics of the County.

Table 2-6: Population Demographics for Washoe County

Location	Unemployment			Median Income per Household	
	2000	2006	% Change	2000	2006
Washoe County	5.0%	3.9%	-1.1%	$45,815	$56,839 (2007)
Reno	3.8%	3.9%	0.1%	$40,500	$53,390 (2005)
Sparks	2.9%	3.9%	1.0%	$45,475	$51,413 (2007)

2.3.3 Future Growth

Washoe County has seen consistent growth over the last decade in both population and employment. Between 1990 and 2000, the U.S. Census showed the county population increased from 254,000 to 340,000, a 3.0% per year increase. During this same time, employment increased from 132,000 to 188,000, a 3.7% per year increase.[2] **Table 2-7** lists population and employment forecasts for Washoe County for the years 2007, 2012, 2020 and 2030. The projections of future growth are based upon the Washoe County Consensus Forecast adopted in 1993 and revised annually. The 2030 population and employment forecasts represent completion of the master-planned and approved development as provided by the Cities of Reno and Sparks and Washoe County. Population and employment are expected to grow

[2] *Washoe County 2030 Regional Transportation Plan*

by 3.4% per year and 3.6% per year, respectively, over the 30-year period of the Regional Transportation Plan (2030). The population and employment growth projected from year 2007 to 2030 is approximately 80% and 83%, respectively.

Table 2-7: Projected Population & Employment Growth Between 2000 and 2030

Year	2007	2012	2020	2030	Projected Percent Increase from 2007 - 2030
Population	379,518	493,996	583,327	682,619	79.86%
Employment	218,593	295,989	362,168	400,694	83.31%

2.4 RTC Transit ITS Implementation

RTC completed the installation, testing and acceptance of a comprehensive transit ITS in 2007. The system was deployed for fixed-route and paratransit operations. The transit ITS included the following major features:

- Automatic Vehicle Location (AVL) on approximately 147 fixed-route, paratransit and supervisor vehicles
- Transit Signal Priority (TSP) installed on at least 56 fixed-route vehicles, but not yet operational at the signals
- Automatic Passenger Counters
- Computer-Aided Dispatch
- Transit Signal Priority
- Real-time traveler information

Other features of the transit ITS include a new radio system for the base station and all vehicles, remote engine diagnostics, automated stop annunciation on fixed-routes, new scheduling software for fixed-route operations, automated paratransit scheduling, management and manifests.

RTC's six goals of the ITS Technologies Implementation were to:

1. Make public transit more attractive to the general population
2. Maximize passenger movements
3. Reduce operational costs
4. Reduce emission/energy use
5. Improve safety of transit system
6. Increase awareness of ITS benefits

The RTC goals align with the following goals and objectives of the Federal Transit Administration's (FTA) Strategic Research Plan developed in 2005.

FTA Strategic Research Goal #2: Increase Transit Ridership.

Objective #2.1 Identify best practices and technologies to increase transit ridership.

Objective #2.4 Identify and overcome barriers to the adoption of ridership enhancement techniques.

FTA Strategic Research Goal #3: Improve Capital and Operating Efficiencies.

Objective #3.3 Identify methods and technologies to improve transit operating efficiency.

FTA Strategic Research Goal #4: Improve Safety and Emergency Preparedness.

Objective #4.1 Identify solutions to improve transit safety.

FTA Strategic Research Goal #5: Protect the Environment and Promote Energy Independence.

Objective #5.1 Facilitate development of technologies to improve energy efficiency and reduce transit vehicle emissions.

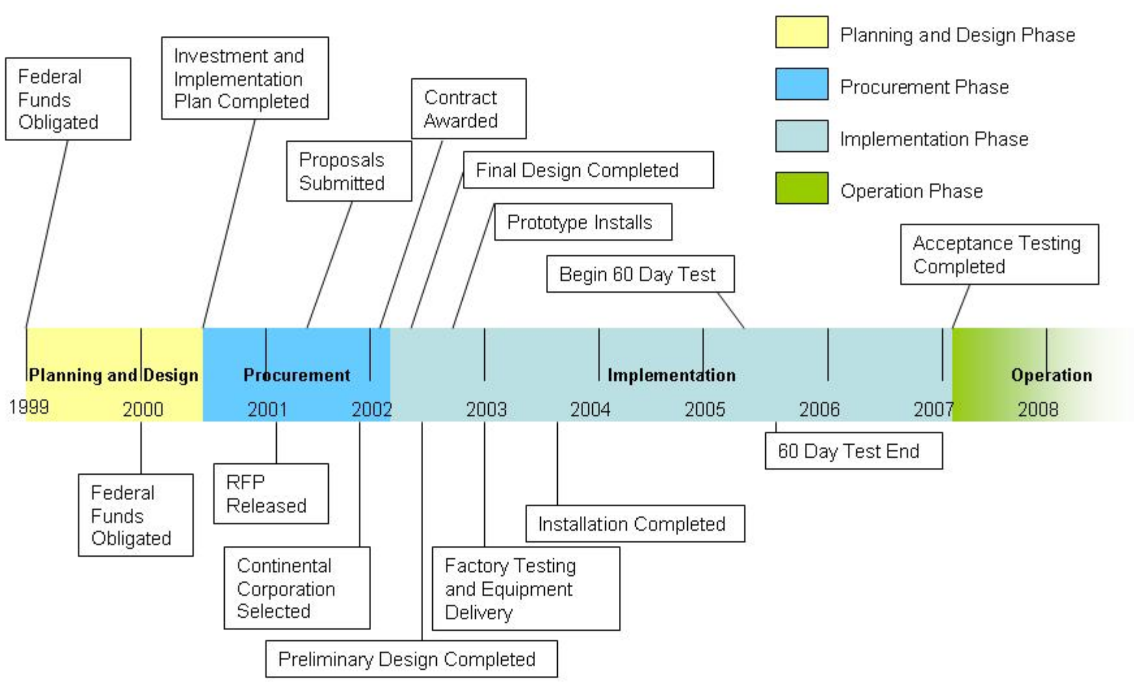
RTC contracted with Iteris, Inc. to perform an evaluation of the transit ITS using the guidelines established in FTA Circular 6100.1C, Chapter 3, Section 6. This Report documents the findings of the evaluation.

3. RTC TRANSIT ITS IMPLEMENTATION PROCESS

RTC began its process to start the installation of transit ITS in 2003. The agency accepted the deployed system in 2007. As is typical for large and complex deployments, the agency experienced setbacks and changes in design and implementation during the deployment process. This section discusses each phase of the deployment process, the RTC staff involved, how decisions were made and subsequent impacts.

Figure 3-1 is a timeline of the major milestones in RTC's transit ITS deployment process.

Figure 3-1: RTC Transit ITS Deployment Timeline



3.1 System Planning

In 1998, RTC was identified in the Intermodal Surface Transportation Efficiency Act (ISTEA) as an ITS federal grant recipient. The total funding was $5,468,750, with 80% of that federal funds and 20% local match. At the time, RTC had not identified specific ITS to be deployed; however, the agency was aware of the potential for ITS in transit operations. RTC hired a consultant team to develop an investment and implementation plan. The emphasis of the plan was to focus on a need-based approach and develop a plan that met the agency's goals. RTC seeks to utilize proven technologies to meet its needs. The agency's philosophy is to be on the "cutting edge", not on the "bleeding edge". The six goals defined in that plan have remained constant throughout deployment and operation. They are:

1. Make public transit more attractive to the general population.
2. Maximize passenger movements.
3. Reduce operational costs.
4. Reduce emission/energy use.
5. Improve transit system safety.
6. Increase awareness of ITS benefits.

A wide range of ITS was initially considered and narrowed down to technologies that could most effectively achieve the six goals. In recognition that not all desired technologies could be procured with the available funding, RTC worked with the consultant team to develop a phased deployment plan. The plan, completed in June, 2000, identified the following technologies for the first phase of deployment (0 to 18 months):

- Automatic Vehicle Location with Computer-Aided Dispatch for fixed-route and paratransit operations
- Dynamic bus stop signage at RTC CITICENTER and RTC CENTENNIAL PLAZA
- On-board automated stop announcements

Each of these technologies has been procured and deployed, with the exception of dynamic signs at RTC CITICENTER and RTC CENTENNIAL PLAZA. Elements of the second phase (18 months to five years) that have also been deployed are:

- Automated passenger counters
- Remote engine diagnostics
- Transit Signal Priority (procured and not deployed)

3.2 Transit System ITS Design and Procurement

After completion of the investment and improvement plan, RTC hired a consultant team to help develop the specifications for the desired system and produce a Request for Proposals (RFP). The development of the RFP took four months and the RFP was issued in January, 2001. Tina Wu, a Senior Planner with RTC, managed the project for RTC.

The RTC approach under Ms. Wu was to develop the RFP with the input and support of many members of RTC's staff. While the investment and implementation plan established the types of technologies to deploy, the RFP specified how they would be deployed, interact with other systems, and how RTC staff would use them. In addition to a review of the state of transit ITS, the project got input from staff on their needs. In particular, RTC Information Technology (IT) staff played a critical role in the proposal development. IT staff were responsible for ensuring integration with existing systems and the communications network. IT staff also had a significant role in ensuring that hardware and facilities were available and capable of working with new systems.

Once the RFP was released to potential bidders, the procurement process was delayed due to key staff changes on the consultant team. The consultant project manager was replaced after the RFP's release. The new consultant was initially not prepared to answer the questions of potential bidders. As a result, RTC extended the proposal submittal date. The bidders' proposals were submitted in April, 2001.

The proposal evaluation and selection processes were also slowed due to site visits. Eventually, Trapeze ITS was selected in December 2001, and a contract was signed in February 2002. Some technical specifications in the RFP were outdated due to the elapsed time between the release of the RFP and the signing of the contract. RTC and Trapeze ITS did a "walk through" of the specifications and re-negotiated the computer specifications prior to finalizing the system design. Trapeze ITS completed the preliminary design and documentation of the system in June 2002.

3.3 System Implementation

RTC began to procure computer and network equipment once the system design was accepted. Trapeze ITS set up the equipment and completed factory acceptance testing at its facility in Iowa in January 2003. RTC staff and their consultant were present for the factory acceptance testing. Subsequently, the equipment was delivered and installed at RTC. A description of the impact of equipment delivery and implementation is separated into operations center, vehicle equipment and implementation management.

3.3.1 Operations Center

The delivery and installation of hardware and software was, as expected, a disruptive process. However, RTC noted that disruptions for actual system installation were kept to a minimum.

One advantage the project had was that Trapeze ITS delivered all new hardware, including workstations, servers, routers, and switching equipment. The delivery of all new equipment reduced the need to reconfigure existing hardware to accommodate new systems, or to integrate the TransitMaster™ with legacy systems. It required 50% of the time for two to three members of RTC's IT staff for two months to configure new hardware and modify the existing network.

New hardware at the operations center required one additional rack in the room where RTC houses IT equipment. Because of the heat generated by the new equipment, RTC had to increase the cooling capacity in the room by the addition of a second air conditioner. The air conditioning, racks, energy and facility space are costs that were not considered in the investment planning.

Wireless local area networks (WLAN) were installed in the maintenance yard. It uploads and downloads data from the vehicle In-Vehicle Logic Units (IVLU) when they arrive in the yard. The initial wireless implementation used the proprietary PROXIM wireless technology. The system worked well; however, the proprietary nature of the hardware resulted in a limited availability of replacement parts. RTC has subsequently switched the WLAN to the Institute for Electrical and Electronics Engineer (IEEE) open standard 802.11b, for which parts are more readily available and less expensive.

A Trapeze ITS recommendation for implementation was the addition of subnets in order to separate ITS network traffic from RTC traffic. This required significant IT staff time to accomplish.

At the time of implementation, RTC found that its existing fixed-route scheduling process were not compatible with TransitMaster™. Before procuring TransitMaster™, RTC manually developed its fixed-route schedules in a spreadsheet. At the time of procurement, Trapeze ITS assured RTC that the data from the spreadsheet could be easily imported into TransitMaster's database. Upon implementation, however, RTC could not import the spreadsheet data without an extraordinary investment of manpower. To resolve the issue, RTC and Trapeze ITS agreed that RTC would procure HASTUS™, a commercial scheduling application that does exchange the schedule data with TransitMaster™. RTC and Trapeze ITS agreed to each pay half of the purchase price.

The existing paratransit schedule software, Trapeze PASS DOS™ version, did not interface with the TransitMaster™. As a result, RTC elected to upgrade to a more automated and comprehensive version of Trapeze™ in order to take advantage of TransitMaster's capabilities, including uploading manifests to vehicles and exchanging information about pickups, drop-offs and no shows. Procuring and implementing the new version of Trapeze™ occurred three years after TransitMaster™ was operational.

3.3.2 Vehicle Equipment

In August 2002, Trapeze ITS completed prototype installation of vehicle equipment on all RTC vehicle types. The fixed-route vehicle equipment included:

- In-Vehicle Logic Unit
- Automated Stop Announcement System
- Automated Passenger Counter
- Mobile Data Terminal
- Radio
- Geographic Positioning System (GPS) antenna
- Transit Signal Priority System
- Automated Engine Diagnostics
- Wheelchair Lift sensor

These components are described in **Section 4**.

When ITS was implemented, RTC RIDE added the duties of two master mechanics who are responsible for onboard electronic equipment repair. Their duties include the ITS equipment described here, as well as headsigns, video security systems, radio systems and fareboxes. During hardware installation; however, the two focused primarily on overseeing and supporting the installation efforts.

Trapeze ITS hired private contractors to perform the installation on the fleet of fixed-route vehicles at a pace of two per day. Installations were performed at night, in order to minimize the disruption to daily operations. RTC RIDE staff were present to observe the installations. This has proven to be invaluable experience, because it has allowed RTC RIDE staff to correct installation procedures instantly.

The same contractor performed the installations on paratransit vehicles for RTC ACCESS. The installations were simpler and included:

- In-Vehicle Logic Unit
- Mobile Data Terminal (MDT)
- Radio
- Geographic Positioning System (GPS) antenna
- Wheelchair Lift Sensor

At RTC ACCESS, four to five paratransit vehicle installations were performed each night. RTC ACCESS Maintenance staff observed one night of installations. Initially, RTC ACCESS vehicles had numerous installation issues that disrupted the RTC ACCESS operations due to lack of staff oversight, but the issues were quickly resolved when Trapeze ITS switched to a new installation contractor.

Another component of vehicle equipment, the Mobile Supervisor Module, was not installed, because the software was not fully developed at the time. The Mobile Supervisor Module is described in **Section 4.11**.

3.3.3 Project Management

RTC has maintained the same project manager throughout the procurement and operations processes. The manager, Ms. Wu, has been the point of contact for Trapeze ITS or other vendors involved in the transit ITS project. Trapeze ITS used six project managers and four project engineers during the project. The frequent changes in the vendor's project management are cited by RTC as a cause of delay. With each new vendor project manager or project engineer, it took time for the person to become knowledgeable about the project issues and familiar with RTC staff and resources.

3.4 Training

During system installation, Trapeze ITS also conducted training for RTC. Training consisted of classroom instruction and hands-on practical use of the system components. RTC requested Trapeze ITS provide a "bus-in-a-box", which is a cart containing a working set of vehicle hardware for training. Vehicle operators, supervisors and maintenance staff used the bus-in-a-box during the initial training, and continue to use it for training new staff or testing purposes. The classroom portions of the training were videotaped, and RTC can use a copy for training new staff.

Because training was conducted during implementation, some portions were taught before the corresponding system components were operational. This may have been detrimental to the users' understanding because RTC staff uniformly indicated that real-world application of the system was the most useful training.

Initial training for most groups consisted of two to four days. Most of that time was spent in a classroom. Exceptions were for the information technology, administrative and management staff. IT staff had approximately one week of classroom training and several weeks of on-site practical support during implementation. Administrative and management staff had seven to twelve days of training per person in database management, report generation and HASTUS™. The project manager for RTC has taken part in training in full or in part for each aspect of the TransitMaster™ system, and is responsible for ensuring that RTC staff are properly trained. Ongoing training is done in-house. For both RTC RIDE and RTC ACCESS vehicle operators, the transit ITS is included in new-driver training and takes about two hours.

3.5 Sixty-Day Test

The sixty-day test is intended to represent system stability. It occurs when the vendor and agency believe the system is running reliably and effectively. RTC used the transit ITS in its daily operations while Trapeze ITS resolved any remaining system bugs. The bugs tended to be hardware or vehicle-specific particular to a geographic area the buses travel, or caused by network issues. The sixty-day test is not an acceptance test.

RTC and Trapeze ITS agreed that the system was operating well enough to begin the sixty-day test in 2005. The test was not successfully completed.

3.6 Acceptance Testing

Acceptance testing is conducted in accordance with an Acceptance Testing Plan at the end of the sixty-day test. The plan, written by the vendor, details a series of tests that verify the transit ITS achieves all of the contracted functional requirements. The testing was a final verification for the vendor and agency that the system was operational and correct. Typically, once acceptance testing is successfully completed, the warranty period begins.

Several issues resulted in multiple failures of the acceptance test at RTC. The issues included but were not limited to:

- Messages from RTC ACCESS vehicles were not consistently reaching RTC ACCESS dispatch.
- Some fixed-route vehicle headsigns were not correctly setting and resetting their messages. This means that the customer facing signs on the bus would not refresh to accurately indicate the vehicle's destination.
- Supervisor vehicle MDTs were not able to query the TransitMaster™ main database (RouteManager) to get headway data. There were major radio transmission problems between vehicles and the dispatch center. Operators and dispatchers couldn't hear each other.
- Automated passenger counters were not achieving the target 90% accuracy.
- Transit Signal Priority parameters for vehicle occupancy load were not met.
- RTC CITICENTER real-time information display was not operational.

Each issue was resolved satisfactorily, and the system was accepted in January 2007.

3.7 Transit ITS Operation

While the system was accepted in January 2007, RTC RIDE and RTC ACCESS have been using the system in daily operations since 2003. **Section 4** discusses how each component of the transit ITS is used. This section focuses on the impacts and issues of daily operation for the staff who keep the system operational.

3.7.1 System Maintenance

For vehicle maintenance, two master mechanics have been dedicated to technology maintenance for RTC RIDE. In addition to vehicle ITS equipment, they maintain camera systems, fareboxes and headsigns. The RIDE Maintenance staff estimate that their labor on the transit ITS per year is approximately 1300 hours, or 0.65 Full Time Employee (FTE) equivalent. Maintenance includes:

- Replacing MDTs
- Replacing IVLUs
- Replacing/reprogramming Automated Passenger Counter
- Replacing corrupted IVLU memory cards
- Replacing radio equipment
- Bench testing components before sending them back to the factory

The most labor intensive time of the day for the maintenance staff is at start of the morning shifts when vehicle operators log in and may discover that their memory card is corrupted. This typically would happen on two to three vehicles per day at the beginning of service change, but the situation would usually stabilize after the first week.

RTC ACCESS Maintenance staff have two people performing all vehicle maintenance, including ITS. In general, they spend less than 10% of their time on ITS issues. When an IVLU or MDT is non-operational in a paratransit vehicle, they swap it out for a replacement and send the bad unit to RTC RIDE Maintenance for analysis or return to Trapeze ITS.

3.7.2 Information Technology

Information Technology has been responsible for ensuring the operations center hardware and software are operational. They also maintain the wired and wireless networks used by transit ITS. The IT department added two staff members at the time of transit ITS implementation. However, the addition was made partially to accommodate transit ITS, and partially because of the expanding role of information technology in RTC's daily operations. The IT department estimates that for operations, no more than two hours a week, or 100 hours per year, is spent directly on transit ITS. That time is used to do the following:

- Software installs and system configurations
- Server maintenance
- Scheduled hardware replacement

The labor estimate does not include time spent managing and maintaining the networks.

The IT staff noted that Trapeze ITS does not automate software updates. Although the vendor has remote access to RTC computers, software installations and upgrades still require an RTC IT member to be present to configure the hardware and make modifications.

While no new skills were required for RTC's IT department, staff members noted that the following skills are necessary to manage the IT perspective of transit ITS:

- Strong network management knowledge and experience
- Database management experience
- The ability to configure hardware and systems
- Knowledge of radio systems management
- Knowledge of wireless networking
- Systems security experience and knowledge

3.7.3 Project Management

No additional staff have been hired by RTC to manage the transit ITS. The project manager for RTC is a planner with extensive knowledge of transit operations. Her role in daily operations is to address and resolve issues with the system, either personally, with the help of other RTC staff, or by working with the vendor. The role requires 25% of the manager's time, or approximately 500 hours or 0.25 FTE per year. The remaining 75% of the project manager's time is spent on duties she had previous to becoming the transit ITS project manager.

The job of the project manager on an ongoing basis includes:

- Knowledge of radio system, networking, hardware and software configurations
- Ability to build data files
- Ability to perform database queries and generate reports
- Understanding how transit ITS is used by all other RTC staff
- Communicating with operations staff and RTC management
- Championing transit ITS and commit to resolving issues
- Negotiate with vendors
- Perform training for other staff as needed

On an ongoing basis, perhaps the most important responsibility for the project manager is ensuring that the agency maximizes its benefits from the transit ITS by keeping all staff aware of changes, upgrades and functionalities. Recently, the project manager hired a third-party consultant to develop customized reports that will allow RTC to more easily and effectively mine TransitMaster™ for data.

4. DESCRIPTION OF THE RTC TRANSIT ITS

This section discusses RTC's transit ITS components as they were planned and as they actually are deployed and used. It is intended to provide a basic description of the functions that transit ITS can and does perform. Information on the system will help the reader understand the decisions and issues that resulted in changes between what RTC had specified and what was deployed. It also provides a background for comparison with how the transit ITS was deployed and how it is used by RTC.

The planned components of RTC's transit ITS are:

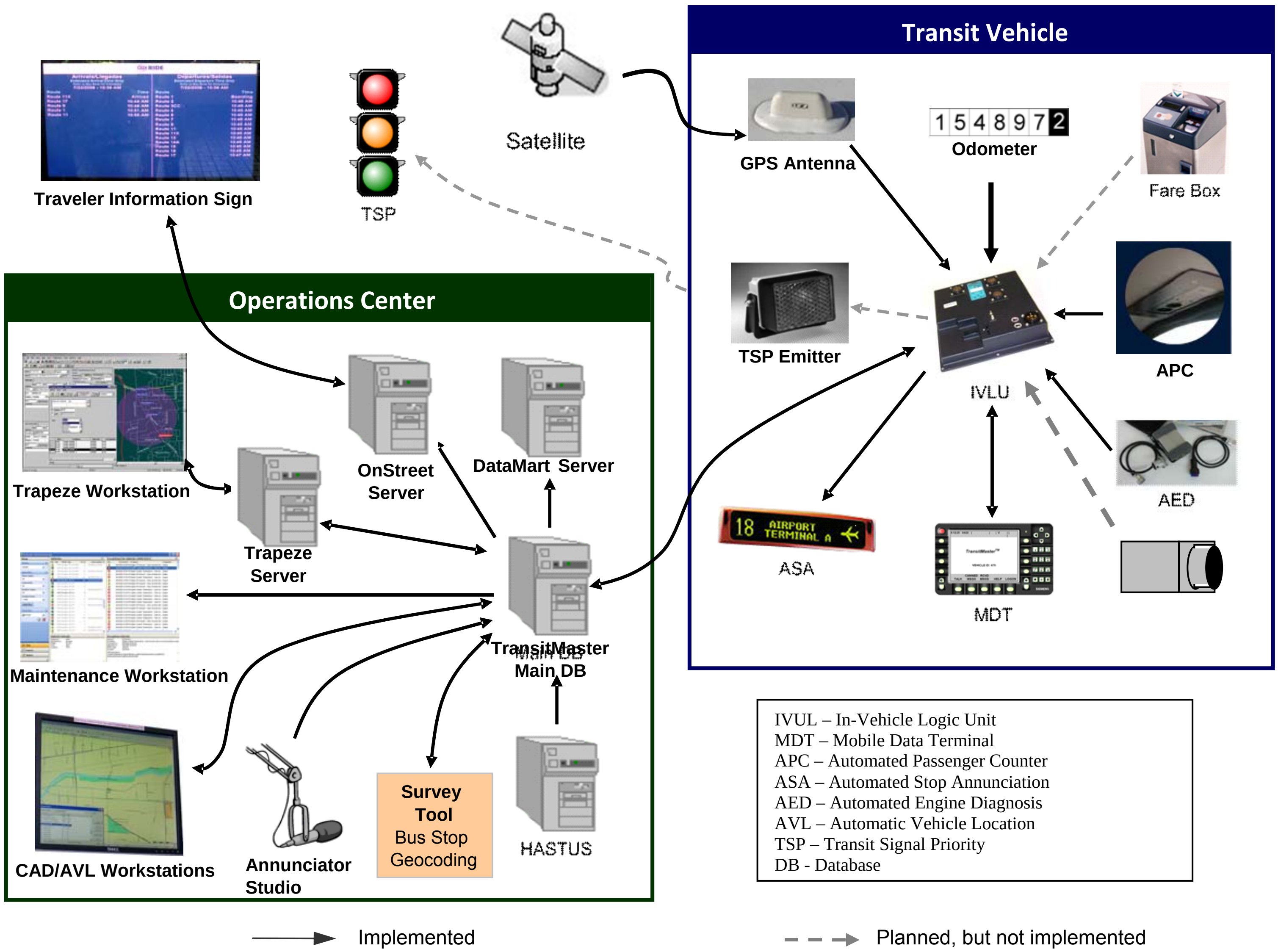
- AVL on fixed-route, paratransit and supervisor vehicles
- Computer-Aided Dispatch
- Paratransit scheduling and reservation software
- Automatic Passenger Counters on fixed-route vehicles
- Remote Engine Diagnostics
- Automated Stop Announcement System on fixed-routes
- Next Arriving Bus real-time notification
- TSP installed on most fixed-route vehicles
- Mobile Supervisor Module, which would provide on-street supervisors with many of the computer-aided dispatch

Components that were added later include:

- Fixed-Route Scheduling Software
- DataMart™ for data analysis and reporting
- Real-time Traveler Information for fixed-route vehicles

Figure 4-1 illustrates the planned interaction of all RTC transit ITS components. It also illustrates the components that have been implemented and are in operation. Following the diagram are summary descriptions of each component interaction.

Figure 4-1: Planned RTC Transit ITS



4.1 Automated Vehicle Location

RTC's AVL is a GPS-based tracking system that can determine the location of equipped paratransit, fixed-route and supervisor vehicles. This information is used for many purposes, including vehicle tracking, schedule adherence, security, and collecting data for planning and scheduling. For the purposes of this study, the AVL system is considered the onboard component of the TransitMaster™ that collects, processes and reports vehicle location information.

The AVL components of TransitMaster™ are GPS-based, and consist of three major onboard components: (1) GPS antenna, (2) IVLU, and (3) MDT.

GPS Antenna - Each fixed-route, paratransit and supervisor vehicle is equipped with a GPS antenna that receives data transmitted from a network of satellites. Each satellite continuously sends the time it was sent from the satellite, which is compared with the time it is received at the GPS receiver to determine the distance the satellites are from the antenna. By simultaneously receiving data from several satellites with known locations, GPS can trilaterate its location. The GPS antenna receives the satellite signals and sends the data to IVLU for processing. **Figure 4-2** shows a typical GPS antenna. It is normally mounted on the top of the vehicle where it will have minimal obstruction in its line-of-sight with the satellites.

Figure 4-2: GPS Antenna

Mobile Data Terminal – **Figure 4-3** shows two MDTs. One is the type initially installed on RTC RIDE and RTC ACCESS vehicles. The other is a newer type being installed at the time of this report. While older MDTs are monochromatic, the newer ones have a color display surrounded by several "smart" keys that can be preprogrammed to perform specific functions. Both have numeric keypads that can be used for logging in and out, among other functions. The functionality and operation of the monochrome and color MDTs are similar.

The MDT is the vehicle operator's interface and is used to enter and receive information about operations. It also is the interface for voice communications, and is connected to the IVLU. The MDT is installed within easy sight and reach of the vehicle operator.

Figure 4-3: Older and Current Mobile Data Terminals

Integrated Vehicle Logic Unit – The IVLU is an Intel Celeron-based on-board processor that contains the onboard system software for managing or processing data from systems such as ASA, APC and AED. The IVLU also includes the embedded GPS processor, radio modem and a WLAN module for uploading and downloading data while in the maintenance yard. The IVLU is connected by wire to other in-vehicle equipment and installed out of sight. **Figure 4-4** shows one similar to those deployed on RTC vehicles.

Figure 4-4: Integrated Vehicle Logic Unit

In addition to connecting the radio and GPS antennas, the RTC IVLU exchanges information with and/or controls the:

- Automated Passenger Counter
- MDT
- Vehicle Engine
- Stop Announcement System
- TSP

The IVLU serves as both the data collector and processor on the vehicle. It sends data to the MDT regarding schedule and route adherence. It also processes data, such as location information, to and from the dispatch center, including text messages and voice communications. For fixed-route stop annunciation, the IVLU determines which announcement to make by comparing the actual location and route pattern to parameters established for each stop announcement.

On board the vehicle, the IVLU uses data from the GPS antenna to calculate the vehicle position. It can be compared to planned schedules and routes to determine route and schedule adherence. That information can be displayed to the vehicle operator through the MDT. The IVLU is in constant communication with the TransitMaster™ application and the database server. Vehicle location data is also transmitted to the dispatch center, where it can be displayed on digital maps on the AVL workstations. The IVLU will also use AVL data to determine the message to display or announce to passengers, and to set the destination signs on the outside of the vehicle. The IVLU is hooked into the vehicle odometers to track and automatically report mileage; however, RTC does not use the data generated as the sole source to report mileage.

Planned connections at RTC that have not been implemented are between the IVLU and the onboard cameras to display exact incident locations, and between the IVLU and fareboxes to display farebox data on the MDT, as well as to exchange data directly with the farebox. The Transit Signal Priority elements for the fixed-route vehicles have been installed but not implemented. When operational, the TSP emitter will be triggered by the IVLU based on parameters, such as predefined passenger load and schedule adherence.

4.1.1 AVL System Interactions

Figure 4-5 shows the planned and implemented system interactions of the AVL technology.

Figure 4-5: Planned System Interactions of AVL Technology

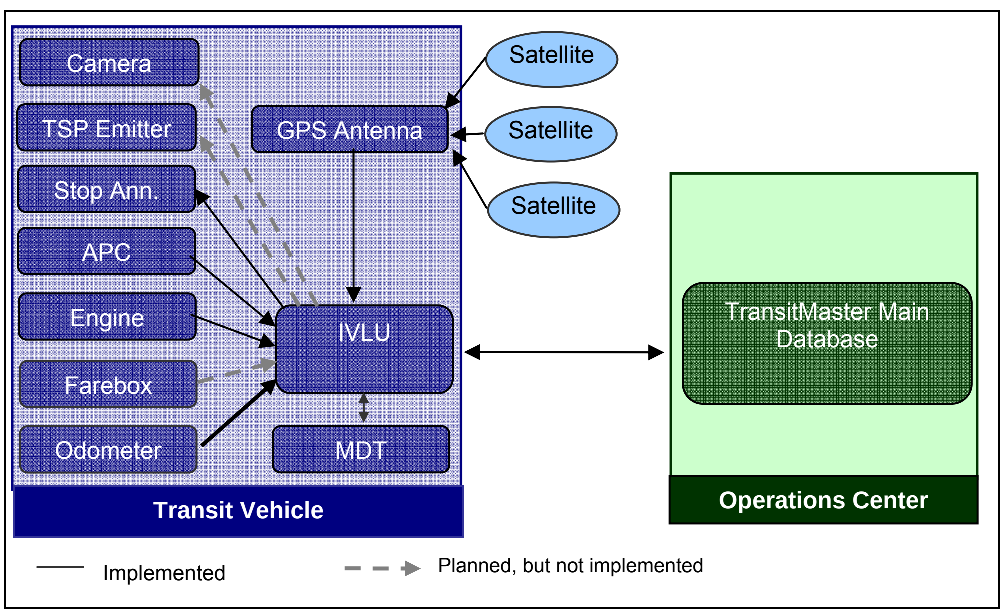


Table 4-1: AVL Technology Data Flows

From Component	Data Flow	To Component
Satellite	Time Data	GPS Antenna
GPS Antenna	Time Data	IVLU
IVLU	Stop Data	Stop Announcement System
APC	Passenger Count Data	IVLU
Engine	Engine Diagnostic Data	IVLU
MDT	Messages, Log-on, Log-off Data, Communications Requests, Passenger Count Data	IVLU
IVLU	Messages, Time, Schedule Data, Schedule Adherence, Route Adherence, Paratransit Manifests Passenger Count Data	MDT
IVLU	Vehicle Location Data, Schedule Adherence, Engine Diagnostic Data, Passenger Count Data, Engine Fault Data	TransitMaster™ Main Database (RouteManager)
TransitMaster™ Main Database (RouteManager)	Messages, Schedule Data, Paratransit Manifests	IVLU
Planned but not Implemented		
Farebox	Fare Collection Data	IVLU
IVLU	Fare Collection Data	MDT
MDT	Fare Collection Data Adjustments	IVLU
Odometer	Mileage Data	IVLU
IVLU	Fare Collection Data	TransitMaster™ Main Database (RouteManager)
IVLU	Mileage Data	TransitMaster™ Main Database (RouteManager)
IVLU	Signal Priority Request	TSP Emitter
Camera	In-vehicle images	IVLU
IVLU	In-vehicle images	TransitMaster™ Workstation

4.1.2 AVL Capabilities

Table 4-2 illustrates how the capabilities of AVL can address RTC's ITS implementation goals.

Table 4-2: AVL Capabilities to Meet RTC Goals

RTC Goal	Technology Capability
Make public transit more attractive to the general population	• By providing real-time, accurate updates on vehicle location through customer service and real-time traveler information signs.
Maximize passenger movements	• By better tracking vehicles and identifying vehicles that are off route or schedule. • By enabling transfer requests among fixed-route vehicles. • By providing more complete and accurate data for planning and scheduling purposes.
Reduce operational costs	• By improving the efficiency of passenger transfers. • By automating the collection of operational data.
Reduce emission/energy use	• By collecting better schedule and route adherence data, and better tracking paratransit vehicles to improve more efficient scheduling and trip planning.
Improve transit system safety	• By automatically locating and reporting vehicle locations to the dispatch center • Through the emergency alarm function of the MDT which lets vehicle operators alert the dispatch center of incidents on the bus without making passengers aware an alarm has been issued.

4.1.3 Current RTC Application of AVL

There are three user groups at RTC for the on-board AVL: fixed-route vehicle operators, paratransit vehicle operators, and on-street supervisors. In all three cases, the users interface with the MDT.

Fixed-Route Vehicle Operator Observations. **Table 4-3** summarizes the planned and actual interface of fixed-route vehicle operators with the AVL system.

Table 4-3: Fixed-Route Vehicle Operator AVL Interaction

Current Interactions (Planned)
• Log-on and log-off their employee identification number, the route to be driven and the run number for that route. • View the time of day • View the route schedule • View their schedule adherence • Request to talk (RTT) to a dispatcher, or make a priority request to talk (PRTT) to a dispatcher • Receive and acknowledge messages sent by dispatchers, off-street supervisors and others using the TransitMaster™ Computer Aided Dispatch (CAD) • Send canned messages to dispatch, off-street supervisors and others using the TransitMaster™ CAD • View and adjust automated passenger count data • Play "canned" announcements regarding rules and passenger instructions • Make transfer requests to other fixed-route vehicles • Onboard emergency notification and tracking
Current Interactions (Not Planned)
• Receive and respond to staff schedule messages from a personnel scheduler regarding shift duration, overtime or schedule changes • Receive and respond to messages from customer service regarding items left on the vehicle by a passenger
Planned Interactions Not Used
• Transfer requests directly between two fixed-route vehicles – *Transfer request is operational; however, most vehicle operators are unaware the function is available. Additional training may be required.*

Fixed-route operators are very satisfied with the AVL and use of the MDT. They believe it makes their job much easier to do. While the system's location accuracy was considered somewhat unreliable at its implementation, the issue has been resolved and vehicle operators said location errors are infrequent and quickly corrected by the system.

The fixed-route vehicle operators' primary interaction with the MDT is to view the time, their route schedule, and their schedule adherence. While some vehicle operators rely on the MDT's display of minutes ahead or behind schedule, others prefer to compare the current time with the printed schedule, which can also be viewed on the MDT.

Text messaging is also very useful to vehicle operators. They prefer it to voice communications because it can be viewed at their discretion, resulting in not having to take a hand off the wheel to hold the radio handset. The text messages also provide a copy they can refer back to, which is useful for detours or schedule changes.

Of the fixed-route vehicle operators interviewed, fewer than half were aware of the transfer request function, which is implemented. This function allows one operator to contact another to request he/she wait for a passenger transfer at a mutual stop. The operators all felt it would be a useful tool to have. Additional training may be needed if RTC chooses to utilize it.

Other issues observed by operators: the color MDTs which are replacing the older monochromatic ones are harder to see in bright daylight; and an additional canned message to report "Standing Room Only" would be preferred over having to call dispatch to report it.

RTC ACCESS Vehicle Operator Observations. **Table 4-4** summarizes the planned and actual interface of paratransit vehicle operators at RTC ACCESS with the AVL system.

Table 4-4: RTC ACCESS Vehicle Operator AVL Interaction

Current Interactions (Planned)
• Log-on and log-off their employee identification number and the run number for that route • View the time of day • View the trip manifest • Record pick-up, drop-off, no-show and other trip-related information • View their schedule adherence • Request to talk (RTT) to a dispatcher, or make a priority request to talk (PRTT) to a dispatcher • Receive and acknowledge messages sent by dispatchers, reservationists, off-street supervisors and others using the TransitMaster™ CAD • Receive—but not acknowledge—messages sent by reservationists using the Trapeze™ automated demand-response scheduling application • Send canned messages to dispatch, off-street supervisors and others using the TransitMaster™ CAD • Onboard emergency notification and tracking

Overall, RTC ACCESS vehicle operators are very satisfied with the AVL system and rely on it to help them perform their jobs. The AVL and MDT give them assurance that they have performed their jobs correctly and completely. The paratransit operators use the system in more—and different—ways from the fixed-route operators because of the individualized nature of their trips. They use the MDT to view manifests, but also carry paper copies that are printed out each morning. The paper version can contain more detail than the MDT version and also serves as a backup in case there is a communication failure or other fault that prevents them from using the MDTs.

RTC ACCESS vehicle operators use the MDT to monitor schedule adherence, be alerted to changes in their manifests, or additional details, such as a message from a reservationist or dispatcher with specific pick-up or drop-off details for a passenger. They also use the MDT to inform the dispatchers of an issue, such as a no-show, and can communicate to resolve the issue with the dispatcher.

The operators prefer text messages to voice messages for many functions, such as directions and detours. This is especially important in paratransit, where the information may be detailed. Previously, the operators would have to write down information using a pen and paper, which would require them to pull over, or write while driving. Using the MDT, the information is displayed on-screen and can be reviewed at any time.

The same MDT unit is used for both paratransit and fixed-route service; however, the paratransit vehicle operators would prefer a larger display because they view much more detail than fixed-route operators. The operators would also prefer to receive notification from the dispatchers and reservationists when their manifests have changed. This is possible to do through text messaging; however, the dispatchers and reservationists are not in the habit of doing so. The result is that a vehicle operator, who has already reviewed his manifest or is using the paper manifest, may not be aware that a change has been made.

On-Street Supervisor Observations. **Table 4-5** summarizes the planned and actual interface of on-street supervisors with the AVL system.

Table 4-5: On-Street Supervisor AVL Interaction

Current Interactions (Planned)
• Log-on and log-off their employee identification number • View the time of day • View route schedules • View the schedule adherence of specific vehicles • RTT to a dispatcher, or make a PRTT to a dispatcher • Receive and acknowledge messages sent by dispatchers, off-street supervisors and others using the TransitMaster™ CAD • Send canned messages to dispatch, off-street supervisors and others using the TransitMaster™ CAD
Planned Interactions Not Implemented
• Observe multiple vehicles on a graphical interface • Make direct voice contact with operators • Make direct text message contact with operators – *The non-implemented interactions were to be part of the Mobile Supervisor Package, which is described in more detail in **Section 3.11***

Supervisors were originally intended to have an in-vehicle application called "Mobile Supervisor" that would have given them access to many computer-aided dispatch functions from their vehicles. As explained later in this report, the Mobile Supervisor module was not implemented. Instead, on-street supervisors have AVL-equipped vehicles. Overall, on-street supervisors are satisfied with the AVL system and believe it helps them perform their on-street duties. They also believe the system is too limited to provide the information they need to manage on-street operations. The text display gives abbreviated messages that provide minimal information. For example, when searching for a specific vehicle, the supervisor can view the schedule and estimate its location, but cannot pinpoint its location between stops as it would be able to do with a graphic interface.

Supervisors would like to be able to send text messages directly to vehicle operators. Currently, they can contact dispatch, or an off-street supervisor, and ask them to forward a message. But they cannot send one directly. Supervisors also cannot directly speak to vehicle operators without working through a dispatcher or off-street supervisor. These limitations are due to the designs of the communication software which makes the dispatcher the pilot of the AVL system.

4.2 Computer-Aided Dispatch

CAD can provide the operations center with fleet management, real-time display of AVL, schedule adherence, event playback, emergency alarm monitoring, text messaging, transfer coordination, work-force automation, incident reporting, vehicle monitoring, and off-line report generation. At the RTC ACCESS dispatch center, CAD workstations are installed with the TransitMaster™ software suite to perform these functions. It provides an interface usable for both fixed-route and paratransit fleet management; however RTC RIDE and RTC ACCESS have separate dispatch facilities and operations. A system administrator configures system-wide parameters through the CAD interface. Key components of the CAD application include:

- AVL map tool
- CAD/AVL fleet management tools

- Situation review tools

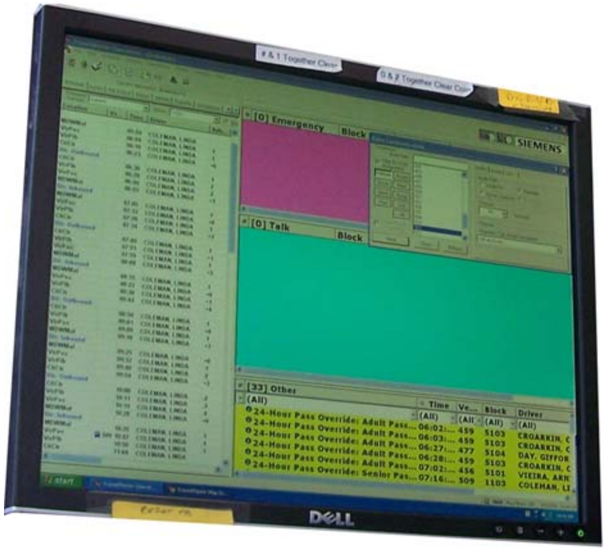
AVL Map Tool – The AVL map tool is available for fixed-route and paratransit dispatchers to view real-time vehicle locations and operational information on the dispatch workstations. At RTC, supervisors, paratransit reservationists, customer service and operations management staff also have access to the CAD interface with varying levels of permission to perform its functions.

Vehicles are represented on the map as icons which include a directional indicator and vehicle identification. Icons can be color-coded according to current vehicle status, such as for schedule and route adherence, or a vehicle operator's pending request to talk. Vehicle status is normally pulled every 30 seconds. Vehicles that transmit an emergency message are displayed on the map application on an automatically created tab that centers and tracks the vehicle while the emergency status is active. Vehicle status is pulled every 15 seconds when it is in the emergency mode. The HASTUS™ scheduling software interfaces with the CAD application in order to track schedule and route adherence information. **Figure 4-6** shows an example of the TransitMaster™ CAD operations map.

Figure 4-6: Example of the TransitMaster™ CAD Operations Map Screen

CAD/AVL Fleet Management Tools - The TransitMaster™ Fleet Management tools allow the dispatchers to closely monitor and react to fleet-wide exceptions and communications. The dispatchers may display one or more functional windows, as needed. All views/windows are protected to ensure no data is lost from inadvertent actions. Real-time data is stored in a database, allowing the planning department to create and review historical reports for system, dispatch, and vehicle operator performance. Dispatchers and others can send and receive messages to/from vehicle operators through the system. Dispatchers can also manage voice communications, including prioritizing and selecting vehicle operators with whom to speak. Vehicle operator covert alarms can be managed and the incident logged through fleet management tools. The Fleet Management tool allows dispatcher and supervisors to monitor schedule adherence by route or vehicle, and advise on-duty supervisors of the situation so they can respond appropriately. **Figure 4-7** is an example of the TransitMaster™ CAD screen for Fleet Management.

Figure 4-7: Example of RTC Fleet Management Screen



Playback - Situational Review Tools - The Playback tools allow dispatchers, supervisors, customer service and administration staff to replay any incident, segment of a vehicle run or past event for a specific vehicle or multiple vehicles. The application presents a visual history for a specified time interval, with map location and message details associated with the events. The application allows the administrator to select time frames and vehicles through a query action window. The visual display is message-driven based on a specific message received or transmitted during operation. The messages are extracted from the TransitMaster™ database and viewed adjacent to the map display.

4.2.1 System Interactions

Figure 4-8 shows the system interactions diagram illustrating how data is exchanged by CAD technology.

Figure 4-8: CAD Interactions Diagram

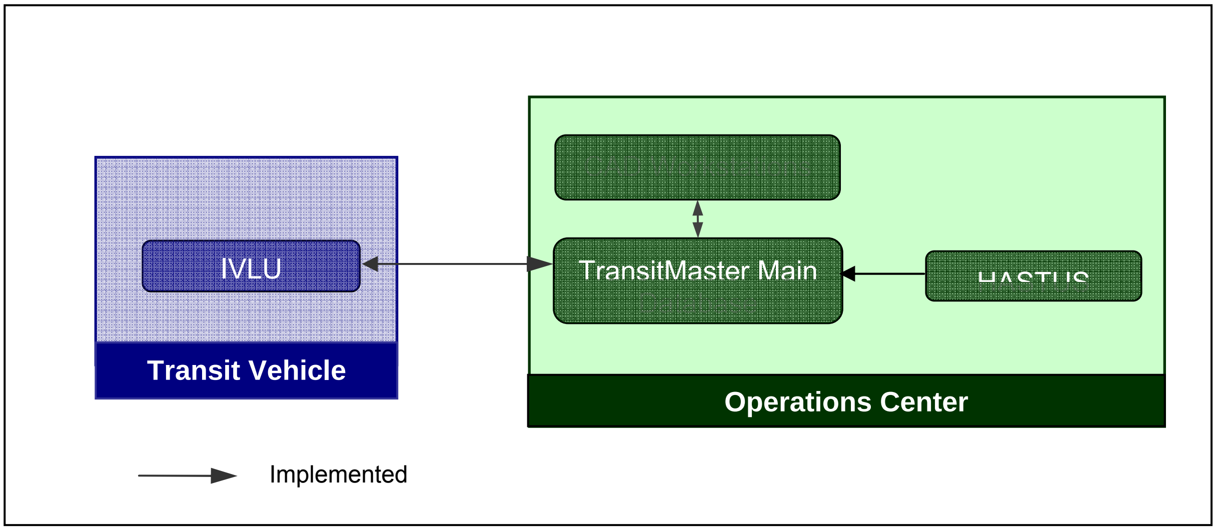


Table 4-6: CAD Technology Data Flows

From Component	Data Flow	To Component
CAD Workstation	Messages, Data Requests, Incident Logs, Notes	TransitMaster™ Main Database (RouteManager)
TransitMaster™ Application Server containing map data	Digital Map Data	CAD Workstation
HASTUS™	Schedule Data	TransitMaster™ Main Database (RouteManager)
TransitMaster™ Main Database (RouteManager)	Messages, Vehicle Location Data, Passenger Count Data, Review Data	CAD Workstation
Trapeze™ Server and Workstation	Paratransit Manifest Data	MDT-IVLU
MDT - IVLU	Paratransit Manifest Data	Trapeze™ Server and Workstation
Planned But Not Implemented		
MDT-IVLU	Fare Collection Data, Mileage Data	TransitMaster™ Main Database (RouteManager)
TransitMaster™ Main Database (RouteManager)	Fare Collection Data, Mileage Data	CAD Workstation

4.2.2 CAD Capabilities

Table 4-7 illustrates how the capabilities of CAD technology can address the RTC goals.

Table 4-7: CAD Technology Capabilities to Meet RTC Goals

RTC Goal	Technology Capability
Make public transit more attractive to the general population	• By providing more reliable, up to schedule service.
Maximize passenger movements	• By generating more accurate schedule adherence information for planning. • By improving the accuracy of schedule information and trip planning.
Reduce operational costs	• By helping dispatchers and vehicle operators make effective adjustments. • By reducing spare vehicles needed.
Increase awareness of ITS benefits	• By improving operational effectiveness and efficiencies via ITS technology – utilizing real-time data.

4.2.3 Current RTC Application of CAD

There are five user groups at RTC for the CAD workstation:

- RTC RIDE dispatchers
- RTC ACCESS dispatchers and reservationists
- RTC customer service
- Supervisors
- Administration

Fixed-Route Dispatcher Observations. **Table 4-8** summarizes the planned and actual interface of fixed-route dispatchers with the AVL system.

Table 4-8: RTC RIDE Dispatcher CAD Interaction

Current Interactions (Planned)
• View vehicle operator and vehicle information • View vehicle locations • View route schedules • Track schedule adherence of vehicles • Manage communications with fixed-route vehicle operators and on-street supervisors • Exchange messages with fixed-route vehicle operators and on-street supervisors • Manage and log emergency events
Planned Interactions Not Used
• Log all calls with vehicle operators and on-street supervisors – *The function is available through the CAD; however, RTC continues to use paper logs*

The RTC RIDE dispatchers accepted the CAD system at implementation and were prepared to work through the debugging process. Partially as a result, the dispatchers are very satisfied with the system and believe it gives them much control over on-street activities. Because of job definitions, dispatchers are limited in their fleet management capabilities; supervisors, and not dispatchers, are authorized to detour vehicles and adjust their operations to achieve schedule adherence.

The most appreciated features by RTC RIDE dispatchers are the ability to see vehicle locations and to be able to communicate through text. Reaching a group of vehicles is much improved over the former "all calls," where all operators were called over the radio and then those the message was not intended for could disconnect only after learning it was not meant for them.

Before the CAD and AVL, RTC RIDE dispatchers had to rely on vehicle operators and supervisors to describe their locations. They are now able to view the locations, and can observe where transfer requests are possible. They are also able to verify on-street supervisor locations to determine who should respond to incidents and operator needs.

The RTC RIDE dispatchers confirmed a recent increase in PRTT usage in situations when RTT is appropriate. The likely cause was cited as the design of the button locations on the new MDTs. The dispatchers also noted that the base maps are approximately four years old and they would like to see new base maps which include changes and additions to the road network. One issue the dispatchers have noticed is that most covert alarms are false, and likely the result of vehicle operator error. When the covert alarm is triggered, the sound quality from the hidden microphone is poor and makes it difficult to understand the situation on board the alerting vehicle.

RTC ACCESS Dispatcher and Reservationist Observations. **Table 4-9** documents the use of the CAD by RTC ACCESS reservationists and dispatchers.

Table 4-9: RTC ACCESS Dispatcher and Reservationist CAD Interaction

Current Interactions (Planned)
• View operator and vehicle information • View vehicle locations • View CAD information to respond to customer calls • Manage communications with paratransit vehicle operators • Exchange messages with paratransit vehicle operators and on-street supervisors • View trip manifests • Send additional manifest data • Manage and log calls • Manage and log emergency events • Record trip mileage

RTC ACCESS dispatchers and reservationists are very satisfied with the CAD. The dispatchers use it to view vehicle locations and schedule adherence. They use that information to help direct vehicles to their destinations, and also adjust trip manifests based on vehicle availability and schedules. The dispatchers also prefer being able to send text messages for manifest changes and directions because the vehicle operators are able to view them when convenient, and it gives a record of the communication that can be referenced later. The dispatchers suggest that voice communications have not been reduced by the use of CAD, and believe this is primarily because the vehicle operators prefer voice over canned messages to report their activities. The reservationists primarily use the scheduling software Trapeze™, but share a single TransitMaster™ CAD workstation that is used to respond to customer service requests, view vehicle locations when determining whether to shift trips among manifests, and to send text messages to vehicle operators when an acknowledgment is needed. The CAD is also used to get directions to include with manifests.

RTC ACCESS dispatchers and reservationists would like to see odometers connected to the in-vehicle ITS so that trip mileage is automatically logged. Currently, the vehicle operators must still manually log mileage, resulting in paper logs. Another issue for the dispatchers and reservationists is that base digital maps are outdated. Due to the Reno-Sparks area's recent growth, many new streets and street changes are not reflected on the four-year-old base maps.

RTC Customer Service CAD Observations. **Table 4-10** documents the use of the CAD workstation by customer service representatives.

Table 4-10: RTC Customer Service CAD Interaction

Current Interactions (Planned)
• View operator and vehicle information • View vehicle locations • Review customer complaints regarding schedule and route adherence • View CAD information to respond to customer calls • Exchange messages with vehicle operators • Use playback to determine validity of customer complaints and plan response
Current Interactions (Not Planned)
• Track lost objects for customers through messaging with vehicle operators

The RTC Customer Service staff are enthusiastically positive about the TransitMaster™ CAD workstation and its ability to help provide better customer service. The dispatchers noted that customer calls have increased significantly since its implementation, and most calls are "Where is my bus?" The Customer Service staff are now able to give an accurate answer to those questions when before they would just use the printed schedule. Customers also call in to report buses that are off-route or off-schedule. Customer Service staff can review a complaint through the CAD and let dispatch know if it is valid.

RTC Customer Service noted that the playback feature lets them respond much more quickly to customer complaints. They can use playback to review a complaint (e.g., a bus missed a stop), quickly validate or invalidate it and respond, occasionally quickly enough that they are able to send a vehicle to pick up the missed customer. Previous complaint investigation was limited and would require at least several hours so that the vehicle driver could be asked about the event. Customer service is not allowed to use the CAD workstation to control vehicles, so cannot make transfer requests or "hold" buses. To do so at a customer's request, staff must contact dispatch or the supervisors.

RTC Customer Service has also found a unique use for the system. When a customer calls in to report a lost item, staff are able to immediately identify the vehicle the passenger was on, and send a text message to the vehicle operator. The operator can then search the bus for the lost item at the next opportunity. This improves the chances the item will be found and allows the operator to either hold the object or pass it to another operator or supervisor to return the item to the passenger.

Supervisor CAD Observations. Table 4-11 documents the use of the CAD workstation by supervisors.

Table 4-11: RTC RIDE Supervisor CAD Interaction

Current Interactions (Planned)
• View vehicle schedule and route adherence • Communicate with vehicle operators and dispatch • Exchange messages with fixed-route vehicle operators and on-street supervisors • Review reports for schedule adherence and passenger loads • Review grievances regarding schedule and route adherence • Exchange messages with paratransit vehicle operators • Use playback to determine validity of customer complaints and plan response • Manage vehicle schedule and route adherence • Manage passenger loads

Supervisors believe the CAD workstation has significantly improved how they perform their jobs. Previously, supervisors were on the roads virtually all of their shifts. Now, however, supervisors may spend as much as half of their time off-street, observing the fixed-route vehicles through the TransitMaster™ CAD workstation. In fact, during busy periods, such as peak times, special events and severe winter weather, the supervisors prefer to have one person using the workstation because it gives them the ability to observe more of the on-street activity than can be done from on-street. Supervisors use the CAD workstation to observe real-time schedule and route adherence, and to review historical schedule adherence data and passenger loads. Investigation of customer complaints and grievances, or validation of on-street supervisor observations is done through playback.

RTC RIDE Supervisors send text messages through the CAD workstation significantly more than they use voice communications. They much prefer its ability to message a selected group of vehicle operators, such as those on a specific route or routes through a specific area, than using the "all call" voice message. Under the current system, supervisors coordinate their voice communication through dispatch; whereas they previously had priority in voice communications.

Supervisors have identified a few minor issues with the vehicle tracking function. Specifically, there are locations where vehicles are temporarily “lost.” The vehicles disappear from the CAD workstation screen, because no AVL data is received from them. This is likely in spots where the satellites cannot be seen by a vehicle GPS antenna due to tall building shadows, and the system quickly “finds” the vehicles once they are outside of the shadows.

A significant issue for supervisors is the absence of the Mobile Supervisor Module application that would provide them with most of the CAD workstation functionality on a laptop while on-street. The vehicle operators prefer the supervisors to be on-street and the Mobile Supervisor Module, as discussed in **Section 4.11**, allows them to be mobile while still observing and managing vehicle performance and locations from a graphic interface.

Administration CAD Observations. **Table 4-12** documents the use of the CAD workstation by administration and other users.

Table 4-12: Administration CAD Interaction

Current Interactions (Planned)
• View vehicle schedule and route adherence • Exchange messages with fixed-route vehicle operators and on-street supervisors • Review reports for schedule adherence and passenger loads • Playback routes and runs to observe schedule adherence • Review grievances regarding schedule and route adherence • Exchange messages with paratransit vehicle operators
Current Interactions (Not Planned)
• Manage vehicle operator schedules through text messaging

Others who do not use the CAD workstation on a regular basis do rely on it for some functions, and find it to be a useful tool. The RTC RIDE schedulers use the playback feature to observe real-world schedule adherence, particularly directly after schedule changes or detours, or during special events. RTC RIDE and RTC ACCESS administration may use it as a tool in the investigation of a grievance, such as a vehicle operator alleged leaving early or late from a stop. Messages to individual vehicle operators may also be used to communicate on various issues.

A unique use that RTC RIDE has developed for the system is the ability to text message to specific vehicle operators to inform them of overtime opportunities, available shifts or when a shift may be extended or cut short. The text message allows a personnel scheduler to reach them quickly and receive an acknowledgment of the message, and a “yes” or “no” response to a request. This has proven to be very useful and has allowed the personnel scheduling to be done more efficiently and with more certainty than when vehicle operators had to be contacted while on break or by leaving messages for them.

4.3 Paratransit Scheduling and Reservation Software

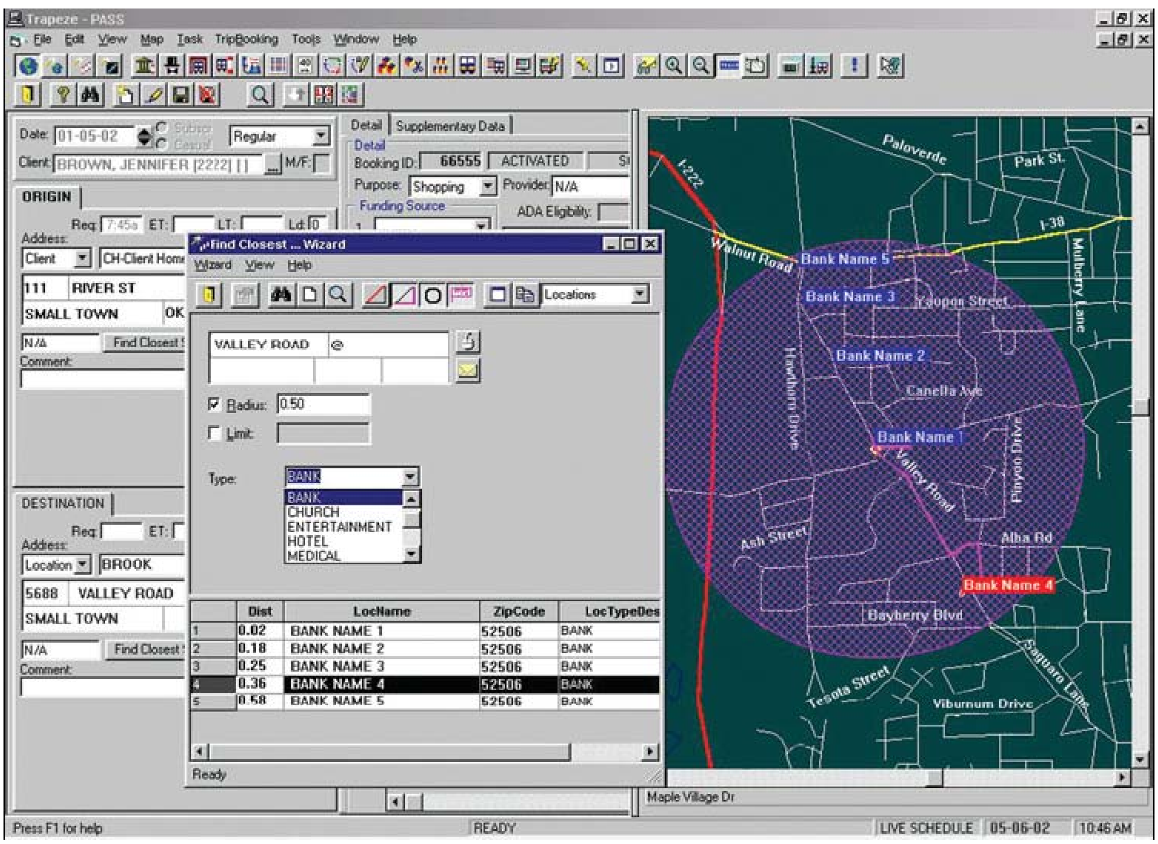
Trapeze™ is the paratransit reservation and scheduling software that is currently used by RTC’s ACCESS service. The software provides the following scheduling and dispatch functions:

- Automatically generate and optimize schedules
- View detailed itineraries including pick-ups, drop-offs and times for each run

- Calculate accurate times of arrival
- Monitor and adjust service in real-time
- Estimates trip distances
- Track incidents, cancellations and no-shows instantly

Trapeze™ software also provides a comprehensive booking tool that indicates fare types, multiple billing sources, and trip purpose with full access to passenger data. The software is interfaced with an integrated map that allows users to view and define service areas, including streets, boundaries, barriers and ADA corridors. The map also generates geographical views of locations, destinations, and routes. **Figure 4-9** shows a screen shot of the Trapeze™ map. The reporting features of the software provide detailed reports on performance, revenue, ridership, clients, and vehicles information.

Figure 4-9: Example Screen Shot of the Trapeze™ Map Interface



The Trapeze™ software can be expanded for additional capability with add-on modules, including:

- Internet trip booking, cancellation and confirmation
- Coordinated transport
- Commendation and compliance tracking
- Certification and suspension management
- MDT and AVL integration
- Interactive Voice Response (IVR)

The IVR feature was implemented in 2008. Other features were not planned and are currently not incorporated at RTC ACCESS. The system is integrated to share information with the TransitMaster™ system, and dispatchers and reservationists use both systems. Trapeze™ is used for scheduling while TransitMaster™ is used for dispatching.

4.3.1 Paratransit Scheduling and Reservation System Interactions

Figure 4-10 shows the system interactions diagram illustrating how data is exchanged with the Trapeze PASS™ paratransit technology.

Figure 4-10: Paratransit Scheduling and Reservation System Interactions

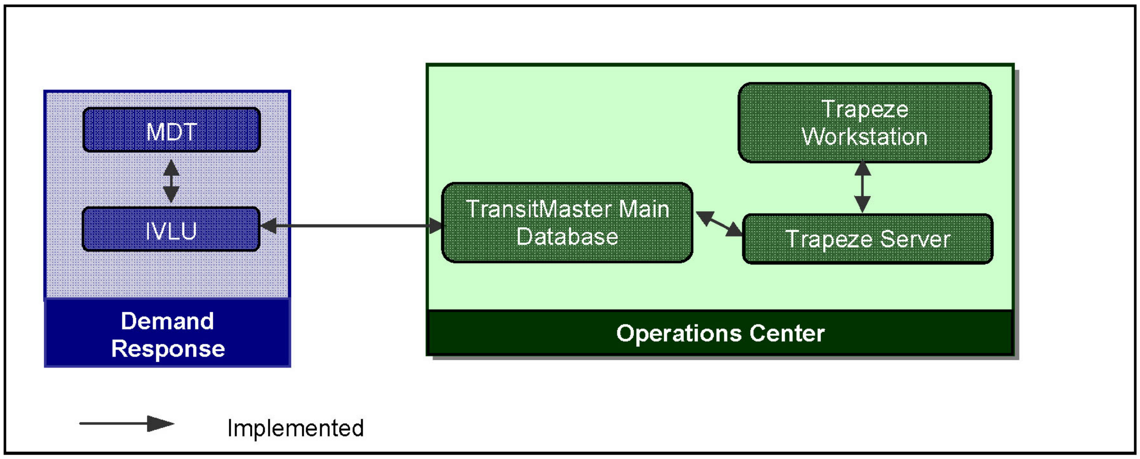


Table 4-13: Paratransit Scheduling and Reservation System Data Flows

From Component	Data Flow	To Component
Trapeze™ Workstation	Reservation Request	Trapeze™ Server
Trapeze™ Server	Trip Manifests	TransitMaster™ Main Database
Trapeze Workstation	Messages	TransitMaster™ Main Database
TransitMaster™ Main Database	Trip Manifests, Messages	IVLU
IVLU	Trip Manifests, Messages	MDT
MDT	Trip-related Data (e.g. pickup, drop-off, no-show)	IVLU
IVLU	Trip-related Data	TransitMaster™ Main Database
TransitMaster™ Main Database	Trip Related Data	Trapeze™ Server
Trapeze™ Server	Trip Related Data	Trapeze™ Workstation

4.3.2 Paratransit Scheduling and Reservation Capabilities

Table 4-14 illustrates how the capabilities of paratransit scheduling and reservation system can address the RTC goals established for transit ITS.

Table 4-14: Paratransit Scheduling and Reservation System Capabilities to Meet RTC Goals

RTC Goal	Technology Capability
Make public transit more attractive to the general population	• By enhancing communication with customers about vehicle location and arrival times. • By improving customer service through faster and more efficient trip scheduling, and documenting and responding to passenger special needs.
Maximize passenger movements	• By improving trip management through geographically-based trip scheduling and manifest optimization. • By minimizing missed and excessively late trips through better scheduling.
Reduce operational costs	• By increasing the productivity of each vehicle. • By increasing reservation productivity through faster, automated scheduling.
Reduce emission/energy use	• By optimizing the number of trips per vehicle and reducing non-revenue vehicle hours and miles per trip provided.

4.3.3 Current RTC Application of Paratransit Scheduling and Reservation System

The user groups who work with Trapeze™ are the RTC ACCESS reservationists and dispatchers. Of the two, the reservationists work more closely with Trapeze™ and do most of the data entry. Dispatchers use Trapeze™ data to track schedule adherence and monitor operations efficiency.

RTC ACCESS Dispatcher and Reservationist Observations. **Table 4-15** summarizes how the reservationists and dispatchers use the system.

Table 4-15: RTC ACCESS Dispatcher and Reservationist CAD Interactions

Current Interactions (Planned)
• Track paratransit vehicle schedule adherence • Create and modify trips based on customer requests • Automatically generate trip manifests • Manually adjust trip manifests • Observe and verify pickups, drop-offs, no-shows and other events specific to trips • Send text messages to paratransit vehicle operators • Respond to customer service requests for information • Generate reports on trips, operations efficiency, no-shows, schedule adherence and other information

Both RTC ACCESS reservationists and dispatchers like the Trapeze™ software and believe it is robust. They said they “never” experience system crashes. The reservationists are generally satisfied with the Trapeze™ software. It is noted that they were using a previous version of Trapeze™ prior to this implementation, and the upgrade did not significantly impact how they perform their jobs. The Trapeze™ software has rudimentary maps that the reservationists do not use for giving directions to vehicle operators. When directions are needed, they use the TransitMaster™ CAD workstation to get them, and then enter them into the trip manifest details through Trapeze™. The ability of Trapeze™ to automatically generate trip manifests is considered very good by the reservationists, and they have to do little manual adjusting; however, when manual adjustments to trips are necessary, they are easy to do through Trapeze™.

Reservationists said the travel time estimates generated by Trapeze™ are fair, but fail to consider some road issues that may change travel times, including not optimizing the routes between stops. The RTC ACCESS dispatchers and reservationists believe the previous version of Trapeze™ produced more accurate travel time estimates, which helped in optimizing trip scheduling. There are two primary issues the reservationists have with the use of Trapeze™. One is that the maps are outdated and require the reservationists to refer to Google™ online maps or a paper map to locate some pickup and drop-off points. The other is that messages can be sent from Trapeze™ to the paratransit vehicle operators, but no acknowledgment can be received. When reservationists send a message requiring acknowledgment, they must use the TransitMaster™ CAD workstation.

Dispatchers primarily work with the TransitMaster™ CAD workstation to verify schedule adherence, confirm pickups and drop-offs, and track where vehicles should go next. They also use it to determine availability of vehicles. If Trapeze™ verifies that a vehicle is available to make a new trip, the dispatcher returns to the TransitMaster™ workstation to find its location and determine whether performing the trip is feasible. Dispatchers use TransitMaster™ for all text messaging.

Trapeze™ also offers services that allow integration into services-oriented architectures, such as customer information and IVR. IVR was implemented at RTC ACCESS in February 2008.

4.4 Fixed-Route Scheduling Software

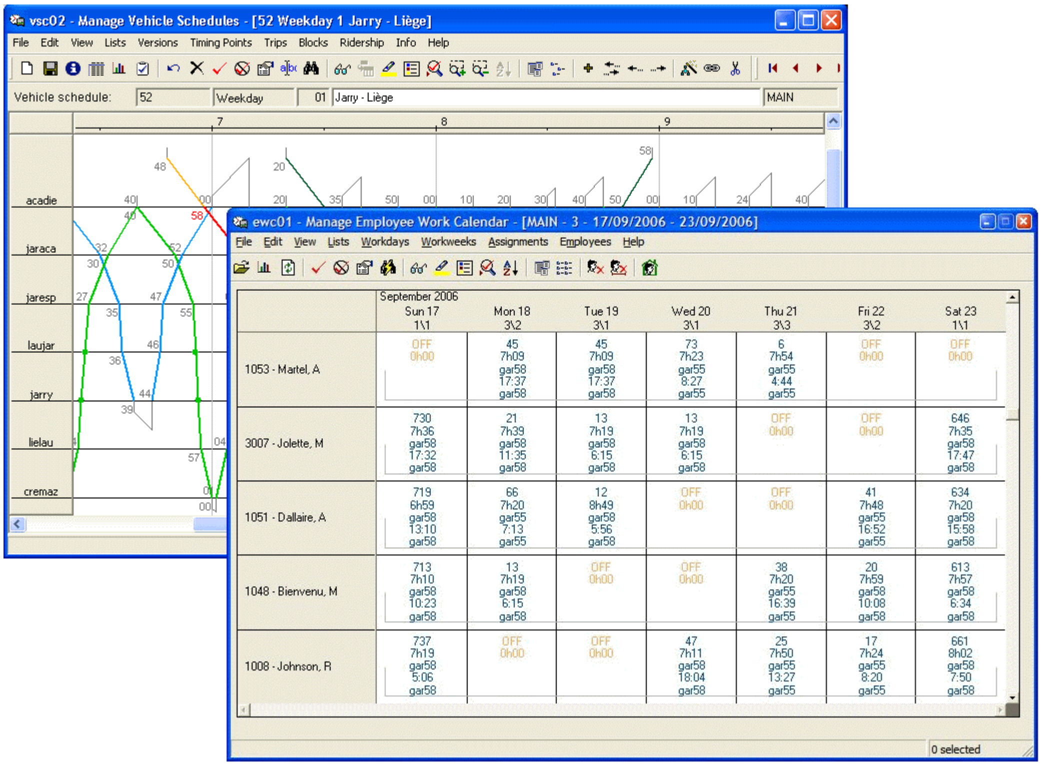
HASTUS™, a software package by GIRO Inc., is used by RTC RIDE for fixed-route scheduling and operations. It contains the routing, scheduling, vehicle assignment, bus stop and bid database. HASTUS™ consists of several modules including core modules that cover scheduling and daily operations, with complementary modules available for planning and analysis, as well as customer information.

Basic module – The Basic module provides the user a tool to describe the route network and define desired timetables. The system can then generate cost-effective vehicle and crew schedules, as well as multi-day rosters by using its optimization algorithms.

Complementary Modules – The complementary modules offer analysis and planning tools to provide network and timetabling modeling functions, including synchronization while minimizing vehicle requirements. Run time and ridership data analysis modules contribute to improved use of the fleet and to service better tailored to customer needs.

Figure 4-11 shows an example screen of the HASTUS™ software.

Figure 4-11: Examples of HASTUS Screens



HASTUS™ supports Oracle® and Microsoft SQL Server® relational databases. It offers a variety of reporting capabilities including standard reports, configurable lists, XML outputs, and built-in support for Crystal Reports®. Data stored in the HASTUS™ database can be shared with other applications via the configurable data extraction tools. Standard interfaces allow HASTUS™ to be integrated with complementary products and applications such as TransitMaster™, and payroll systems from other vendors.

Although not planned or implemented at RTC RIDE, HASTUS™ also offers basic web services that allow integration into services-oriented architectures, such as customer information, Interactive Voice Response (IVR) and agency Web sites, as well as receiving transactional updates from enterprise applications. The Web Services are fully interoperable with any other systems complying with industry-standard protocols. In addition, the Daily Operations Modules start from planned schedules and allow users to manage daily service changes, as well as vehicle and operator assignments. Users can compare actual versus planned schedules, monitor operator performance statistics, and export timekeeping data for payroll.

4.4.1 System Interactions

HASTUS™ interfaces and exchanges data with the TransitMaster™ HASTUS™ Application residing on the RTC Public Transportation workstations. Schedule and route data is exported from the HASTUS™ and imported into the TransitMaster™ server. It uses the data to calculate schedule adherence by comparing actual vehicle locations and their scheduled locations. **Figure 4-12** illustrates the interaction of HASTUS™ at RTC.

Figure 4-12: HASTUS™ System Interactions

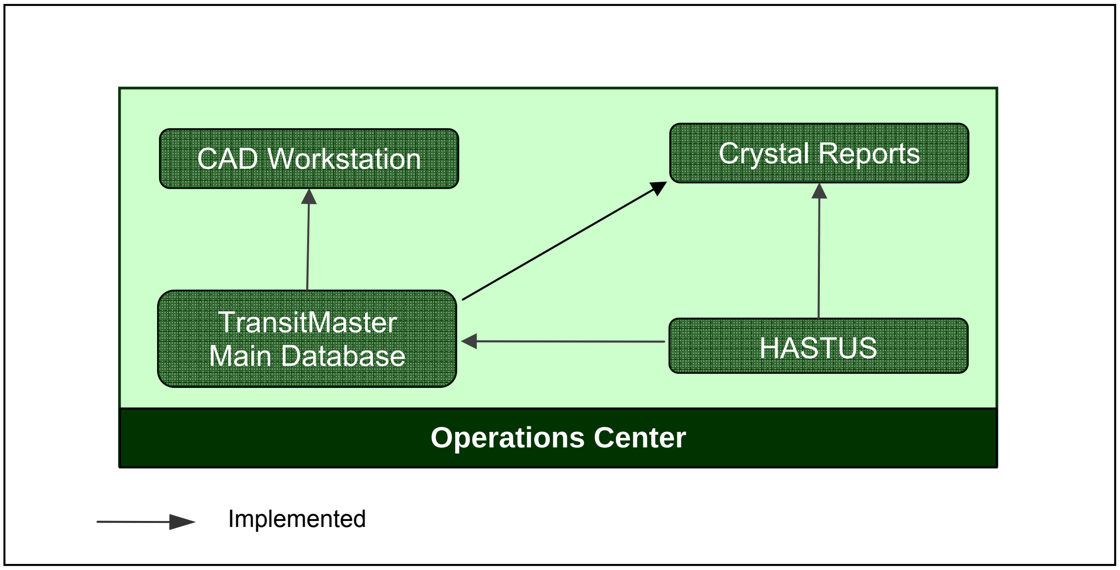


Table 4-16: Fixed-Route Scheduling Software Technology Data Flows

From Component	Data Flow	To Component
HASTUS	Schedule, Stop and Route Data	TransitMaster™ Main Database (RouteManager)
TransitMaster™ Main Database (RouteManager)	Schedule, Stop and Route Data	TransitMaster™ CAD Workstation
TransitMaster™ Main Database (RouteManager)	Schedule, Stop and Route Data	Crystal Reports Workstation
HASTUS	Bus and Operator Schedule, Stop and Route Data, Vehicle and Operator Assignment Data, Operator Performance, Service Reports	Crystal Reports Workstation

4.4.2 Fixed-Route Scheduling Software Capabilities

Table 4-17 describes how the Fixed-Route Scheduling Software helps RTC meets its transit ITS goals.

Table 4-17: Fixed-Route Scheduling Software Technology to Meet RTC Goals

RTC Goal	Technology Capability
Make public transit more attractive to the general population	• By providing quality service information (planned or real-time) to customers.
Maximize passenger movements	• By optimizing scheduling for vehicles and staff, RTC can improve transit efficiency and passenger transfers.
Reduce operational costs	• By automating the fixed-route scheduling process, better scheduling should be possible using the same, or fewer resources.

4.4.3 Current RTC Application of Fixed-Route Scheduling Software

The RTC Public Transportation staff responsible for fixed-route scheduling use the HASTUS™ software to document all fixed-route schedules. **Table 4-18** summarizes the planned and actual interaction of fixed-route schedulers with the fixed-route schedule software.

Table 4-18: Fixed-Route Scheduling Software Interaction

Current Interactions (Planned)
• Geocode the stops for each fixed-route • Document fixed-route schedules for use by TransitMaster™ and output to GoogleTransit™ Feed Specification • Compare planned schedules with actual vehicle time point data
Planned Interactions Not used
• Develop schedules for each route • Optimize use of vehicles for fixed-route operations • Optimize staffing of vehicle operators for fixed-route operations

RTC RIDE Scheduler Observations. While the HASTUS™ fixed-route scheduling software is capable of developing and optimizing schedules, RTC RIDE continues to manually develop schedules using a spreadsheet. HASTUS™ is used to document the schedules and make them available to TransitMaster™ for use in tracking schedule adherence and publishing to the CAD workstation and MDT. HASTUS™ also formats the fixed-route data for use in a Google Transit™ Feed Specification. The specification is used by Google™ to publish a dynamic web site trip planning tool available to the public.

Because RTC RIDE staff are satisfied with their current scheduling process, they do not expect to transition to fully using HASTUS™ for scheduling in the near future.

4.5 DataMart™

DataMart™ is TransitMaster's reporting database. It is populated with real-time data from the TransitMaster™ system using a Data Staging Service. The automated service extracts, transforms, and loads transit data into the system database in a way that can be easily extracted for analysis and reporting.

The DataMart™ system was not part of RTC's original specifications and design; however, it was provided to the agency to enhance the reports generated by TransitMaster™. The advantage of DataMart™ for RTC is its ability to aggregate data in a structure that allows for faster and easier data mining and report generation. DataMart™ runs separately from the TransitMaster™ main database (RouteManager) and systems, so queries and report generation do not affect the TransitMaster™ system performance. It supports both Oracle and Microsoft SQL database platforms. RTC uses Microsoft SQL and Crystal Reports for report generation. DataMart™ also contains filters and error-checking to ensure that its data is complete and accurate. Data that is only understandable to the computers in the TransitMaster™ system is converted into tables and data sets that are understandable and relevant to the transit agency staff.

RTC procured the DataMart™ with the understanding it would make the large amounts of data generated by the transit ITS more easily available. While the data is organized and structured within the DataMart™, RTC found it necessary to hire a contractor to develop the actual report queries. A set of standard reports that were provided with DataMart™ are largely considered inadequate, particularly for fixed-route operations. While DataMart™ makes data available; RTC's experience is that it does not make it easily accessible.

4.5.1 DataMart™ Interactions

DataMart™ interacts with the TransitMaster™ main database (RouteManager) to collect data. It is then accessible through many reporting tools. RTC uses Crystal Reports to extract data and perform analysis. **Figure 4-13** illustrates the interactions of DataMart™ at RTC.

Figure 4-13: DataMart™ System Interactions

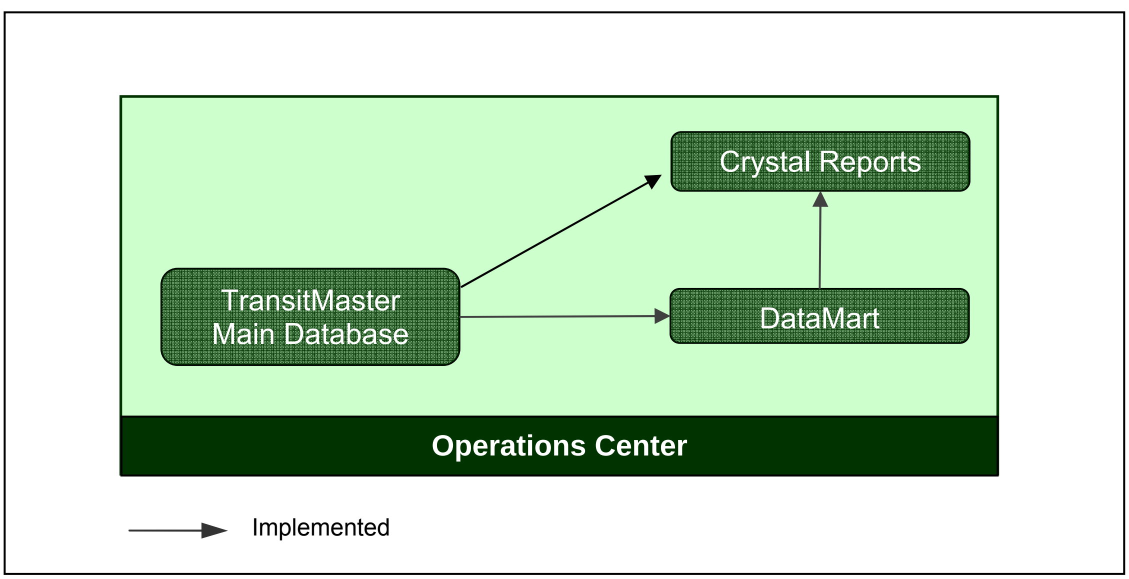


Table 4-19: DataMart™ Data Flows

From Component	Data Flow	To Component
DataMart™	Transit ITS Data, including schedule adherence, route adherence, passenger counting	Crystal Reports
TransitMaster™ Main Database (RouteManager)	Transit ITS Data, including schedule adherence, route adherence, passenger counting	Crystal Reports
TransitMaster™ Main Database (RouteManager)	Transit ITS Data, including schedule adherence, route adherence, passenger counting	DataMart™

4.5.2 DataMart™ Capabilities

Table 4-20 illustrates how the capabilities of the DataMart™ can address the RTC goals established for transit ITS.

Table 4-20: DataMart™ Capabilities to Meet RTC Goals

RTC Goal	Technology Capability
Maximize passenger movements	• By optimizing service through the use of comprehensive and accurate data
Reduce operational costs	• By reducing the time needed to perform data collection and analysis

4.5.3 Current RTC Application of DataMart™

RTC administrative staff responsible for fixed-route and paratransit scheduling use DataMart™ for data analysis. Administrative staff also use it to evaluate revenue, system efficiency, generate reporting data and monitor operations. **Table 4-21** summarizes the actual interaction of administrative staff with DataMart™.

Table 4-21: Administrative DataMart™ Interaction

Current RTC RIDE DataMart™ Interactions (Planned)
• Use standard reports to generate route, vehicle, revenue, mileage, ridership and other reports • Analyze ridership, boardings and alightings for schedule adjustments and facility planning • Track schedule adherence • View historical data over periods of time

Administration Observations. RTC RIDE scheduling staff believe DataMart™ provides "vast time savings" over the previous method of manual data collection. It is used to generate data on operations performance, route and run data. Passenger counts are also reported through DataMart™. The "canned" Crystal Reports queries that were provided with the system have been found to be inadequate for RTC. In particular, the types of reports available do not meet all of RTC's needs. Also, formatting and data is not consistent with the normally accepted approach to transit reporting.

The impression of RTC staff is that DataMart™ contains much more data than RTC is currently able to extract and use. RTC has hired a contractor to develop customized reports using Crystal Reports to make better use of DataMart™.

The RTC ACCESS administrative staff are satisfied with the Trapeze™ "canned" reports available for paratransit service for their daily uses of analyzing operating efficiency and performance. However, for more detailed and unique reports, RTC ACCESS staff believe more individualized reports would be useful. RTC ACCESS staff also indicated that they believed there was much more data in DataMart™ than they could easily access.

4.6 Automated Passenger Counters

The APC is a device that automatically counts the boarding and alighting of passengers at stops. **Figure 4-14** shows the core components of an APC system. These include the APC module, infrared receivers and transmitters, and the standard integrated mobile equipment including the IVLU, the MDT, cabling and antennas.

Figure 4-14: Components of APC System

Infrared transmitter and receiver pairs are head-mounted at all entrances and exits of RTC's buses. Four infrared beams (per door) detect passenger boarding and alighting by monitoring breaks in the beams. The distance range is 3 to 6 feet for standard sensors. A maximum of 255 on and 255 off events can be stored for any given stop.

The APC processing unit is wired to a J1708 data access box onboard and exchanges passenger count data with the IVLU. RTC's APC system can use route data, vehicle data, GPS data and vehicle operator logon information to generate passenger-count data. Odometer readings can also be used, but are not implemented at RTC. The passenger counts are tagged with a location of the stop and the time it occurred to allow dynamic load-route analysis reports. In some instances, the operator may also tag passenger type information to the passenger counts by manually pressing the pre-assigned numeric keys (indicating passenger type) on the MDT. Boarding or alighting of a wheelchair can also be manually entered through the MDT passenger count page. Wheelchair passengers are also tracked by sensors triggered by the wheelchair or ramp lifts.

The passenger count information is typically transmitted to the transit center in real-time using the IVLU built-in radio modem. The system can also be configured to store-and-forward (all data is stored on-board the fixed-route vehicle fleet for download at the end of the day).

The APC system also has a diagnostic function. It checks infrared sensors, door sensors and counts (both on and off) when activated. This function is included in the IVLU with the operator interface provided through the MDT. It is expected that the Automatic Passenger Counters will measure boarding and alighting to no less than 90% accuracy for each route. RTC believes its accuracy on RTC RIDE routes is near or above 90%. The APC system is checked regularly by Maintenance to ensure that it is functioning correctly.

A range of reports are available at RTC to process the raw APC data into various forms useful to operational personnel. Processed data is used to show ridership patterns and use. The data enables efficiently managing routes and schedules.

4.6.1 APC System Interactions

Figure 4-15 shows the system interactions diagram illustrating how data is exchanged by the APC technology.

Figure 4-15: APC System Interactions Diagram

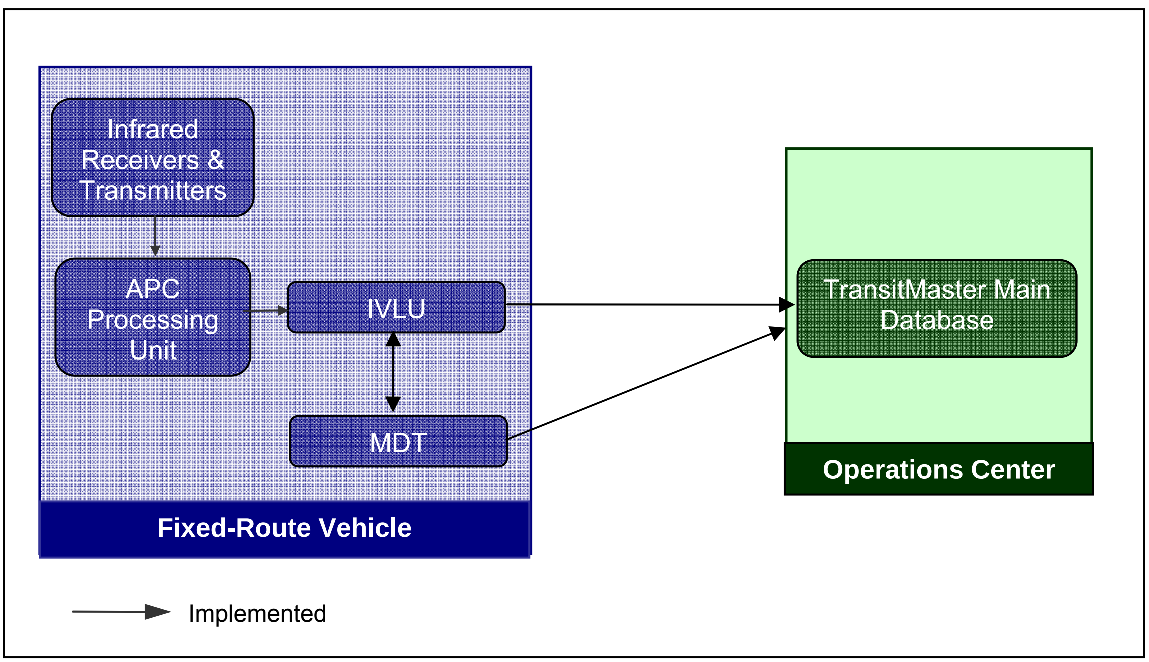


Table 4-22: APC System Data Flows

From Component	Data Flow	To Component
Infrared Receiver and Transmitter	Boarding and Alighting Detection Data	APC Processing Unit
APC Processing Unit	Boarding and Alighting Passenger Count Data	IVLU
IVLU	Boarding and Alighting Passenger Count Data	MDT
MDT	Boarding and Alighting Passenger Count Data (manual input)	TransitMaster™ Server
IVLU	Boarding and Alighting Passenger Count Data	TransitMaster™ Server

4.6.2 APC Capabilities

Table 4-23 illustrates how the capabilities of APC technology can address the transit ITS goals.

Table 4-23: APC Technology Capabilities to Meet RTC Goals

RTC Goal	Technology Capability
Make public transit more attractive to the general population	• By improving facility planning through the use of more comprehensive passenger counts at stops.
Maximize passenger movements	• By optimizing service through the use of comprehensive and accurate passenger counts, RTC can better understand ridership • By adapting routes to observed passenger demand.
Reduce operational costs	• By reducing resources needed to perform manual passenger counting.

4.6.3 Current RTC Application of APC

The APC is currently installed on all fixed-route vehicles and performing automated passenger counts. The data generated by APC is mostly used by two RTC RIDE staff groups: fixed-route planning and scheduling, and fixed-route supervisors.

RTC RIDE Planning and Scheduling Observations. **Table 4-24** describes the supervisor interaction with the APC.

Table 4-24: Current RTC RIDE Planning and Scheduling APC Interaction

Current RTC RIDE Scheduling and Planning APC Interactions (Planned)
• Collect passenger load, boarding and alighting data for route and schedule planning • Review boarding and alighting data for facilities planning • Collect passenger count data to validate National Transit Database reporting
Current Interactions (Not Planned)
• Plan bus stop amenities based on passenger boardings by stop

The planning and scheduling staff at RTC have been slow to adapt the data collected through the ITS into its processes; however, the APC data has been used and is considered very valuable for planning facilities. By having passenger boarding and alighting counts for each stop on each route, they are better able to determine where benches, shelters, trash cans and other facilities should be placed. The previous process counted passenger boarding and alighting for one day every three years. With APC combined with AVL, data is available for all days, including during special events and severe winter weather.

For scheduling purposes, the APC data is used to identify areas where more frequent service is needed, or less frequent service is justified. In addition, it is used to identify locations where a route may be realigned to better serve passengers because a current stop or segment has little to no boardings and/or alightings. APC data is also used to determine amenity needs at bus stops.

The RTC scheduling and planning staff believe the APC accuracy is considered “acceptable” and within 10% of actual passenger boardings and alightings. The passenger count data is most accurate at a route’s mid-trip stops. They believe it is not as accurate at trip beginnings and endings, when the vehicle operator may get on and off the bus, and when more people board or alight simultaneously. The APC also does not recognize “interlined” trips. Those are when the same bus changes routes at an endpoint. Passengers who stay onboard are counted as a single passenger trip instead of two trips – one for each route.

A strong issue that the RTC scheduling and planning staff noted was that, while the APC collects the data, it is difficult to analyze the data or generate useful reports of passenger counts. This is primarily an issue with DataMart™ and reporting functions of RTC’s ITS, and are discussed in more detail in **Section 4.5**.

RTC RIDE Supervisor APC Observations. Table 4-25 describes the current interaction of RTC RIDE supervisors with the APC.

Table 4-25: Current RTC RIDE Supervisor APC Interaction

Current RTC RIDE Supervisor APC Interactions (Planned)
• Manage passenger loads using APC data to determine when vehicles should bypass stops, or additional vehicles should be put into service

Supervisors use the APC to monitor passenger loads. They may observe a vehicle with a large number of passengers and then contact the vehicle operator to determine whether it is at capacity and another vehicle should be dispatched, or it should bypass a stop. In cases where a vehicle breaks down, it can help the supervisors determine the quantity and type of replacement vehicles to dispatch.

Supervisors do not rely solely on the passenger loads provided by the APC. While the indication is that the system is currently stable and reliable, the issues during implementation have kept supervisors wary of its reliability. Before acting on APC data, they usually contact the vehicle operator for verification.

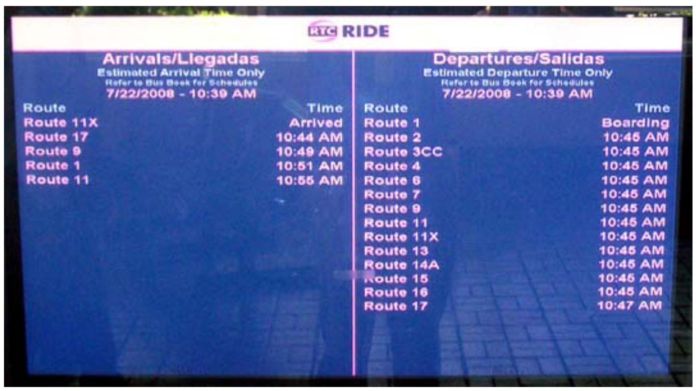
4.7 Real-Time Traveler Information for Fixed-Route Vehicles

Traveler information display signs are available at RTC CITICENTER to inform bus riders of scheduled bus departure times and operational status of RTC RIDE services. These signs are dynamic and report the time until the next bus arrives or departs in minutes, based on the actual bus’ schedule performance. The accuracy of the traveler information signs is dependent upon the accuracy of AVL data. The transit center traveler information signs are capable of displaying the following types of messages by automatic or manual information generation:

- bus destination information
- time of next arrival bus by route
- operational information (such as “Delayed”)
- time of day, system information (such as “Detour on Route 1”)
- emergency messages (such as “Emergency Routes in Effect”)

The display is adjusted to show only route information that is scheduled and actually operated through RTC CITICENTER. **Figure 4-16** shows an example of the traveler information sign at RTC CITICENTER.

Figure 4-16: Example of the RTC CITICENTER Traveler Information Display



An Arrivals/Departures display configuration typically consists of one or more display screens and a personal computer (PC). The PC provides the interface to the TransitMaster™ Arrival/Departures configuration application, which is used to determine how information is displayed. Sign and message parameters are configured through the TransitMaster™ OnStreet™ configuration application, typically located at the operations center. Route messages are provided through real-time adherence messages sent from the vehicles, as well as the TransitMaster™ schedule data. User messages are created and sent through the OnStreet™ configuration application. Messages transmitted to the sign are monitored and managed through the OnStreet™ service.

4.7.1 Real-Time Traveler Information System Interactions

Figure 4-17 shows the system interactions diagram of the real-time transit traveler information technology.

Figure 4-17: Real-Time Traveler Information System Interactions Diagram

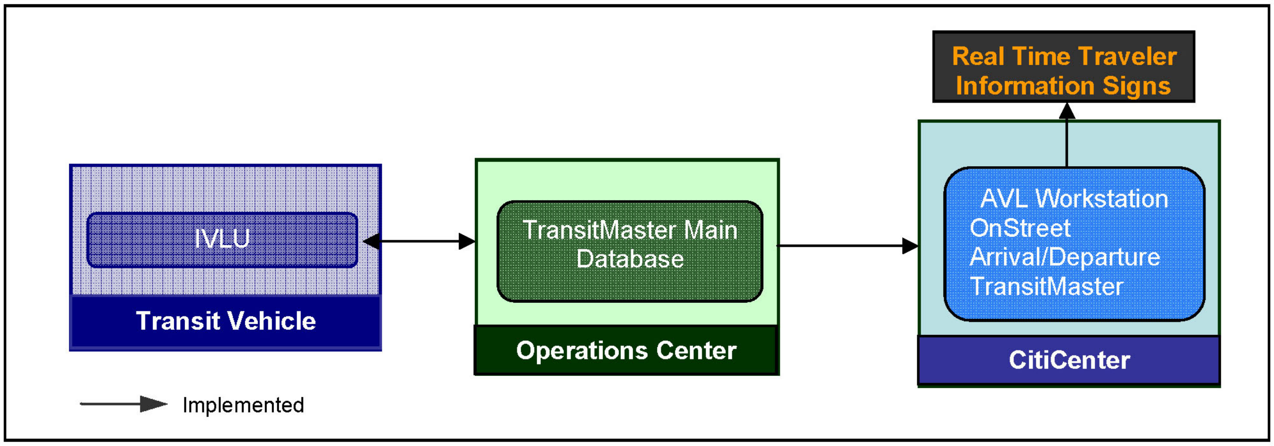


Table 4-26: Traveler Information System Data Flows

From Component	Data Flow	To Component
IVLU	Vehicle Location	TransitMaster™ Main Database (RouteManager)
TransitMaster™ Main Database (RouteManager)	Route, Run and Schedule Data	RTC CITICENTER AVL Workstation
RTC CITICENTER AVL Workstation	Arrival and Departure Data, Messages	Real-Time Traveler Information Sign

4.7.2 Capabilities

Table 4-27 illustrates how the capabilities of transit traveler information technology can address the transit ITS goals.

Table 4-27: Transit Traveler Information Technology Capabilities to Meet RTC Goals

RTC Goal	Technology Capability
Make public transit more attractive to the general population	• Providing accurate real-time traveler information to passengers increases their confidence in the service and the reliability can make it a more attractive alternative.
Maximize passenger movements	• Providing accurate real-time traveler information can ensure passengers will board on time.
Increase awareness of ITS benefits	• Providing real-time traveler information informs passengers that RTC is tracking and monitoring bus performance.

4.7.3 Current RTC Application of Traveler Information Signs

Real-time traveler information is used by two groups: RTC customer service and passengers. **Table 4-28** summarizes the various functions of the Real-time Traveler Information System.

Table 4-28: Customer Service personnel interaction with Real-Time Traveler Information

Current Interactions (Planned)
• Display arriving and departing fixed-route buses at RTC CITICENTER on a Liquid Crystal Diode (LCD) monitor • Display estimated fixed-route bus arrival time based on bus location • Display time of day • Display emergency messages • Display operational status of fixed-route buses
Planned Interaction (Not implemented)
• Display of bus detours and any information about booster vehicles

RTC Customer Service personnel observations. Two traveler information signs are implemented at RTC CITICENTER, the downtown Reno transit station. There is one in each of the two buildings open to the public. The signs list in real-time the estimated time until arrival and departure of the many routes that use the station. One sign is located directly by the customer service counter, and can reduce the number of passenger questions about schedules.

Before the implementation of advanced traveler information system, passengers often asked about bus schedules, and customer service staff used the printed schedule book to estimate when a bus would arrive. Another method they used was to talk to vehicle operators to get locations and estimated arrival times.

Customer service personnel would prefer that passengers also see the bus location on a digital map. The existing LCD signs would then display a modified version of the CAD workstation that shows a bus and its location on its route, as well as its estimated time of arrival or departure. Customer service also noted that the signs do not list information on “booster” buses (buses added in addition to scheduled service as needed). If a booster bus is added, it is not displayed and passengers may be unaware that a bus is available.

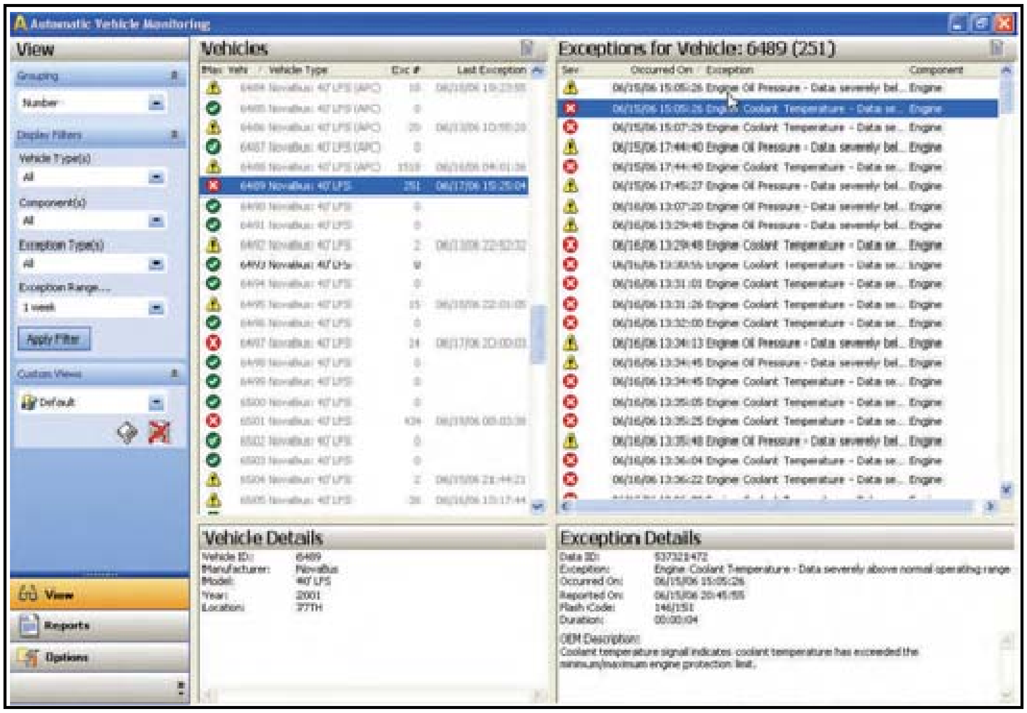
4.8 Remote Engine Diagnostics

The Remote Bus Engine Diagnostic System is a microprocessor-based test and diagnostic tool that provides automatic inspection and detection of bus engine issues. The system is designed to automatically collect faults and performance data from bus engine and report bus health status. When the vehicle odometer is linked to the MDT, vehicle mileage reports can be generated from the system to help schedule preventative maintenance.

Engine faults can be sent to the TransitMaster™ server and displayed at the TransitMaster™ workstations. A customized software interface allows maintenance staff to monitor vehicle health status, view specific vehicle data such as fuel consumption, mileage, speed, emissions and idle time, etc. **Figure 4-18** is an example screen shot of the vehicle monitoring application. Maintenance personnel can be notified of fault conditions at their desktop computers and by automatically generated reports.

Approximately one-half of the RTC fixed-route fleet is newer vehicles for which an engine interface has not been developed for the TransitMaster™ remote engine diagnostic system. These vehicles do not report engine diagnostics, but RTC expects an interface to be developed by Continental in the near future.

Figure 4-18: Example Vehicle Monitoring System



4.8.1 System Interactions

Figure 4-19 shows the system interactions of the remote engine diagnostics technology and how the data is exchanged.

Figure 4-19: System Interactions of Automated Engine Diagnostics Technology

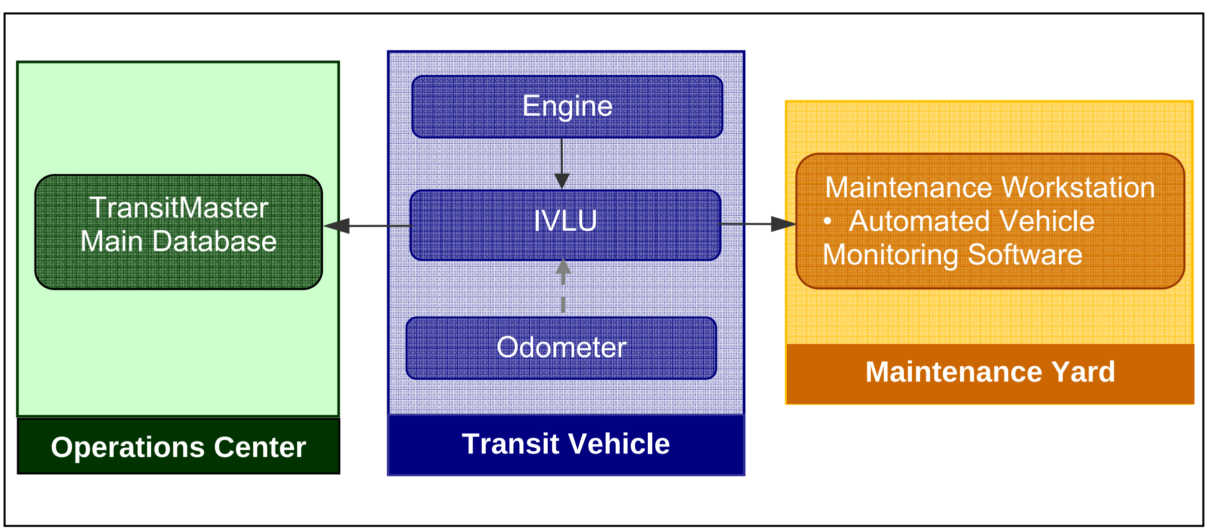


Table 4-29: Remote Engine Diagnostics System Data Flows

From Component	Data Flow	To Component
Engine	Engine Error Codes	IVLU
IVLU	Engine Error Codes	Maintenance Workstation
Planned but not Implemented		
Odometer	Vehicle Mileage	IVLU
IVLU	Vehicle Mileage	Maintenance Workstation

4.8.2 Remote Engine Diagnostics Capabilities

Table 4-30 illustrates how the capabilities of AVL technology can address the transit ITS goals.

Table 4-30: Remote Engine Diagnostics to Meet RTC Goals

RTC Goal	Technology Capability
Make public transit more attractive to the general population	• By quickly detecting and addressing engine trouble to reduce service interruptions and road calls.
Reduce operational costs	• By automating on-street diagnostics and simplifying response. • By providing quick, accurate engine diagnosis that can reduce out-of-service vehicles and extend vehicle life-cycle.

4.8.3 Current RTC Application of Remote Engine Diagnostics

Remote Engine Diagnostics is used by the RTC RIDE maintenance group on fixed-route vehicles. **Table 4-31** summarizes the various functions of the Remote Engine Diagnostics System.

Table 4-31: RTC RIDE Maintenance group interaction with Remote Engine Diagnostics

Current Interactions (Planned)
• Automatic detection and diagnostics of bus engine defects • Record bus vehicle miles for regular maintenance • Record maintenance data such as engine running hours, fuel consumption, speed, etc.
Planned Interactions Not Implemented
• Record vehicle miles travelled – Currently, maintenance personnel record VMT manually

RTC RIDE Maintenance Personnel observations. RTC RIDE Maintenance staff use Remote Engine Diagnostics to automatically detect bus engine health. The Maintenance staff are very satisfied with the system. The system automatically indicates any faults with the engine and reports. A detected engine fault is automatically reported to maintenance through a workstation in the maintenance yard, and the information is used by maintenance personnel to determine whether the vehicle needs to be taken out of service, receive immediate repair on street, should the fault be addressed at the end of a run, or be resolved by the vehicle operator. The maintenance staff indicated the system is always correct when sending an error code. Knowing the exact nature of an engine failure has resulted in maintenance being able to keep 50% to 60% of vehicles on the street that would have been brought into the maintenance yard before remote engine diagnostics. Maintenance staff also use the TransitMaster™ CAD workstation to print out a map of the location of a disabled vehicle. The map is given to the responding maintenance staff so they can find the disabled vehicle quickly.

RTC RIDE has replaced half of its fleet in recent years. Newer vehicles have a newer type engine interface, while older vehicles have another. Trapeze ITS has not completed an interface driver for the newer vehicles, so maintenance is unable to remotely monitor the engines of half of its vehicles. There is no set date for a new interface to be provided, but maintenance staff expect it within the next year. While the system diagnoses engine faults, it does not detect transmission issues. Maintenance staff would prefer to also receive transmission faults because they comprise many of the issues that disable vehicles.

4.9 Automated Stop Announcement

RTC RIDE vehicles are equipped with the ADA-compliant Trapeze ITS ASA system. The system provides passengers with information about vehicle stops, rules and rider instructions. Messages are delivered visually through interior Light Emitting Diode (LED) signs, and audibly through announcements broadcasted through the vehicle speakers.

The Automated Stop Announcement System provides the following functionality:

- Automatically announces and displays recorded information, internally, about each stop in each vehicle just prior to arriving and again upon arriving at the stop
- Records the announcements and constructs the related text
- Automatically controls on-board Destination signs

The system provides administrative preparation, reporting, analysis, and support tools.

The IVLU compares vehicle location and travel pattern with the known location of stops. At the approach to designated stops, the IVLU alerts the Automated Stop Announcement system to announce the name of the stop. The system is also integrated with the “stop requested” feature, and can also make other “canned” messages when activated by the vehicle operator.

The onboard display signs are designed to be compliant with environmental specifications. The interior signs on RTC RIDE vehicles are single-line LED. As the vehicle approaches a stop, the sign automatically scrolls the stop name. When a passenger requests a stop, the interior sign displays “Stop Requested.” When the vehicle operator selects a “canned” announcement from the MDT, such as “No Smoking”, it is displayed on the sign. **Figure 4-20** shows a picture of the onboard LED display of stop announcements:

Figure 4-20: Example of an Interior Stop Announcement Sign

The audible announcements occur simultaneous with the visual display. The stop, stop request or canned message is announced through the vehicle’s interior speakers in English and Spanish.

The Annunciator Studio™ software suite is used to create both audio and visual announcement data. The RouteManager™ application is used to map announcements to specific locations and patterns

Annunciator Studio creates the sound files and indexes used by the TransitMaster™ Main Database (RouteManager) and vehicles. Sound files and indexes are sent from the Operations Center to each vehicle. The indexes are associated with the sound files that are played on the vehicle. The indexes are imported into the TransitMaster™ Main Announcement table. The index links announcements to stops and identifies which announcement to play per stop.

Annunciator Studio allows for agencies to record their own messages. RTC has elected to hire local, professional voice talent to record the audible announcements in order to secure consistency and clear and accurate enunciation.

4.9.1 Automated Stop Announcement System Interactions

Figure 4-21 shows the system interactions for the ASA technology.

Figure 4-21: ASA System Interactions Diagram

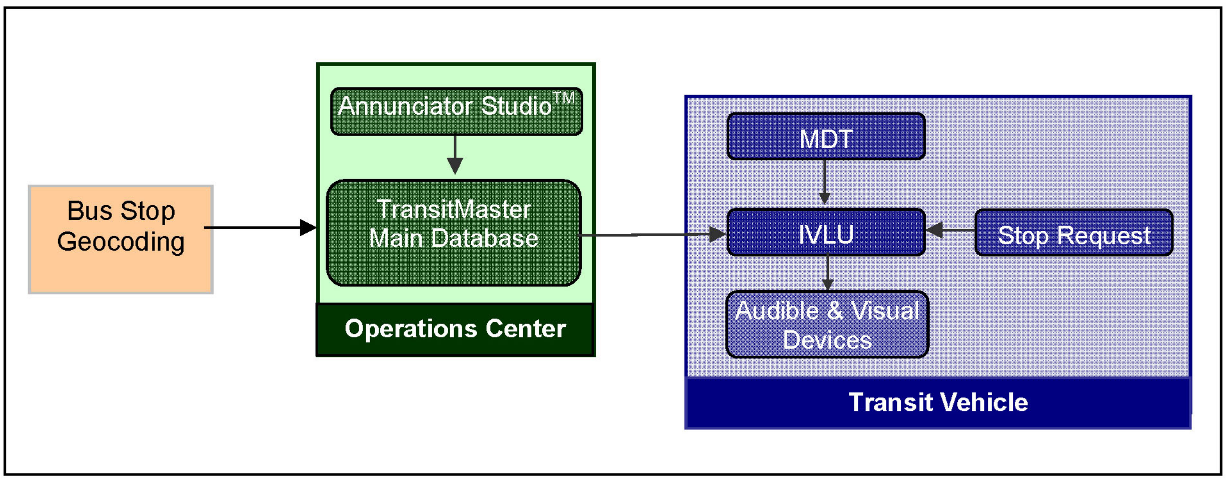


Table 4-32: ASA System Data Flows

From Component	Data Flow	To Component
Annunciator Studio	Announcement Files	TransitMaster™ Main Database (RouteManager)
TransitMaster™ Main Database (RouteManager)	Announcement Files	IVLU
MDT	Canned Announcement Requests	IVLU
Stop Request System	Stop Requests	IVLU
IVLU	Stop Announcement, Canned Messages, Stop Request Announcement	Audible and Visual Devices

4.9.2 Automated Stop Announcement Capabilities

Table 4-33 illustrates how the capabilities of ASA technology can address the transit ITS goals.

Table 4-33: ASA Technology Capabilities versus RTC Goals

RTC Goal	Technology Capability
Make public transit more attractive to the general population	• By helping RTC achieve compliance with the ADA, the ASA assists riders who are blind, cognitively impaired, or hearing impaired, as well as commuters and tourists reach their destinations.
Maximize passenger movements	• By helping riders with disabilities to use accessible fixed-route bus systems instead of relying on paratransit service.
Increase awareness of ITS benefits	• By providing clear announcements, ASA provides passengers with more information and improves the rider experience through ITS.

4.9.3 Current RTC Application of Automated Stop Annunciation

ASA is used by fixed-route vehicle operators and passengers. **Table 4-34** summarizes the planned and actual interface of fixed-route vehicle operators with the Automated Stop Announcement system.

Table 4-34: Fixed-route vehicle operator interaction with ASA

Current Interactions (Planned)
• Provide stop information along route • Inform vehicle operator to stop at next location based on the 'stop requested' option • Announce stop locations both visually and audibly • Automatically manage destination signs

RTC RIDE Vehicle Operator Observations. RTC RIDE vehicle operators are generally satisfied with the automated stop annunciation system. They believe it has helped them perform their jobs better by providing audible and visual display of stop location. The service answers common passenger questions about stop locations and allows the drivers to focus on driving. It also allows them to keep both hands on the steering wheel instead of using one to hold the handset. The system has canned messages, such as "no smoking" in English and Spanish, but most vehicle operators do not use these. The reason is that they believe they are not as effective as directly speaking to a passenger.

One observation of the ASA is that the "stop requested" message abruptly terminates a stop announcement. If a stop announcement is made while the next stop is being announced, it cuts it off. Vehicle operators also said that while the system announces intersections, it does not announce enough of the landmarks that passengers are traveling to, such as hospitals and libraries.

4.10 Transit Signal Priority

RTC planned for TSP in its ITS procurement and has equipped 56 of its fixed-route vehicles with the Opticom Infrared TSP hardware. The agency has not deployed TSP at any intersections in the Reno-Sparks area because the field equipment is not yet installed. This section describes how it is planned to work.

TSP provides transit vehicles with extended green time or shortened red time at traffic signals to reduce the time they are slowed down by traffic signals. TSP is made up of three major components: 1) the transit vehicle detection/priority request system, 2) the traffic signal control system, and 3) a communication system.

Transit Vehicle Detection / Priority Request System – For RTC's TSP application, the vehicle onboard infrared strobe emitter can send a signal to an infrared roadside detector on the local intersection approach. The vehicle IVLU will use pre-defined parameters to determine when a vehicle will request a transit signal priority. When the parameters are met, the IVLU activates the emitter. The emitter sends a cone of infrared and visible strobe light in the forward direction. **Figure 4-22** shows a typical infrared strobe emitter.

Figure 4-22: Infrared Strobe Emitter

Traffic Signal Control System – Detectors mounted on the mast arm facing approaching traffic receive the infrared transmission and relays the request to the Opticom phase selector card installed in the traffic signal controller cabinet. The interface provides authentication and authorization of priority phases. The traffic signal control system processes the priority request and determines whether to grant signal priority based on a series of pre-defined conditions. The local traffic controller makes applicable changes to the signal timing to provide priority based on the defined transit signal priority strategies. Typically, when the transit vehicle is approaching the intersection while the green signal is on (for the approach the bus is on), the controller will extend the green time to allow the bus to pass through the intersection. Or if the transit vehicle is approaching the intersection while the red signal is on, the controller will shorten the green time on the cross street approach to provide an earlier green time for the transit vehicle. After the transit vehicle has passed through the intersection, the traffic controller will receive a signal from the vehicle detection system to restore the normal signal timings through a predetermined logic. **Figure 4-23** shows a typical Opticom-type strobe detector.

Figure 4-23: Opticom Strobe Detector

4.10.1 System Interactions

Figure 4-24 illustrates the planned system interactions of a locally-controlled TSP system such as this one at RTC.

Figure 4-24: System Interactions Diagram of a Locally Controlled TSP System

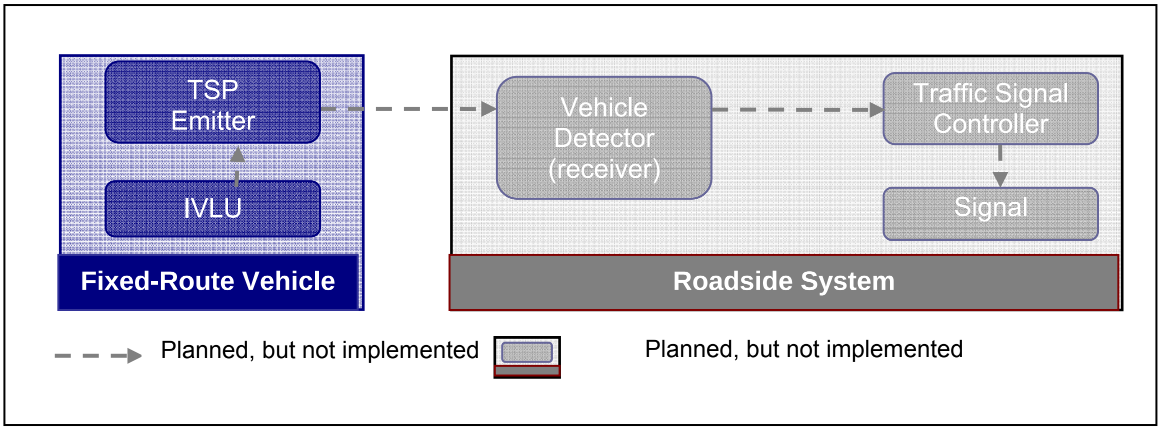


Table 4-35: TSP Technology Data Flows

From Component	Data Flow	To Component
	Planned But Not Implemented	
IVLU	Priority Request	TPS Emitter
TSP Emitter	Priority Request Signal	Vehicle Detector
Vehicle Detector	Priority Request Detection	Traffic Signal Controller
Traffic Signal Controller	Timing Change	Traffic Signal

4.10.2 Transit Signal Priority Capabilities

Table 4-36 illustrates how the capabilities of TSP technology can address the transit ITS goals.

Table 4-36: TSP Capabilities to Meet RTC Goals

RTC Goal	Technology Capability
Make public transit more attractive to the general population	• By improving schedule adherence and reducing transit travel time and variability.
Maximize passenger movements	• By improving schedule adherence and ensuring transfer points are utilized.
Reduce emission/energy use	• By reducing dwell times at intersections, both for transit vehicles and vehicles behind them.

4.10.3 Current RTC Application of TSP

RTC is not currently using TSP. It will be deployed at a date to be determined. **Table 4-37** lists the planned, but not used, interactions with TSP by RTC planning staff. **Table 4-38** lists the planned, but not used, interactions with TSP by RTC Traffic Management, a division outside of public transportation responsible for managing traffic signals.

Table 4-37: Planned RTC RIDE Planning TSP Interaction

Planned Interactions Not Implemented
• Program thresholds in schedule adherence, passenger load and other parameters for signal priority • Monitor use of TSP and adjust parameters as needed

Table 4-38: Planned RTC Traffic Management TSP Interaction

Planned Interactions Not Implemented
• Program thresholds in traffic signal phases to accept and adapt to transit signal priority requests • Monitor use of TSP and its impact on traffic congestion, delay and signal cycles

TSP Observations. While TSP has been installed on 56 RTC RIDE vehicles, no intersections have been equipped to detect transit signal priority requests. At this time, RTC Traffic Management is still planning how TSP will be used to balance transit's needs and its impact on traffic management.

4.11 Mobile Supervisor Module

The TransitMaster™ Mobile Supervisor is a module that serves as a mini dispatch suite running on a laptop computer mounted within the supervisor vehicle and connected to the TransitMaster™ system through a high-speed wireless connection. The Mobile Supervisor Module displays a digital map with vehicle locations, very similar to the CAD workstation used by the off-street supervisors and dispatchers. The purpose is to allow field supervisors to monitor vehicles in real-time.

The Mobile Supervisor Module also allows the on-street supervisors to communicate directly with the vehicle operators. The Mobile Supervisor Module allows them to call and receive calls from vehicles, instead of working through dispatch. The system uses an IVLU to perform GPS, serve as radio modem, manage communications and exchange data with the TransitMaster™ Main Database.

The Mobile Supervisor Module addresses two key issues with vehicle operators and supervisors. The first is that vehicle operators prefer supervisors to be on the roads so they can respond quickly to operator needs. The second is that supervisors believe they can better manage the fleet by seeing an overall picture of performance and status through the CAD display. Using the Mobile Supervisor Module, supervisors can be on-street while monitoring the performance of all vehicles.

Although it was planned and specified, the Mobile Supervisor Module was not implemented at RTC because the software was not fully developed at the time. Mobile Supervisor Module requires a high-speed wireless network in order to exchange large amounts of data regarding the location and status of each vehicle, as well as communications information and messages. At the time of RTC's transit ITS implementation; there was no cost-effective means for providing high-speed wireless data communications to supervisor vehicles. The radio data system is adequate for the data exchanged between the operations center and transit vehicles, but it does not provide enough bandwidth for Mobile Supervisor Module's needs. The cost of cellular data transmission was explored, but deemed cost-prohibitive in 2002. RTC instead opted not to implement Mobile Supervisor Module.

Since 2002, significant improvements have been made in cellular data transmission. The networks are more robust and more companies provide them. The result is that high-speed cellular data transmission is considerably less expensive today. Given that, RTC may consider deploying Mobile Supervisor Module at a future date.

4.11.1 System Interactions

Figure 4-25 illustrates the planned system interactions of the Mobile Supervisor Module at RTC.

Figure 4-25: System Interactions Diagram of a Mobile Supervisor Module

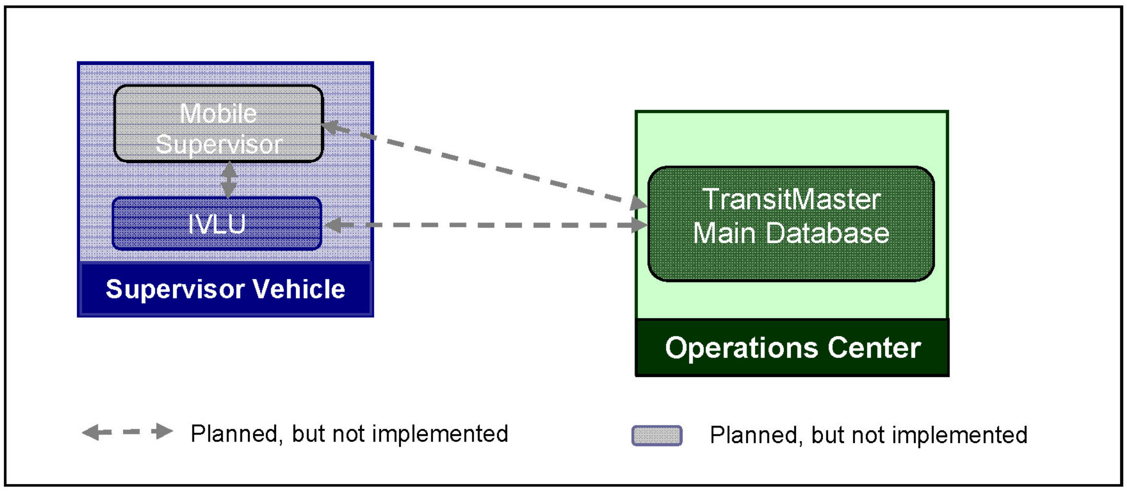


Table 4-39: Mobile Supervisor Module Data Flows

From Component	Data Flow	To Component
Planned But Not Implemented		
Mobile Supervisor Module	Messages, Communications Data, Data Requests, Incident Logs, Notes	IVLU
Mobile Supervisor Module	Messages, Communications Data, Data Requests, Incident Logs, Notes	TransitMaster™ Main Database (RouteManager)
IVLU	Messages, Vehicle Location Data, Communications Data, Passenger Count Data, Review Data	Mobile Supervisor Module
IVLU	Messages, Communications Data, Data Requests, Incident Logs, Notes	TransitMaster™ Main Database (RouteManager)
TransitMaster™ Main Database (RouteManager)	Messages, Communications Data, Vehicle Location Data, Passenger Count Data, Review Data	IVLU

Note that the data flows describe above are only those relevant to Mobile Supervisor Module and do not include those described in **Section 4.1**, AVL. If Mobile Supervisor Module were deployed, the supervisor vehicle would still be equipped for AVL.

4.11.2 Mobile Supervisor Module Capabilities

Table 4-40 illustrates how the Mobile Supervisor Module can address the transit ITS goals.

Table 4-40: Mobile Supervisor Module Capabilities to Meet ITS Goals

RTC Goal	Technology Capability
Maximize passenger movements	• By providing more accurate schedule adherence information.
Reduce operational costs	• By helping supervisors make effective adjustments. • By reducing spare vehicles needed.
Increase awareness of ITS benefits	• By improving operational effectiveness and efficiencies via ITS technology – utilizing real-time data.

4.11.3 Current RTC Application of Mobile Supervisor Module

RTC has not deployed the Mobile Supervisor Module. **Table 4-41** describes how the field supervisors may have used Mobile Supervisor Module.

Table 4-41: Planned RTC RIDE Mobile Supervisor Module Interaction

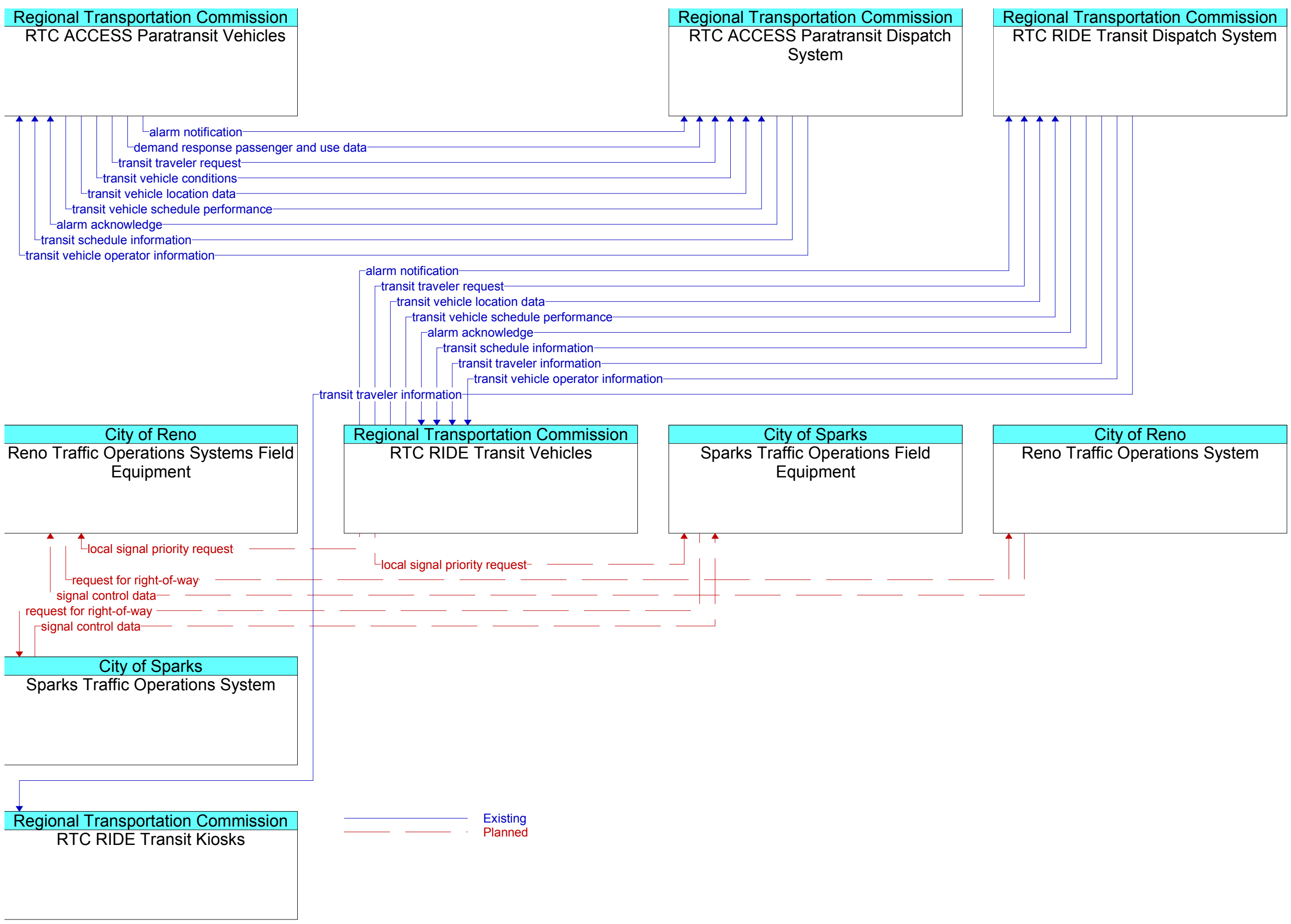
Planned Interactions Not Implemented
• View vehicle schedule and route adherence • Communicate with vehicle operators and dispatch • Exchange messages with fixed-route vehicle operators and on-street supervisors • Review reports for schedule adherence and passenger loads • Review grievances regarding schedule and route adherence • Exchange messages with paratransit vehicle operators • Use playback to determine validity of customer complaints and plan response • Manage vehicle schedule and route adherence • Manage passenger loads

Note: Since completion of this study's on-site review and evaluation, RTC IT staff have developed a vehicle-mounted laptop for supervisors to use on the road. The laptop remotely runs TransitMaster™ AVL and CAD modules over cellular broadband.

5. RTC ITS ARCHITECTURE

The Nevada Department of Transportation developed a regional ITS Architecture for Northern Nevada in 2004. The Architecture included the existing and planned operations of RTC. This section summarizes the Market Packages and data flows planned and/or implemented as they were reflected in the Northern Nevada ITS Architecture. **Figure 5-1** shows the existing and planned physical architecture for RTC transit ITS.

Figure 5-1: RTC Transit ITS Architecture

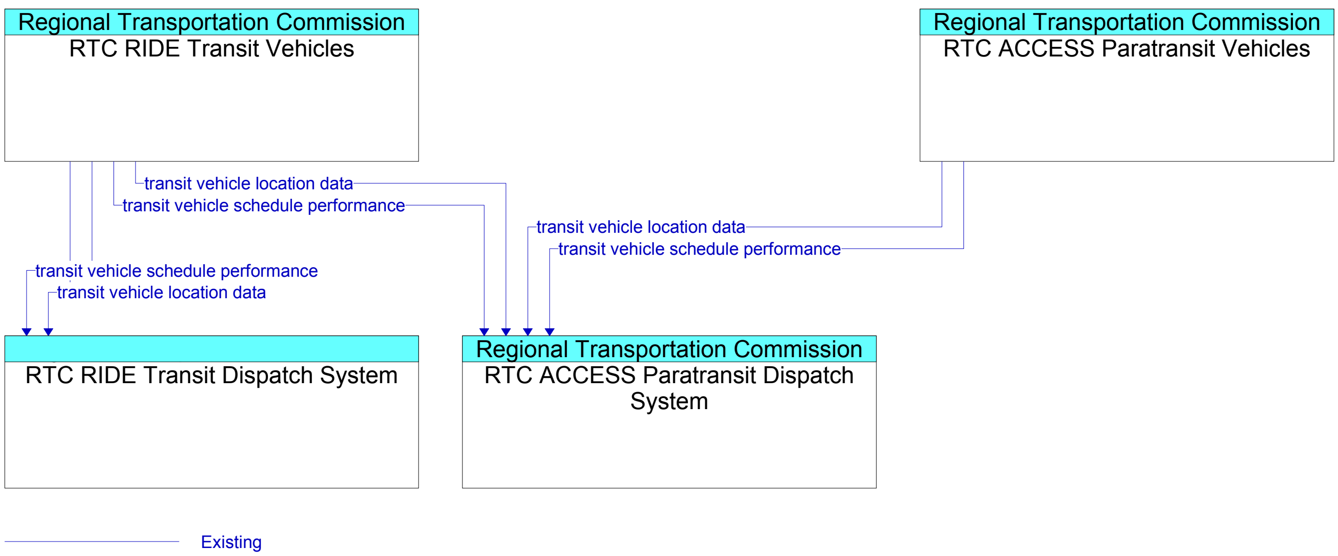


The Northern Nevada Regional ITS Architecture that included RTC was developed in 2004. The national ITS architecture has evolved since that time. As a result, the following summary of the RTC transit ITS includes notes regarding the national ITS Architecture changes since 2004 that affect the RTC ITS Architecture.

5.1 Transit Vehicle Tracking

The transit vehicle tracking market package (APTS01) monitors current transit vehicle location using an Automated Vehicle Location System. The location data may be used to determine real-time schedule adherence and update the transit system's schedule in real-time. Vehicle position may be determined either by the vehicle (e.g., through GPS) and relayed to the infrastructure or may be determined directly by the communications infrastructure. A two-way wireless communication link with the Transit Management Subsystem is used for relaying vehicle position and control measures. Fixed-route transit systems may also employ beacons along the route to enable position determination and facilitate communications with each vehicle at fixed intervals. The Transit Management Subsystem processes this information, updates the transit schedule and makes real-time schedule information available to the Information Service Provider.

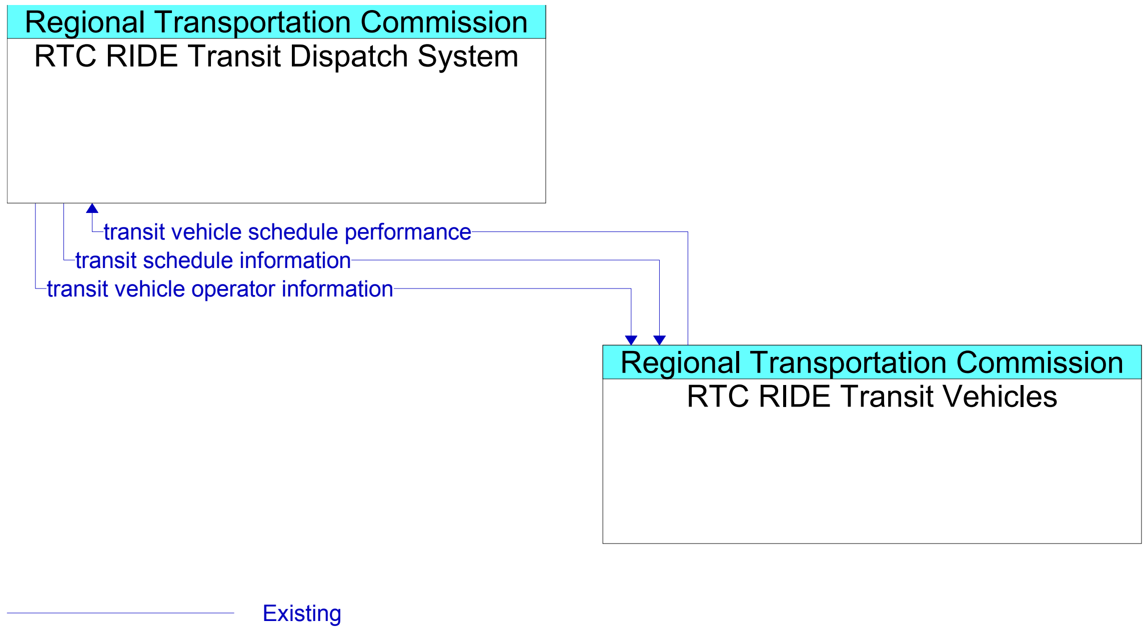
Figure 5-2: RTC Transit Vehicle Tracking



5.2 Transit Fixed-Route Operations

The Transit Fixed-Route Operations market package (APTS02) performs automated dispatch and system monitoring for fixed-route and flexible-route transit services. This service performs scheduling activities including the creation of schedules, blocks and runs, as well as operator assignment. This service determines the transit vehicle trip performance against the schedule using AVL data and provides information displays at the Transit Management Subsystem. Static and real-time transit data are exchanged with Information Service Providers where it is integrated with that from other transportation modes (e.g. rail, ferry, air) to provide the public with integrated and personalized dynamic schedules.

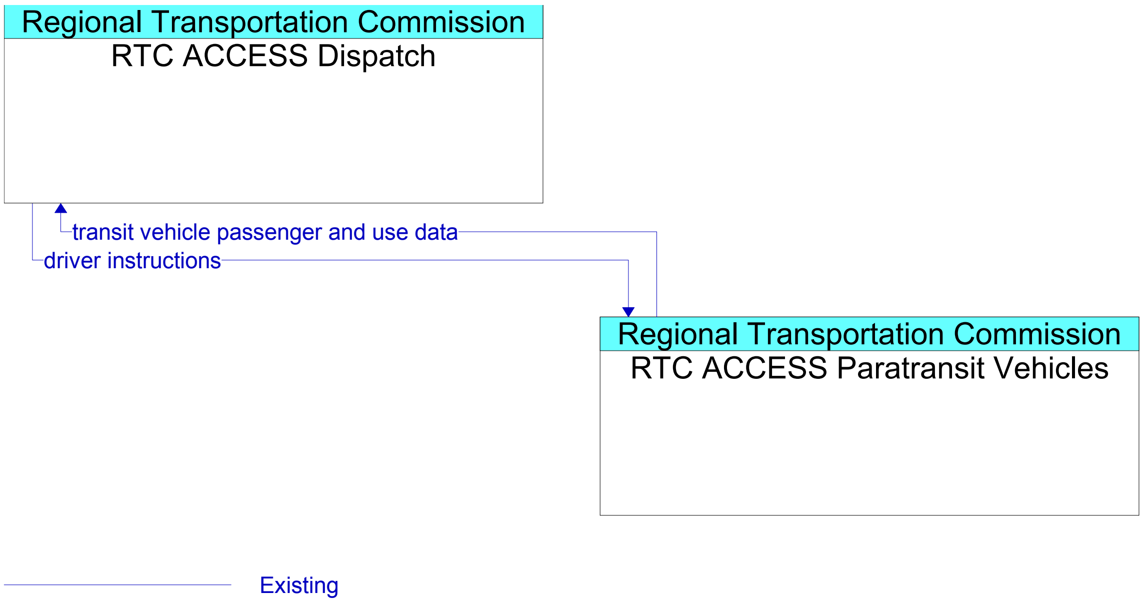
Figure 5-3: RTC Transit Fixed-route Operations



5.3 Paratransit Transit Operations

The Paratransit Transit Operations market package (APTS03) performs automated dispatch and system monitoring for demand responsive transit services. This service performs scheduling activities, as well as operator assignment. In addition, this market package performs similar functions to support dynamic features of flexible-route transit services. This package monitors the current status of the transit fleet and supports allocation of these fleet resources to service incoming requests for transit service while also considering traffic conditions. The Transit Management Subsystem provides the necessary data processing and information display to assist the transit operator in making optimal use of the transit fleet. This service includes the capability for a traveler request for personalized transit services to be made through the Information Service Provider (ISP) Subsystem. The ISP may either be operated by a transit management center or be independently owned and operated by a separate service provider. In the first scenario, the traveler makes a direct request to a specific paratransit service. In the second scenario, a third party service provider determines that the paratransit service is a viable means of satisfying a traveler request and makes a reservation for the traveler.

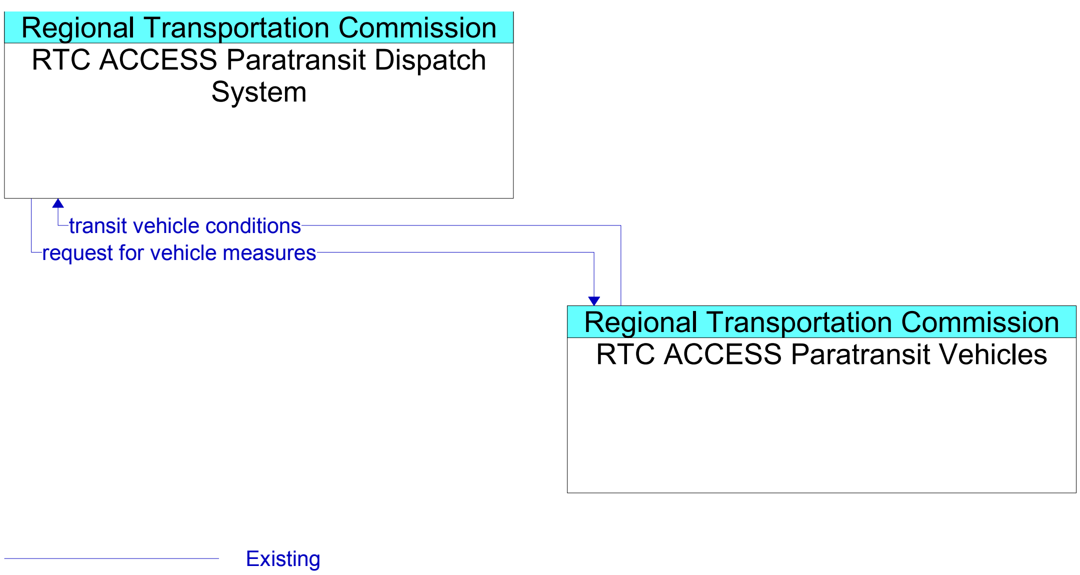
Figure 5-4: RTC Paratransit Transit Operations



5.4 Transit Fleet Management

The Transit Fleet Management market package (APTS06) supports automatic transit maintenance scheduling and monitoring. On-board condition sensors monitor system status and transmit critical status information to the Transit Management Subsystem. Hardware and software in the Transit Management Subsystem processes this data and schedules preventive and corrective maintenance. The market package also supports the day to day management of the transit fleet inventory, including the assignment of specific transit vehicles to blocks.

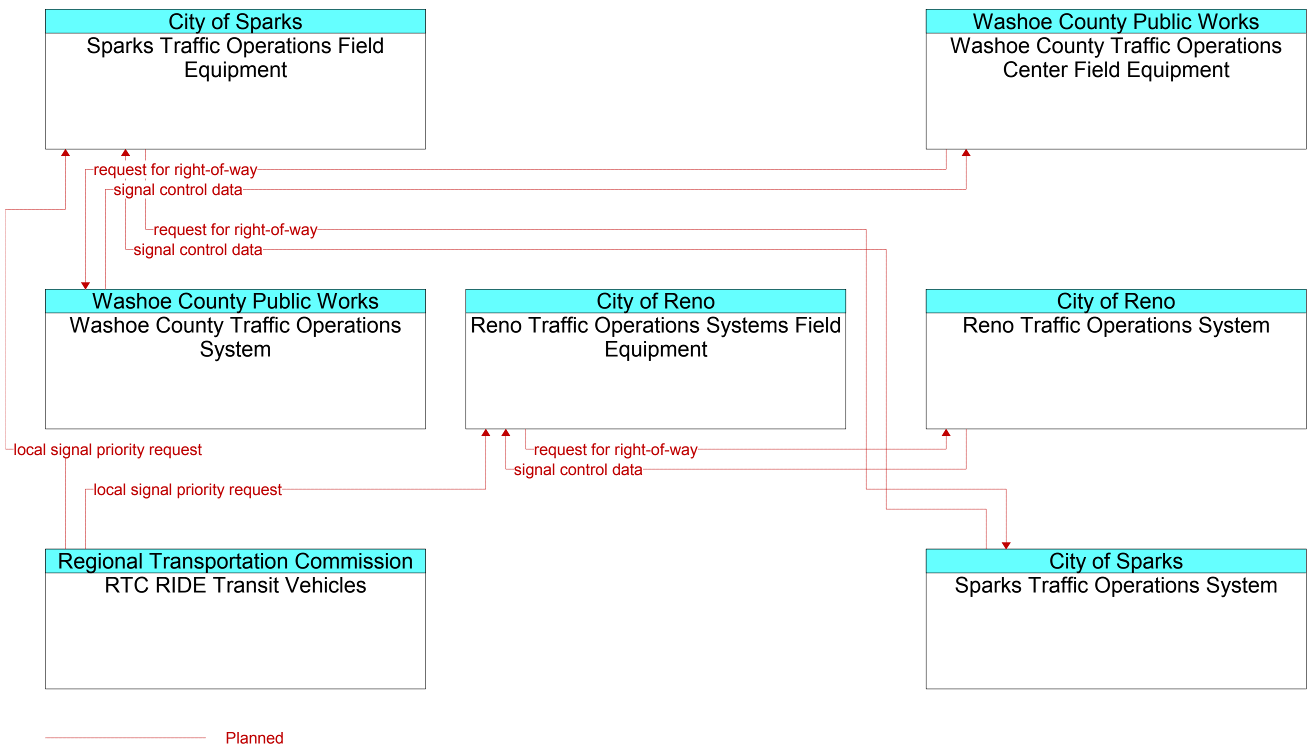
Figure 5-5: RTC Transit Fleet Management



5.5 Multi-Modal Coordination

The Multi-Modal Coordination market package (APTS07) establishes two-way communications between multiple transit and traffic agencies to improve service coordination. Multi-modal coordination between transit agencies can increase traveler convenience at transfer points and clusters (a collection of stops, stations or terminals where transfers can be conveniently made) and also improves operating efficiencies. Transit transfer information is shared between Multi-modal Transportation Service Providers and Transit Agencies.

Figure 5-6: RTC Multi-Modal Coordination

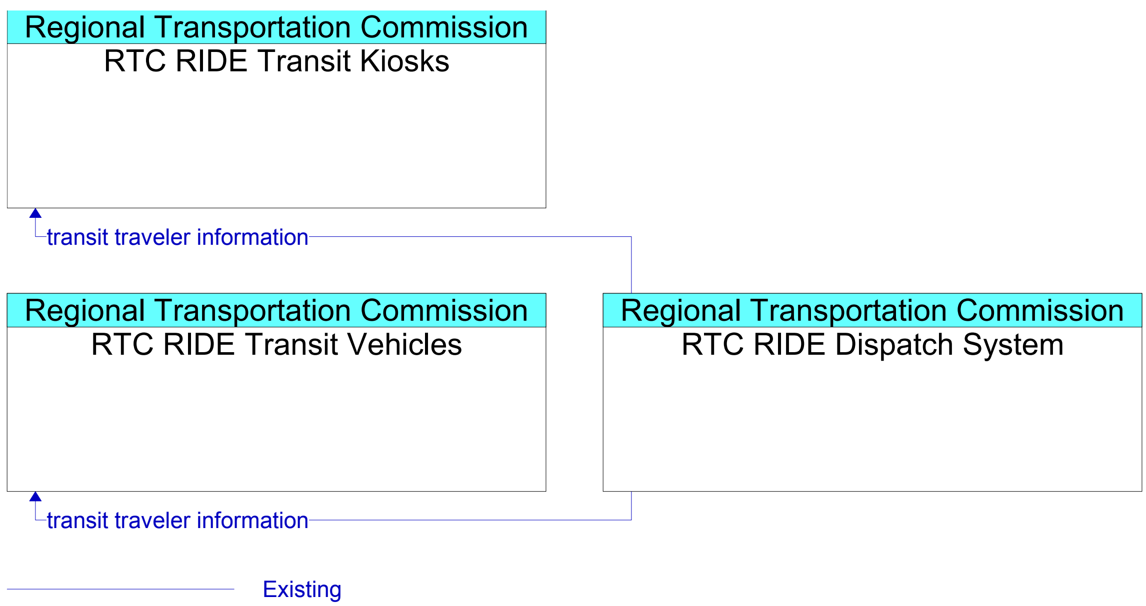


For RTC, multi-modal coordination is limited to TSP. More recently developed architectures have a separate market package (APTS09) specifically for TSP. It is no longer considered a portion of Multi-Modal Coordination. The northern Nevada Regional Architecture shows RTC RIDE vehicles planning to communicate with traffic signals controlled by Sparks, Reno and Washoe County. As previously discussed, TSP has not been implemented. It has not been decided with which traffic signals RTC vehicles will communicate.

5.6 Transit Traveler Information

The Transit Traveler Information market package (APTS08) provides transit users at transit stops and on-board transit vehicles with ready access to transit information. The information services include transit stop annunciation, imminent arrival signs, and real-time transit schedule displays that are of general interest to transit users. Systems that provide custom transit trip itineraries and other tailored transit information services are also represented by this market package.

Figure 5-7: RTC Transit Traveler Information



6. RTC ITS IMPLEMENTATION GOALS

At the start of the ITS implementation planning in 1998, RTC developed six goals for ITS. The goals, based on a review of the agency's priorities that directly correlated to customer service improvements, improved operations and maintenance, and enhanced safety, were as follows:

1. Make public transportation more attractive to the general public
2. Maximize passenger movements
3. Reduce operational costs
4. Reduce emissions/energy use
5. Improve public transportation safety
6. Increase the awareness of ITS benefits

This section analyzes and discusses the impact of ITS on each of the goals. It considers quantitative data and the perception of RTC staff to describe the role of ITS in achieving each goal.

6.1 Make Public Transportation More Attractive to the General Public

RTC has actively increased its use of the ITS system to improve its customer service and system performance in the last two years (2006-2008). The following measures are considered functions of transit ITS that make transit more attractive to the general public:

- Improved schedule adherence
- Improved scheduling and planning
- Improved bus stop facilities
- Improved traveler information

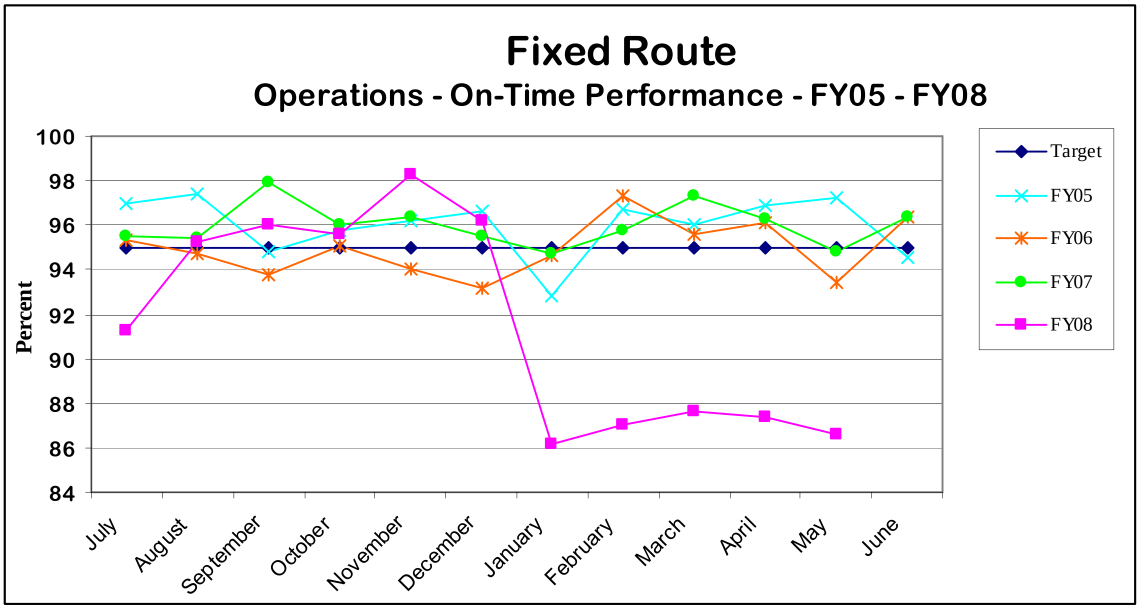
A description of how each of these elements is being enhanced at RTC RIDE through the use of ITS follows.

6.1.1 Improved Schedule Adherence

Prior to the implementation of ITS, RTC RIDE manually collected on-time performance data. The data was primarily collected through observation by on-street supervisors. Because of the supervisors' other duties, data was collected infrequently. It was usually not collected during peak periods or major events that required the supervisors' attention. The supervisors also tended to collect schedule adherence data at the beginnings and ends of routes, such as RTC CITICENTER, where they were able to collect time data for multiple routes at one location. The stops at remote locations, or mid-route, were not as regularly collected. The supervisors believe that RTC RIDE buses tend to be off schedule more frequently mid-route than at the beginning or end of a route.

The AVL on RTC RIDE vehicles automatically collects schedule adherence data for every stop on every route, with the exception of the Sierra Spirit route, which does not have published time points. RTC began using its AVL data to document on-time performance in January 2008. **Figure 6-1** illustrates RTC RIDE's measured on-time performance from 2005 to 2008. Prior to 2008, RTC RIDE vehicles routinely achieved on-time performance rates between 94% and 98%. **Since the use of AVL data, on-time performance is documented between 86% and 88%**. An RTC RIDE vehicle is considered on-time when it leaves a stop no more than 30 seconds before the schedule time, or arrives at the stop no more than five minutes after the scheduled time.

Figure 6-1: Fixed-Route On-Time Performance, FY2005 through FY2008



The dramatic change in the documented on-time performance in 2008 does not reflect a decrease in RTC's system performance. Rather, it reflects the change in data collection. It appears the previous data collection by supervisors provided an incomplete picture of system performance. The data collected since January 2008 gives a more accurate documentation of on-time performance.

Using AVL data, RTC RIDE is now able to view schedule adherence and analyze how different conditions affect it. For example, special events, such as Hot August Nights, a popular vintage car show, and winter weather conditions, such as snow, are included in the schedule adherence records and may skew the overall performance. Similarly, mid-route stops, peak, off-peak and weekends are counted, and each may have an impact on on-time performance differently.

RTC RIDE has not collected schedule adherence data long enough for it to impact on-time performance; however, it will be used in many ways to improve performance:

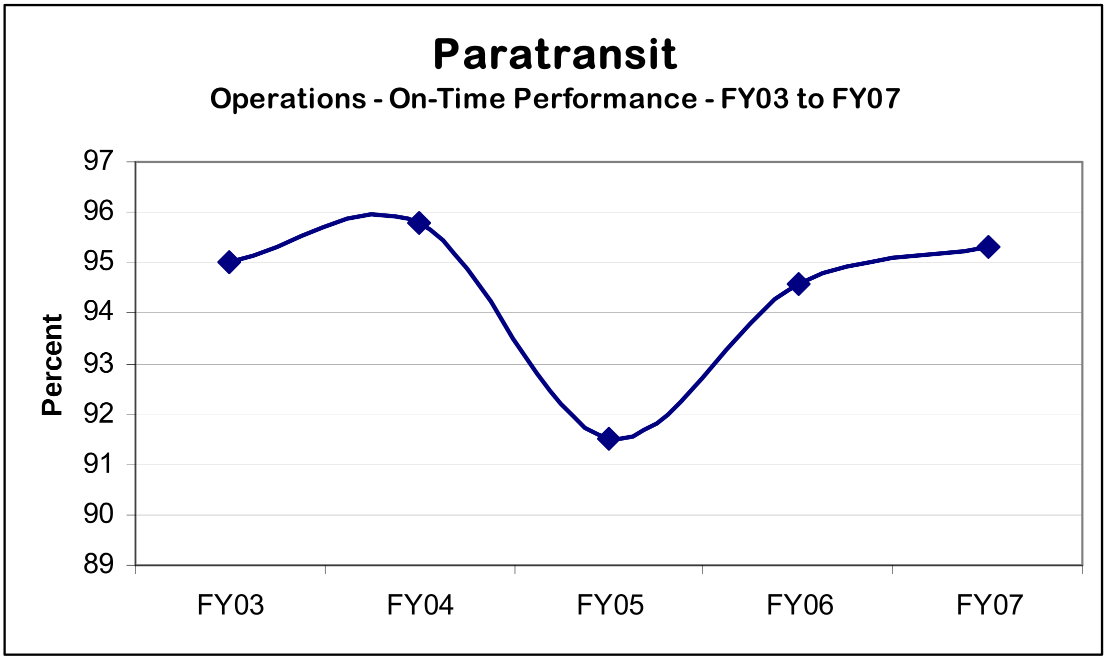
- Make schedule adjustments: While a route may arrive and depart from some points on time, it may have difficulty meeting the schedule for some midpoints. By reviewing route-specific data for peak and off-peak times, RTC RIDE will be able to make subtle adjustments to its schedules to better reflect real-world conditions, such as traffic patterns.
- Make routing adjustments: Because of changes in road geometry, long-term construction projects or traffic patterns, the ability of a vehicle to meet its schedule on some segments of its route may change. Using AVL data, troublesome segments can be easily identified and RTC RIDE can determine whether the route can be adjusted to better serve its customers.
- Isolate and review the impact of special events: In the future, the historical data collected by the AVL system may be used to customize schedules to reflect the impact of special events, such as Hot August Nights.
- Isolate and review individual vehicle operators: The AVL data can be reviewed to isolate individual operators and identify issues, such as an operator leaving or arriving at a stop early or

late. The data can be compared with the statistics for the route in general and, if the operator appears to be the cause, RTC RIDE can work with him or her to correct the issue.

- Perform playback of individual routes: Using the AVL systems playback feature, RTC RIDE can watch individual routes and identify specifically where along its route a vehicle goes off-schedule. By doing so, RTC RIDE can better understand why a particular trip or series of stops were not performed on-time.

For paratransit, RTC ACCESS schedule adherence depends largely on the ability of the trip scheduling software, Trapeze PASS™, to accurately assign trips and estimate the required travel time. **Figure 6-2** illustrates the trend in paratransit on-time performance for FY2003 to FY2007.

Figure 6-2: On-Time Performance, FY2003 through FY2007



RTC ACCESS on-time performance dropped from 95.8% to 91.5% between FY2004 and FY2005. During this time, RTC ACCESS went through several major transitions, including changing the contractor who provides the paratransit service and the implementation of Trapeze™ trip scheduling software, and to using electronic manifests for the drivers. As would be expected, the changes required vehicle operators, dispatchers and reservationists to familiarize themselves with the new functionality. By FY2006, on-time performance improved to 94.6% and to 95.3% in FY2007.

6.1.2 Improved Scheduling and Planning

One of the key elements of improved schedule adherence is realistic and achievable schedules. Section 6.1.1 discusses many ways in which RTC RIDE will use AVL data to improve its scheduling process.

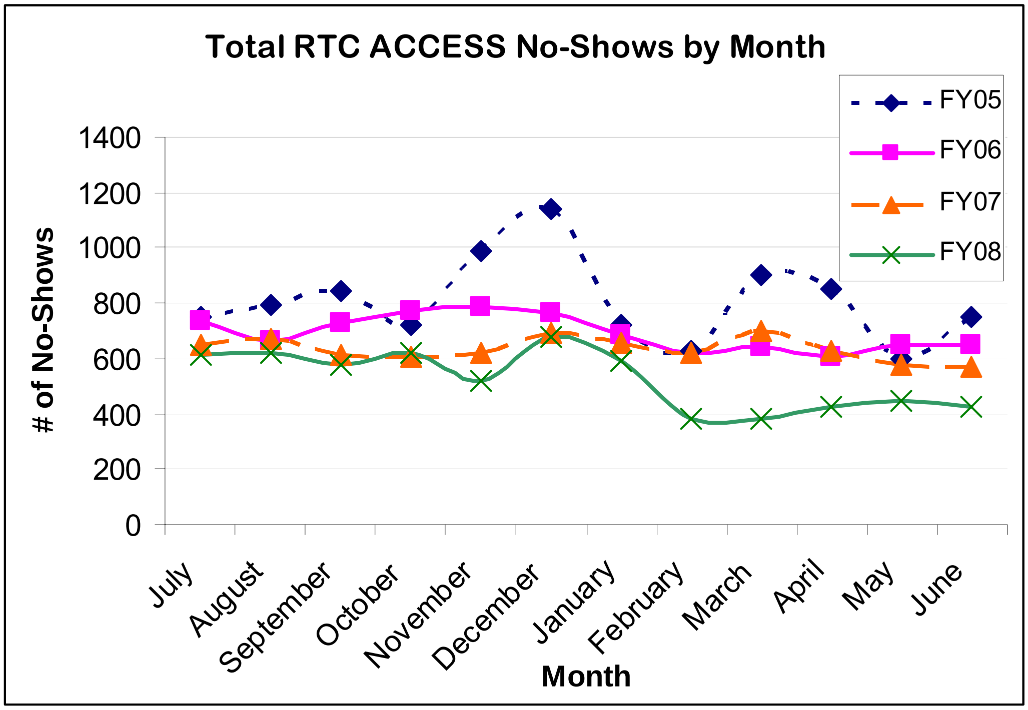
In addition to tracking vehicle locations, the transit ITS added Automated Passenger Counters (APC) that provide significant value for scheduling and planning. In 2008, RTC RIDE has begun to review the data collected by APC and AVL to make scheduling decisions by:

- Analyzing occupancy by time and location on routes: Prior to transit ITS implementation, RTC RIDE manually tracked ridership by route. The transit ITS elements of AVL and APC allow them to determine the number of riders by route segment, as well as the boarding and alightings at each stop. This data allows them to identify segments of route with low and high usage. The usage data can inform the planning staff in determining where to add service or where resources may be better allocated to serve passengers.
- Identifying key transfer points: By geographically locating boardings and alightings of each route at each location, RTC RIDE can identify key transfer points. Schedules can be adjusted to insure that passengers have enough time to make transfers.
- Tracking the impact of events on ridership: Prior to transit ITS implementation, RTC RIDE did not actively collect comprehensive ridership data by stop during special events. Because the data is now automatically collected, RTC RIDE can measure ridership and vehicle occupancy for special events, including where passengers board and alight. The data can be used to determine the amount of service to provide, as well as where the service should be provided.

RTC ACCESS has experienced improved scheduling through upgrading the paratransit scheduling software. The improved scheduling efficiency can be seen in **Figure 6-3** through the decrease of “no-shows” between late FY2005 and FY2008. A no-show is an instance where the customer does not take the trip he or she scheduled. **The 35% reduction in no-shows between FY2005 and FY2008 is interpreted partially as the result of more accurate scheduling**.

In some cases, when the scheduled vehicle is late, a paratransit customer will either give up on making the trip or find another way to make it. Note also that RTC ACCESS implemented an IVR in February 2008. The IVR automatically calls customers and reminds them of upcoming trips. As previously noted, the new scheduling software was implemented in 2005.

Figure 6-3: RTC ACCESS No Shows FY2005 to FY2008



6.1.3 Improved Bus Stop Facilities

RTC RIDE uses APC data to determine the type of amenities to place at stops. Prior to transit ITS implementation, boarding and alighting data were collected once every three years and there was no knowledge of the daily usage of each stop. Now, the APC and AVL track the number of people who get on and off at each stop. This information is used by RTC RIDE to determine whether a stop should be equipped with benches and/or shelters.

Currently, RTC RIDE has deployed and maintains 460 bus stop benches and 100 bus stop shelters. In 2006, the agency had planned to install new shelters. There are specific guidelines on stop usage that dictate whether a shelter should be placed at a stop. RTC used the APC data to determine if ridership at each particular stop justified a shelter. RTC also uses the APC data to make decisions about placing benches.

The value of the APC data to RTC comes partially from being able to observe stop usage by time of day and day of the week. For example, a stop may not appear to have much usage over a week, but further analysis of APC data by specific time or day may show that while the stop's average usage is low, it may have high usage during specific times. That information helps determine whether a bench or shelter should be placed at the stop to improve the passengers' transit experience.

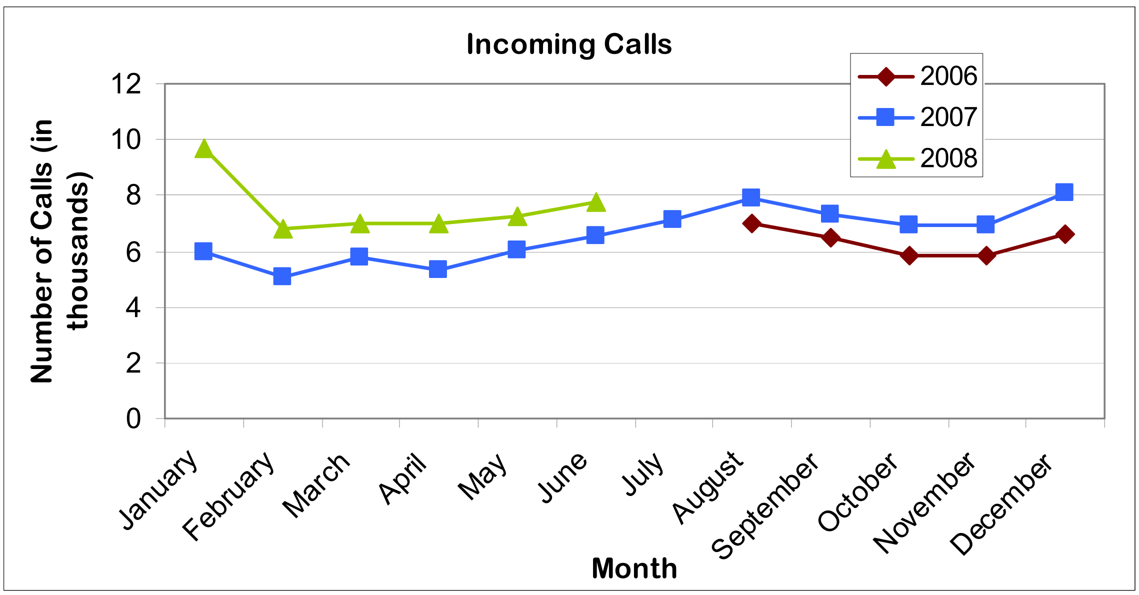
6.1.4 Improved Traveler Information

RTC RIDE and RTC ACCESS are actively using the AVL system to provide traveler information to their customers. At RTC CITICENTER in downtown Reno, RTC RIDE displays the estimated arrival and departure times of routes on an LCD screen. The times are calculated based on actual bus location and travel speeds. The transit center has heated and air-conditioned indoor space with seating for passengers. Because of the display, passengers can wait indoors during summer heat or inclement winter weather until their bus is about to leave.

RTC Customer Service staff are located at RTC CITICENTER. As a result of the traveler information signs, staff receive "far fewer" queries at the customer service window regarding the timing and whereabouts of buses.

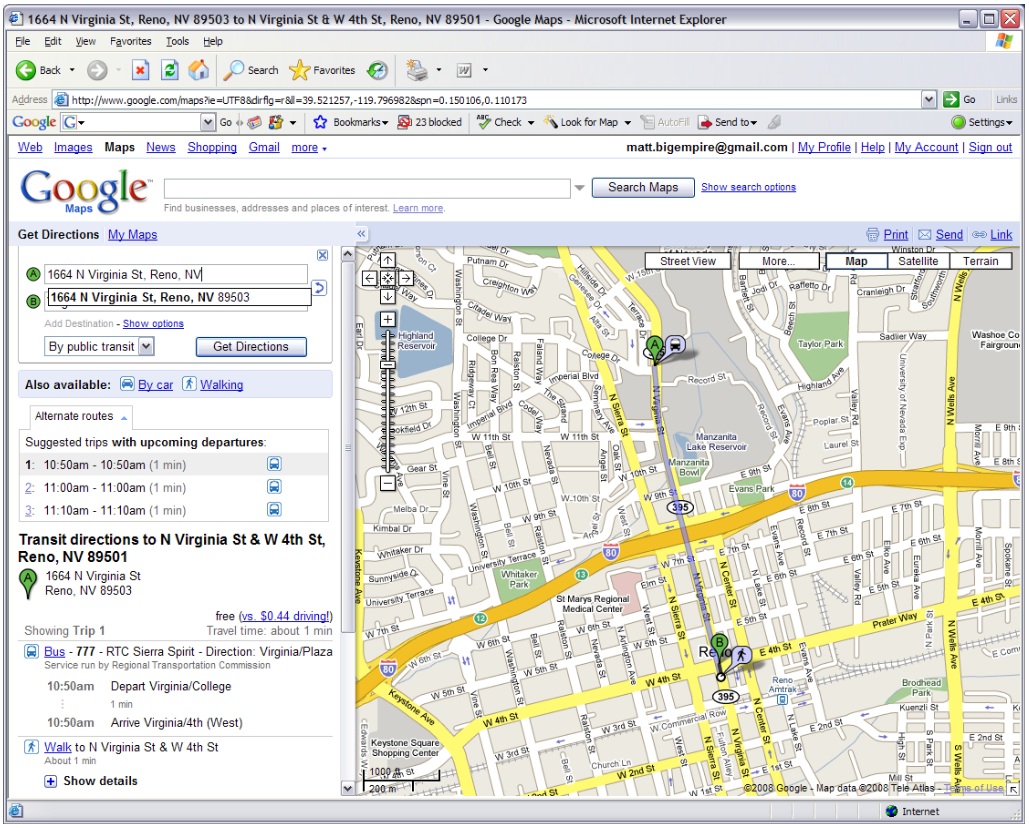
Customer Service staff also have an AVL workstation and are able to monitor the location of vehicles. Using the workstation, Customer Service is able to report to customers the estimated time of arrival of a bus at a specific stop. **Figure 6-4** shows the steady and consistent increase in calls to Customer Service since 2006. Customer Service staff report that this increase comes almost entirely from calls requesting real-time vehicle location information. They also report that customers are becoming increasingly aware that real-time information is available.

Figure 6-4: Change in Customer Service Call Volume 2006-2008



In addition, the transit ITS implementation has enabled RTC to automatically create a Google Transit™ Feed Specification (GTFS). The GTFS is a specific data format required by Google Transit™ in order for Google™ to display an agency's schedules, and provide trip planning for the agency. Google Transit™ is a web-based tool where users can enter their origin, destination and desired time of travel and it will generate a trip plan, including walking directions to and from stops, and a cost comparison to driving. **Figure 6-5** shows an example of Google Transit™ trip planning that uses data supplied by RTC.

Figure 6-5: Example of Google Transit™ Trip Planning in Reno

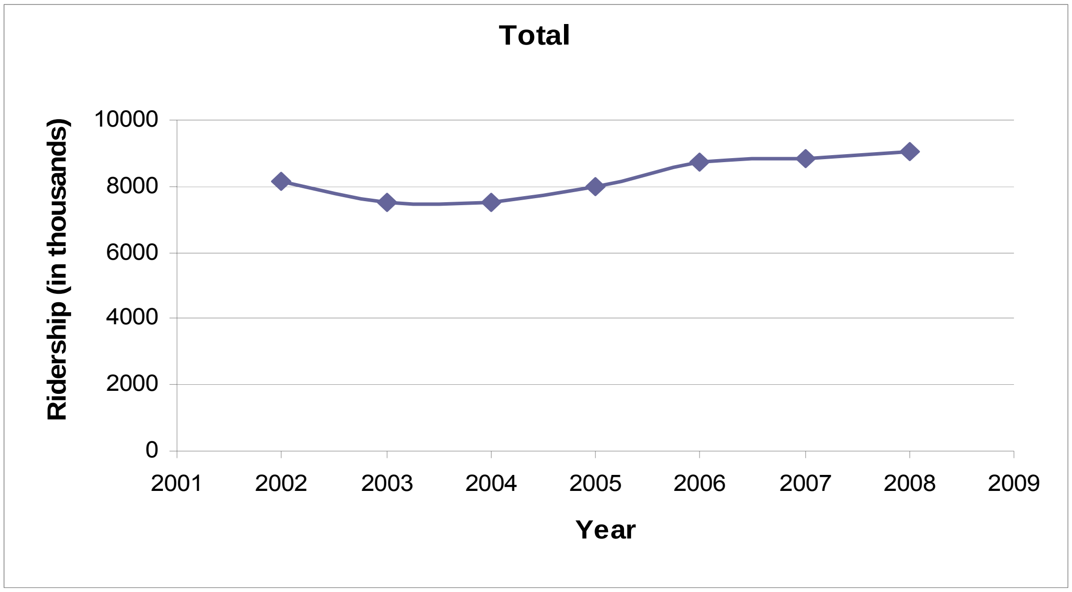


The reservationists at RTC ACCESS also serve as customer service agents for paratransit customers. Prior to transit ITS implementation, customers who called usually did not get real-time estimates of the arrival of the vehicle that would serve them. In rare instances, the reservationist could ask a dispatcher to contact the vehicle operator to determine the vehicle's exact location and estimated time of arrival. Now, reservationists have an AVL workstation and are able to quickly locate paratransit vehicles. They are then able to give customers vehicle locations and real-time estimates of how long they will take to reach their customers.

6.2 Maximize Passenger Movements

A basic measure to determine that a transit system has become more attractive is the change in ridership. If all other factors are static, public transportation ridership will rise as it becomes a more attractive alternative to travelers. In the Reno-Sparks area, **ridership on the RTC RIDE fixed-route services rose between FY2002 and FY2008 by 10.8%**, as illustrated in **Figure 6-6**. In fact, RTC RIDE ridership fell between FY2002 and FY2003, but has since risen by 20.4%.

Figure 6-6. Total Fixed-Route Ridership FY2002 to FY2008

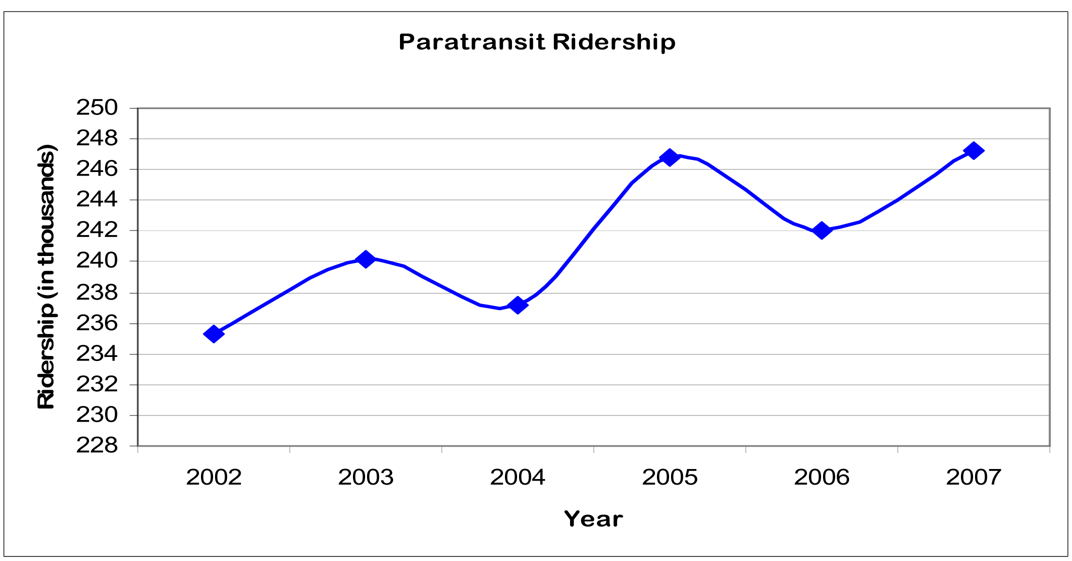


A significant factor in the increase in ridership is the addition of a new service, starting in FY2003. The service, named Sierra Spirit, is a free circulator route that runs from the University of Nevada, Reno through downtown, and back. Excluding the Sierra Spirit, ridership between FY2003 and FY2008 has increased 14.3%.

The 14.3% increase in ridership should partially be credited to the increasing population in the area. According to the U.S. Census Bureau, the population of Washoe County increased by 16.8% between 2000 and 2006.

From 2002 to 2007, **Paratransit ridership has increased by 5.1%** from 235,279 to 247,218 trips per year. The trend in ridership is illustrated in **Figure 6-7**.

Figure 6-7: Paratransit Ridership from 2002 to 2007



Many factors beyond ITS can be attributed to changes in ridership, including increasing fuel costs, fares, marketing campaigns, demographics and population densities. This study did not evaluate all potential factors. At this time, it cannot be stated definitively that RTC RIDE has seen an increase in ridership due to ITS.

6.3 Reduce Operational Costs

Transit ITS is often proposed as a way to reduce operating costs by allowing for more efficient vehicle scheduling, reduced staffing and reduced use of resources through better planning. RTC has largely not realized any operating cost reductions as a result of ITS; however, the agency is providing a higher-quality and more reliable operation with better customer service, without increasing staff.

This section discusses several cost measures used to evaluate RTC operations. Each is discussed in terms of transit ITS and other factors that impact overall operating costs. Operating cost can be assessed according to the following performance indicators:

- Total Operating Costs
- Estimated net cost per passenger trip
- Operating Efficiency

These measures were generated for both fixed-route service and the paratransit service, and are explained in the following sections.

6.3.1 Total Operating Costs

Since 2002, RTC RIDE and RTC ACCESS have each experienced significant operating costs as a result of the increasing costs of fuel, labor, vehicles and vehicle maintenance. As described in section 1.1, both services have seen an increase in ridership and the amount of service provided. **As shown in Figure 6-8, RTC RIDE has seen a 64% cost increase in its total operating costs from 2002 to 2007. Figure 6-9 shows that RTC ACCESS has experienced a 30% increase in costs from 2002 to 2007.**

Figure 6-8: RTC RIDE Total Operating Costs, 2002 to 2008

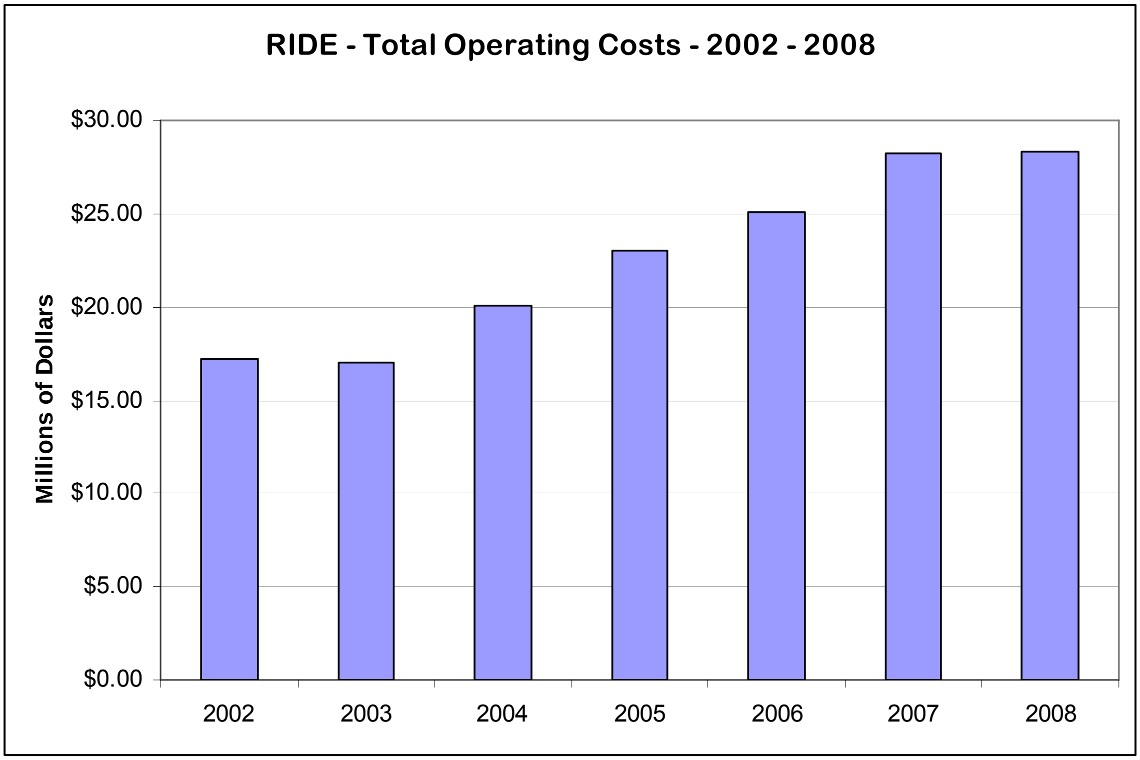
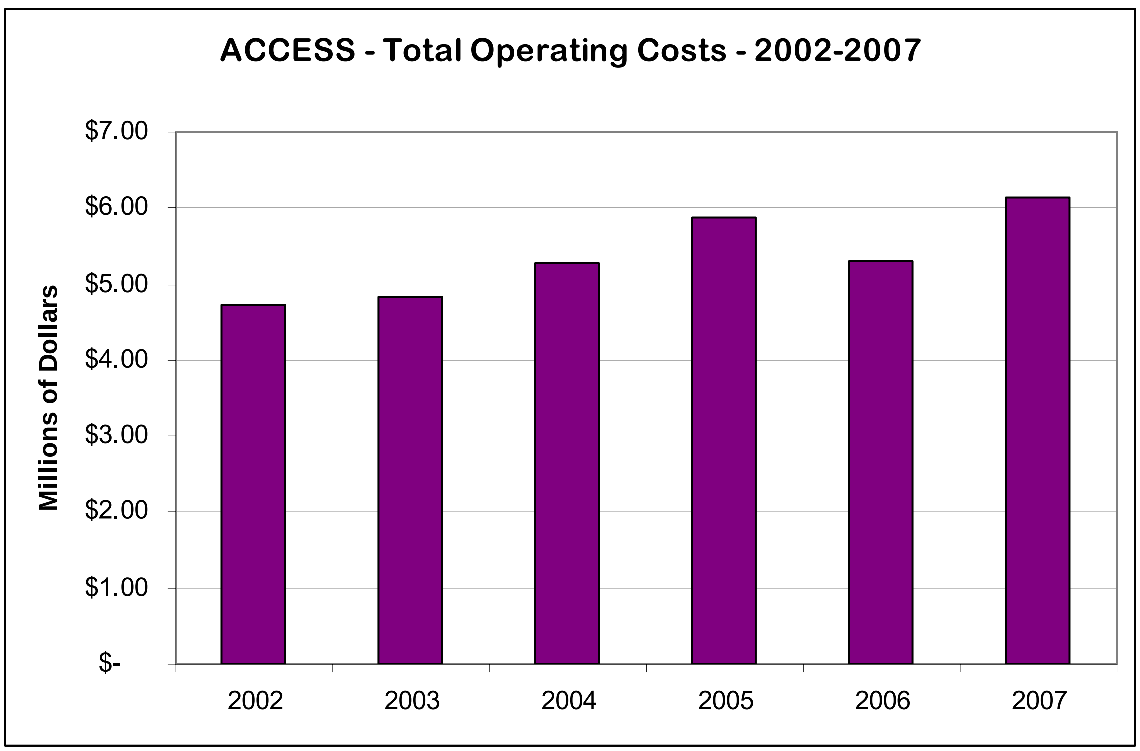


Figure 6-9: RTC ACCESS Total Operating Costs, 2002 to 2008



The increasing operating costs reveal that it has become more expensive for RTC RIDE and RTC ACCESS to operate since the implementation of transit ITS. Many factors have played a more significant role in increasing operating costs than the transit ITS. They include fuel prices that had more than doubled since 2002 at the time of this study, labor costs, accounting reallocation within the agency, vehicle replacement, replacement parts, new air quality regulation requirements and maintenance costs. The remainder of this section examines some aspects of RTC's costs to determine where transit ITS may have an impact.

6.3.2 Estimated Net Cost per Passenger Trip

Since 2002, RTC has experienced a gradual increase in net operating cost for both RTC RIDE and RTC ACCESS passenger trips. **Figure 6-10** shows the trend in RTC RIDE net operating cost per passenger trip, and **Figure 6-11** shows the trend in RTC RIDE operating cost per passenger trip mile.

Figure 6-10: RTC RIDE Net Operating Cost per Passenger, 2002 to 2008

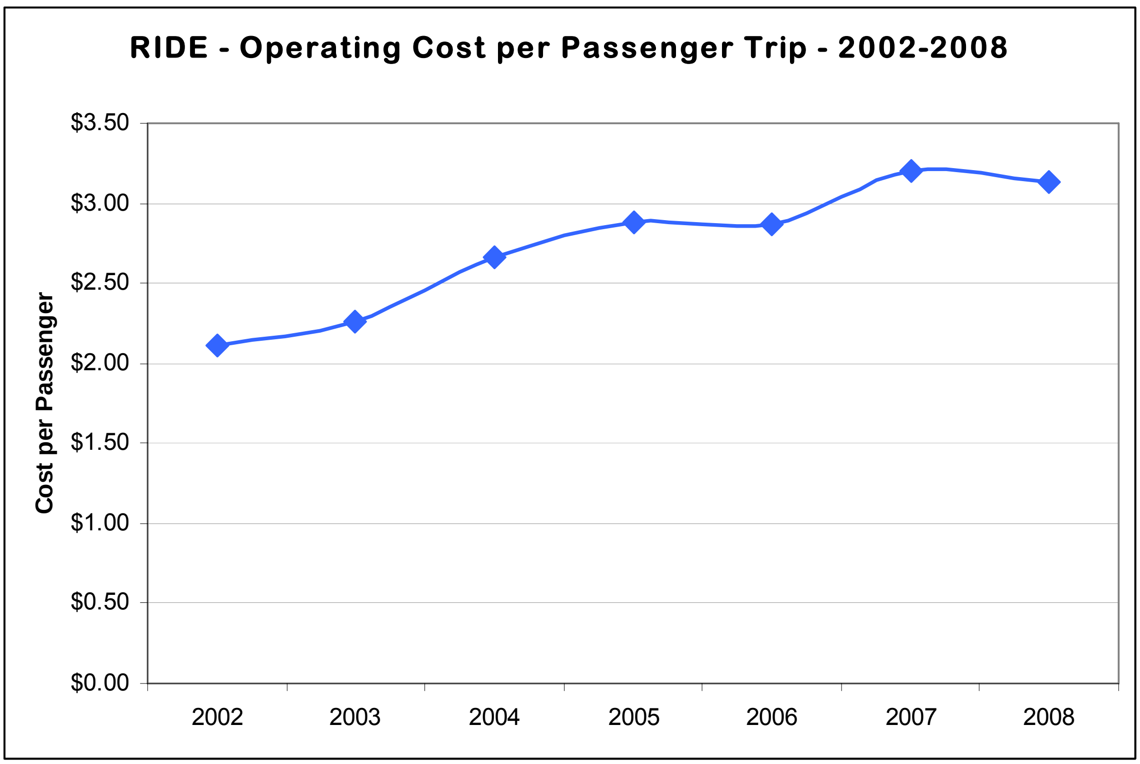
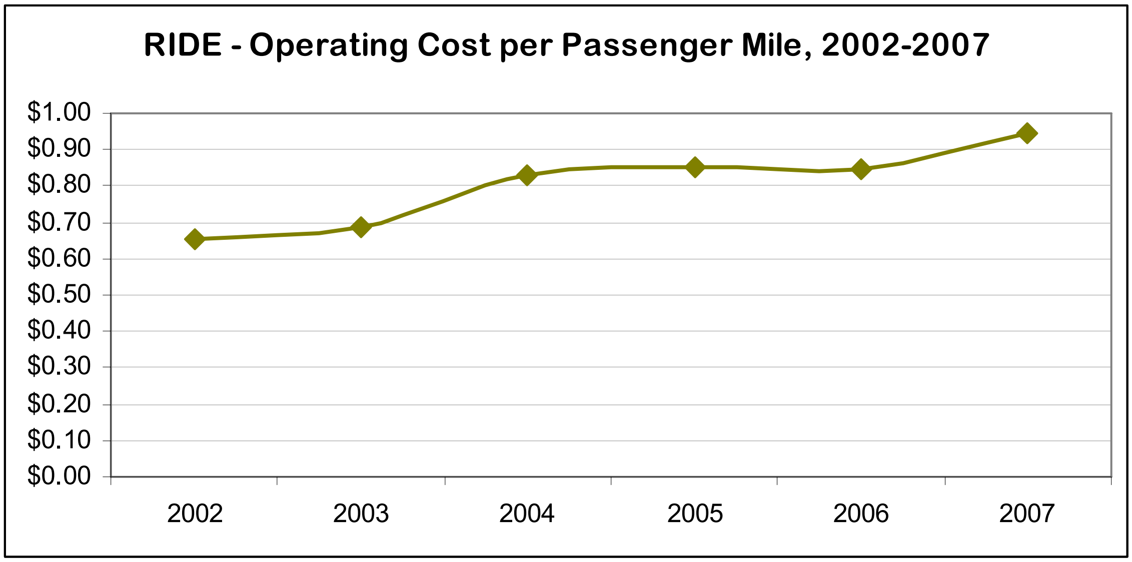


Figure 6-11: RTC RIDE Operating cost per Passenger Mile, 2002 to 2007



RTC RIDE has experienced an increase of 48% in operating cost per passenger trip, and an increase of 45% in the cost per passenger mile since 2002. This cost increase is consistent with the increase in operating costs at other, similar transit providers.

Figure 6-12 shows the trend for the operating cost per passenger at RTC ACCESS. **Figure 6-13** shows the trend in RTC ACCESS operating cost per passenger mile.

Figure 6-12: RTC ACCESS Operating cost Per Passenger Trip, 2002 to 2007

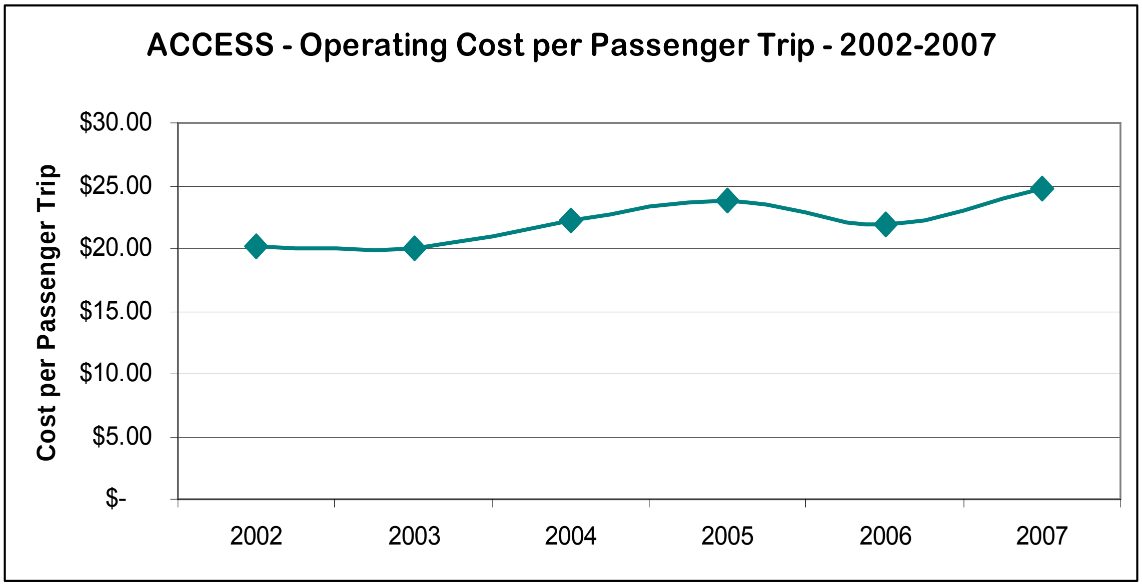
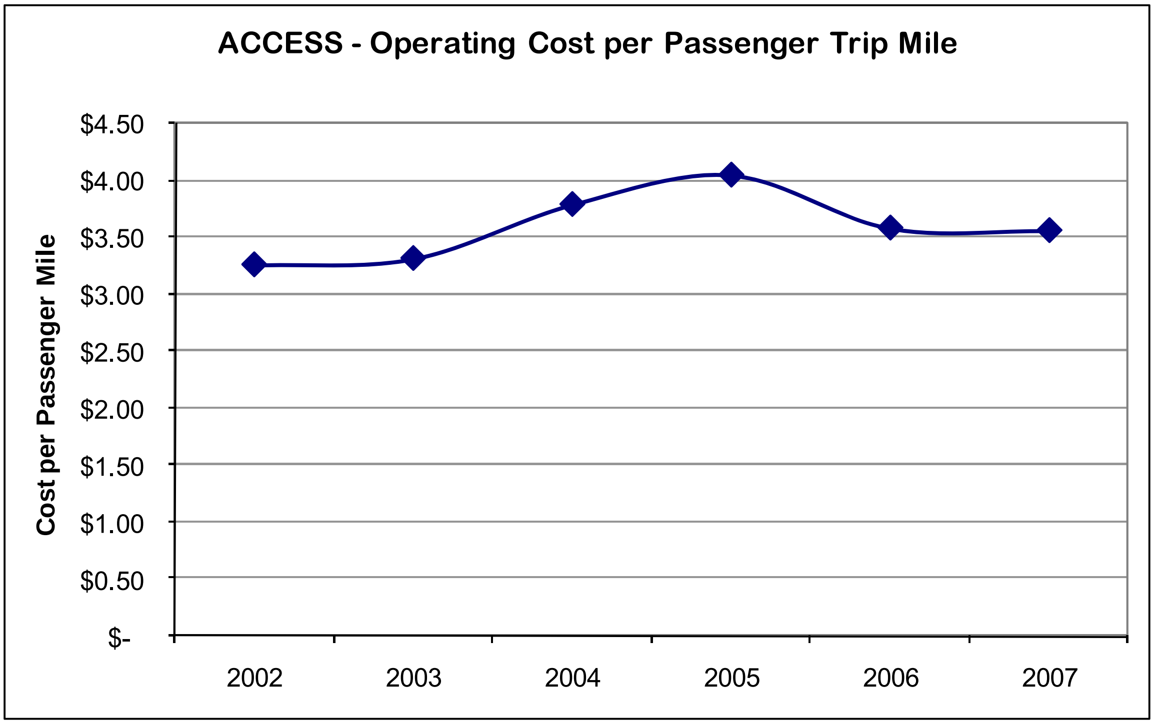


Figure 6-13: RTC ACCESS Operating cost Per Passenger Trip Mile, 2002 to 2007



From 2002 to 2007, RTC ACCESS experienced an increase of 23% in operating cost per passenger trip. This is the equivalent of an annual rate of 4.6% per year. The cost to provide a passenger trip mile increased by only 9% during the same period. This is a relatively low rate of increase given the increase in other transit costs, including fuel. RTC ACCESS attributes some cost savings to the use of transit ITS. Since its deployment, dispatch for paratransit has decreased from seven to five employees. RTC ACCESS management attributes that partially to the use of the new dispatch and trip scheduling software, as well as a new paratransit contractor.

The slow rate of operating cost increase may also be attributable to improved trip scheduling. Better management of vehicle manifests can result in higher vehicle occupancies, more efficient routing and fewer miles between passenger trips.

6.3.3 Operating Efficiency

One way in which transit ITS can reduce costs within an agency is by improving operating efficiency. Beyond delivering more service with fewer resources, operating efficiency can be measured by how well RTC meets customers' needs. Using the data generated by ITS, RTC can better anticipate and plan for its service.

Figure 6-14 shows the trend in vehicle operating hours of RTC RIDE from FY2004 to FY2008. Following that is **Figure 6-15**, which shows the trend in overtime for vehicle operators. The hypothesis is that with better management of fleets and operations through ITS, fewer hours of overtime will be required.

Figure 6-14: Straight Operating Hours for RTC RIDE, FY2004 to FY2008

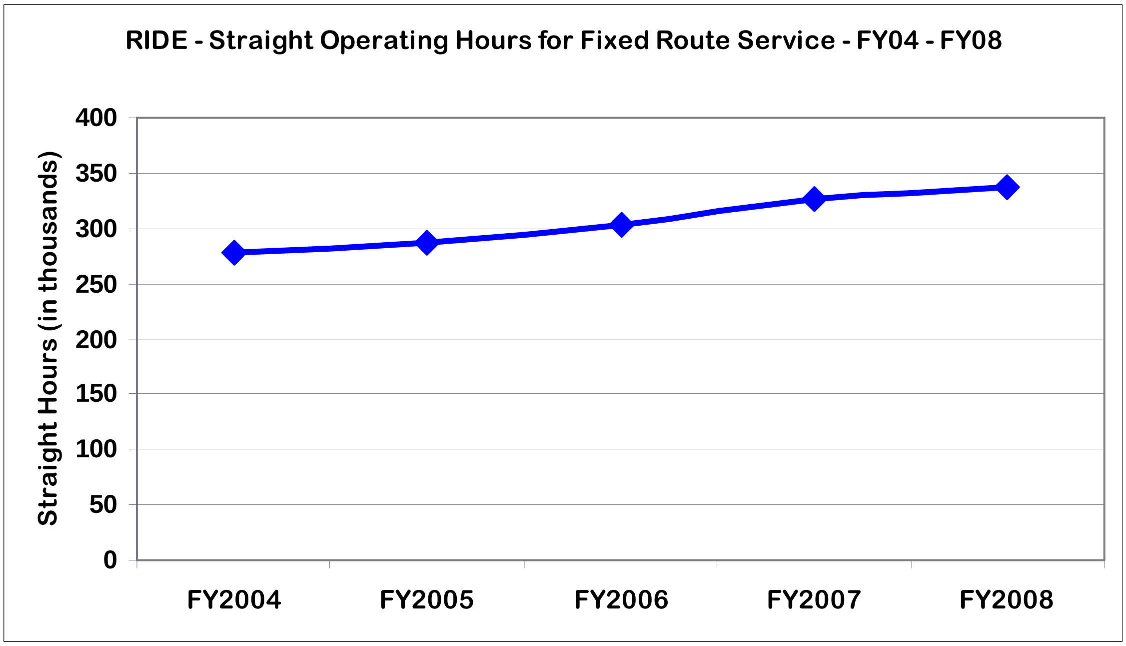
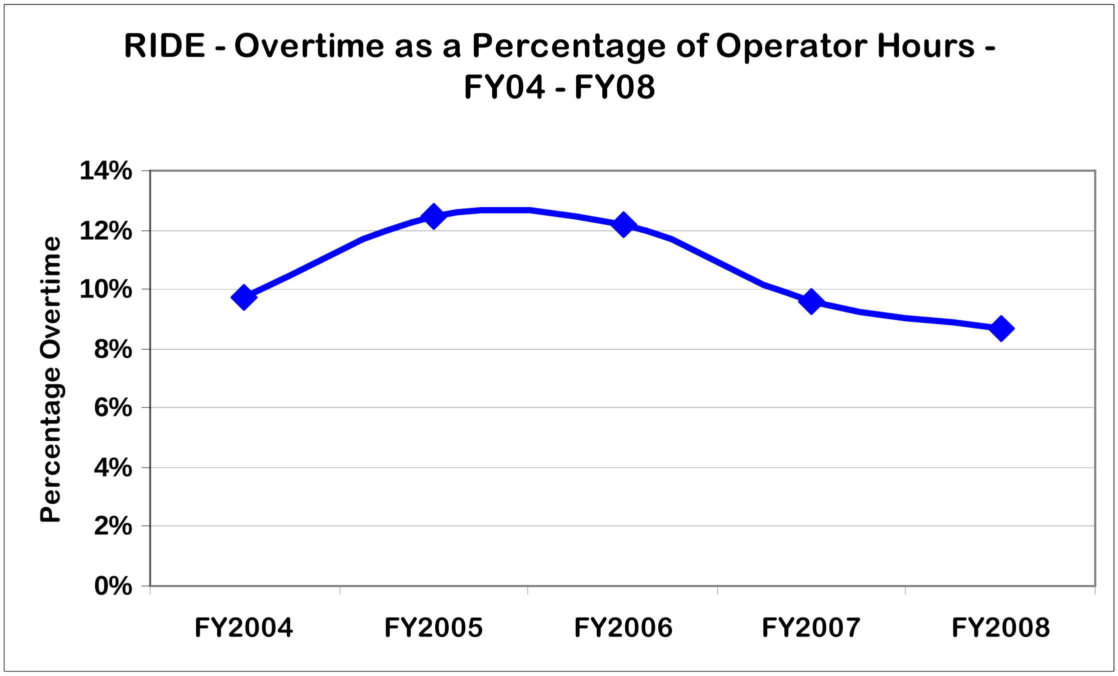


Figure 6-15: Percentage Overtime of all Operating Hours at RTC RIDE, FY2004 to FY2008



In FY2005, 12.4% of all vehicle operating hours were overtime. By FY2008, however, overtime operating hours dropped to 8.4%. Transit ITS may play a significant role in the reduction of overtime operating hours for the following reasons:

- Vehicle operator scheduling – RTC RIDE communicates with vehicle operators while they are on duty using the AVL and radio to adjust operator schedules and assign additional shifts. The AVL text messaging allows the RTC RIDE scheduler to contact several operators quickly, which results in the ability to more efficiently assign schedule changes.
- Route scheduling – Although RTC has not fully utilized the AVL data in its scheduling process, it can use the data to identify occasions where additional service is historically needed. RTC RIDE can then schedule the additional buses in advance, instead of responding ad hoc to demand as it occurs.

6.4 Reduce Energy Use and Emissions

An increase in transit ridership can reduce energy use and emissions in two direct ways. The first is that trips made by bus are not made by personal vehicle, and do not use additional fuel. The second is that increased transit usage should result in less congested roadways. Less congested roadways mean personal vehicles operate more efficiently as the result of fewer delays.

It is difficult to determine the emissions and energy savings resulting from increased RTC ACCESS usage, because the trips may not be made without paratransit. However, the increase in ridership on RTC RIDE can be related to a reduction in the number of personal vehicle trips. As shown in **Figure 6-1**, RTC Washoe has seen an increase in trips provided of 10.4% since FY2002.

Several studies have been conducted to examine the transit leverage effect on vehicle miles traveled, especially the substitution of transit passenger miles for the vehicle miles traveled. **Table 6-1** provides a summary of the results from various studies. The results of these studies show a potential for strong transit leverage effects, where one additional passenger-mile on transit results in 1.4 to 9 miles of reduction in vehicle miles.

Table 6-1: Study Results of VMT Reduction due to Transit

Study	Cities	Vehicle-Mile Reduction per Transit Passenger-Mile	
		Older Systems	Newer Systems
Pushkarev - Zupan	NY, Chicago, Philadelphia, SF, Boston, Cleveland	4	
Newman - Kenworthy	Boston, Chicago, NY, SF, DC	2.9	
Newman - Kenworthy	23 cities in developed countries	3.6	
Holtzclaw, 1991	SF and Walnut Creek	8	4
Holtzclaw, 1994	SF and Walnut Creek	9	1.4
MTC / RAFT	2010 SF Region		4.4

Source: Litman, Rail Transit in America: Comprehensive Evaluation of Benefits, Table 2, Victoria Transport Policy Institute, August 31, 2006.

Based on the statistics presented in Table 6-1, a conversion factor of 4 was used to estimate the automobile vehicle mile reduction per transit passenger mile as a result of ridership increase for the RTC RIDE service. **The increased transit usage that may be attributed to the implementation of transit**

ITS in Washoe County between 2002 and 2007 potentially saved 9.37 million personal vehicle miles. The results are shown in **Table 6-2**. **The resulting estimated total fuel cost savings for this period could be as high as 1.37 million dollars**. Note that the average fuel costs shown in the table are the national level average data obtained from the National Transportation Statistics[3], and a fuel economy factor of 23 miles per gallon was assumed in the calculation.

In addition to fuel cost savings, the total CO_2 emissions were also estimated from the automobile vehicle miles saved from increased transit ridership. According to a study conducted for the American Public Transportation Association (APTA)[4], a single person automobile traveling one mile emits on average 1.0 pounds of CO_2. With an estimated automobile vehicle mile saving of approximately 9.37 million miles, **the potential total CO_2 emission reduction is estimated to be as high as 4,252 metric tons**.

Table 6-2: Estimated Potential Vehicle Energy and Emission Savings from Increase in RTC RIDE Ridership

Year	Passenger Miles	Ridership	Increase in Ridership	Average Transit Trip Length (miles)	Equivalent Average Vehicle Mile per Transit Trip[1] (miles)	Vehicle Miles Saved from Increased Ridership	Fuel Reduction[2] (gallons)	Average Fuel Cost[3] ($/gallon)	Total Fuel Cost Saving ($)	Total CO_2 Emission Reduction[4] (metric tons)
2002	26,335,262	8,168,559	-	-	-	-	-	-	-	
2003	24,725,542	7,520,088	-648,471	3.29	13.15	-8,528,509	-370,805	$ 1.64	$ (607,378)	-3,869
2004	24,274,377	7,528,805	8,717	3.22	12.90	112,416	4,888	$ 1.92	$ 9,399	51
2005	27,113,300	8,001,999	473,194	3.39	13.55	6,413,323	278,840	$ 2.34	$ 651,928	2,909
2006	29,608,223	8,738,397	736,398	3.39	13.55	9,980,520	433,936	$ 2.64	$ 1,143,420	4,527
2007	29,957,989	8,841,419	103,022	3.39	13.55	1,396,306	60,709	$ 2.85	$ 172,960	633
Total						**9,374,055**	**407,568**		**$ 1,370,329**	**4,252**

Notes:

1. A conversion factor of 4:1 (4 vehicle miles:1 passenger mile) is used for calculating the equivalent average vehicle mile per transit trip.

2. The fuel reduction is calculated from vehicle miles saved from increased ridership divided by an assumed fuel economy factor of 23 miles per gallon.

3. The average fuel cost is taken from National Transportation Statistics - Table 4-38. http://www.bts.gov/publications/national_transportation_statistics

4. A CO_2 emission rate of 1 pound per single person automobile mile is used for calculating total CO_2 emission reduction.

6.5 Improve Public Transportation Safety

RTC has an exceptional safety record, both before and after transit ITS implementation. The record has largely remained constant before and after the implementation. For this study, improved safety at RTC has been measured in two ways:

- Reduced collisions per 100,000 vehicle revenue miles
- Reduced mechanical failures and disabled vehicles

This section discusses the trend for each of the measures and the factors underlying the improvements.

6.5.1 Collisions per 100,000 Vehicle Revenue Miles

[3] National Transportation Statistics, Chapter 4, Table 3-8. http://www.bts.gov/publications/national_transportation_statistics

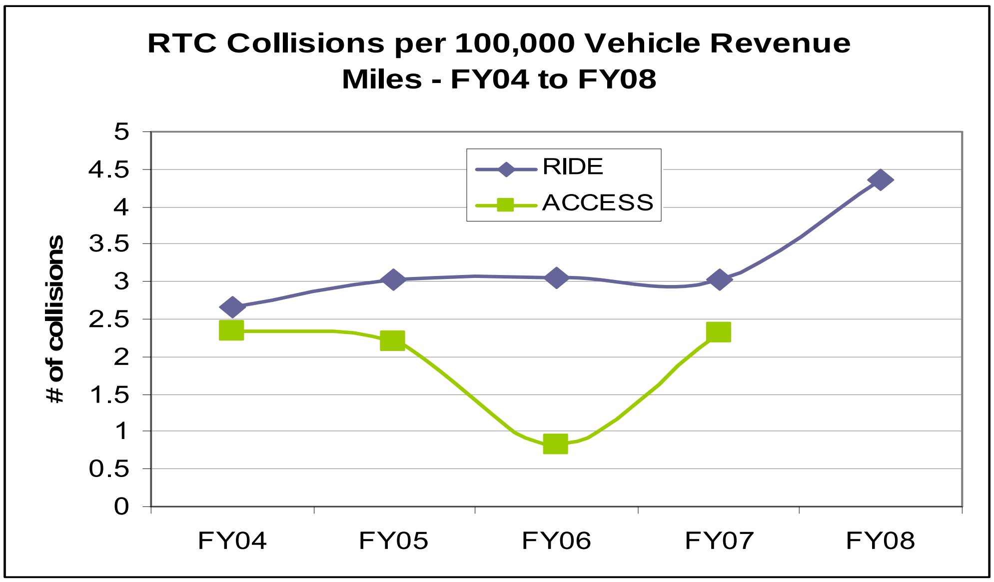
[4] *Public Transportation's Contribution to U.S. Greenhouse Gas Reduction*, American Public Transportation Association (APTA), submitted by Science Applications International Corporation (SAIC), September 2007. http://www.apta.com/research/info/online/documents/climate_change.pdf

From FY2004 to FY2008, RTC consistently maintained accident records of fewer than five collisions per 100,000 revenue miles. It is not expected that the transit ITS will have a significant impact on the number of collisions in which RTC vehicles are involved. Many collisions are caused by circumstances beyond the vehicle operators' control. The transit ITS also does not include any active components to help avoid collisions.

A slight improvement in the collision rate is possibly the result of transit ITS. Vehicle operators for both RTC RIDE and RTC ACCESS indicate that they feel they are able to operate their vehicles more safely because they do not hold the radio handset as frequently while driving. By receiving most information from dispatch through text messages, vehicle operators are able to use both hands to steer.

Figure 6-16 shows the collisions trend over the past five years for RTC RIDE and RTC ACCESS.

Figure 6-16: RTC RIDE and RTC ACCESS Collisions per 100,000 Vehicle Revenue Miles



RTC RIDE and RTC ACCESS have had few collisions from FY2004 to FY2007. In fact, RTC ACCESS went 121 days between collisions in 2002. Because of the infrequency, there is not enough data to indicate a trend in the number of collisions per year since 2004. Other factors also can impact the number, such as severe winter conditions or general condition of the vehicles. In fact, in FY2008, the collision rates were significantly higher from November to January, which coincide with winter snow and freezing roads.

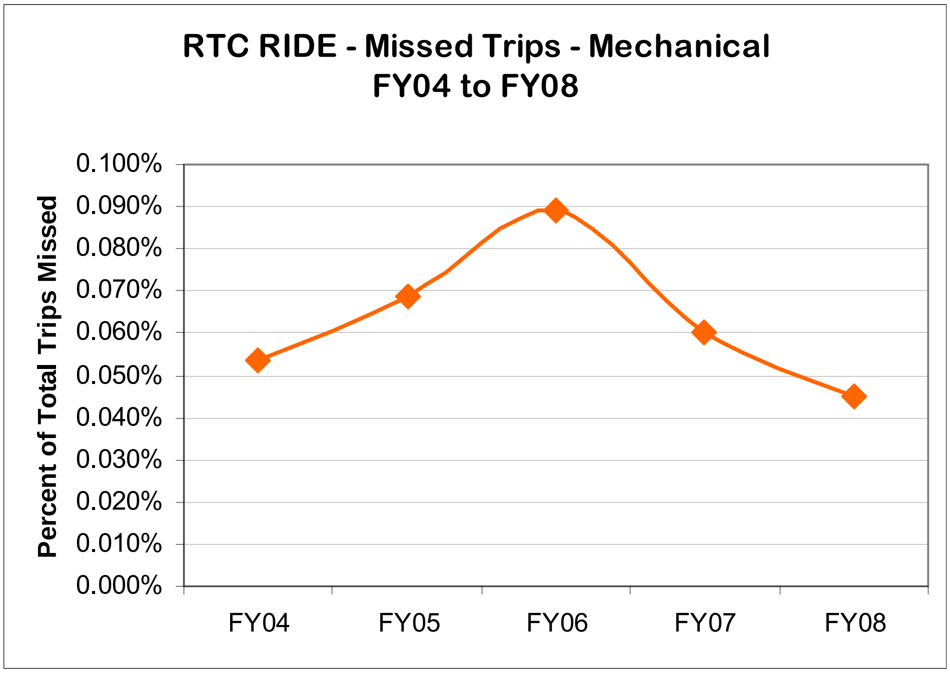
6.5.2 Reduced Mechanical Failures and Disabled Vehicles

Disabled and inoperative vehicles can be a safety issue for passengers for several reasons. The primary one is that passengers can be stranded when a bus becomes inoperative and they must wait for a replacement or other ride. When this happens, it can expose passengers to extreme heat or cold weather. Another way that inoperative vehicles can be a safety hazard is by being disabled in traffic. This may require passengers to either wait on the vehicle in traffic, or to exit the vehicle though traffic.

The transit ITS may help reduce missed trips for mechanical reasons due to the remote engine diagnostics. Through the engine diagnostics, the in-service RTC RIDE vehicles report any detected engine fault codes to the maintenance yard. The RTC RIDE maintenance staff monitor the vehicles and can address problems before they disable a vehicle.

Figure 6-17 shows the trend in missed trips for mechanical reasons from FY2004 to FY2008.

Figure 6-17: RTC RIDE Missed Trips for Mechanical Reasons from FY2004 to FY2008



RTC RIDE maintenance staff began using the remote engine diagnostics between 2005 and 2006. **Since FY2006, RTC RIDE has experienced a 50% decrease in missed trips for mechanical reasons**. The reason for this drop is largely because RTC RIDE replaced half of its aging fleet with newer and more reliable vehicles; however, Maintenance staff indicated that the remote engine diagnostic feature of the transit ITS also plays a significant role.

In addition to being able to monitor vehicles, the transit ITS allows Maintenance staff to more quickly and accurately locate disabled vehicles. Maintenance staff use the AVL maps to locate disabled vehicles and direct the response to them.

6.6 Increase the Awareness of ITS Benefits

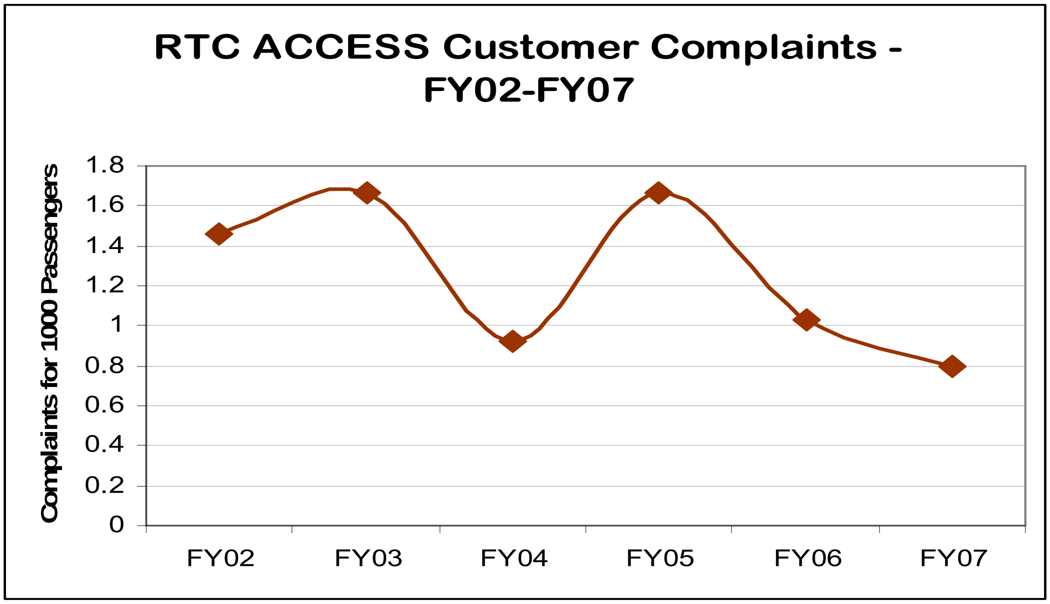
RTC has not actively marketed the benefits of its transit ITS to the public; however, its benefits are visible to the public through many features. They include the real-time traveler information signs at RTC CITICENTER, the real-time information available by phone, and the Google Transit™ trip planning tool available through the RTC web site (www.rtcwashoe.com). RTC has not collected statistics on the impacts of each of these tools; however, as previously noted, RTC RIDE has experienced a steady increase in the number of customer calls requesting bus location information.

RTC ACCESS tracks its customer complaints. **Since FY2002, RTC ACCESS has experienced a 45% decrease in complaints per 1000 passengers**. As previously noted, RTC ACCESS deployed new trip scheduling software in 2005, which required some adjustment and training by staff, and may have resulted in increased complaints during FY2005. Outside of FY2002 to FY2005, the trend has been a significant decrease in complaints since the transit ITS was implemented.

The reduction can be largely attributed to improved information for passengers about vehicle locations and estimated times of arrival, more efficient and accurate scheduling, and better customer service resulting from drivers and dispatchers being able to exchange information about customers through the AVL workstation and MDT.

Figure 6-18 shows the trend of customer complaints at RTC ACCESS from FY2002 to FY2007.

Figure 6-18: RTC ACCESS Customer Complaints from FY2002 to FY2007



7. RTC LESSONS LEARNED

As with any complex technology implementation, RTC's transit ITS has presented the agency with several obstacles and opportunities. As the system has been procured, deployed and operated, RTC learned many lessons and adjusted its approach to maximize the system's value. This section discusses RTC's transit ITS implementation lessons learned. It is divided into sections that discuss lessons learned during planning, procurement, implementation and ongoing operations. The intent of the lessons learned is for RTC to share the knowledge it gained through its transit ITS experience with other agencies.

7.1 Planning Lessons Learned

The planning lessons learned are based on issues that arose or have risen since RTC began its planning for a transit ITS implementation. They represent issues that agencies should be aware of and strategic decisions RTC recommends other agencies consider during the planning process.

7.1.1 Select an Agency Project Manager with the Right Skill Set

The Agency's Project Manager will represent the agency through planning, procurement, implementation and operations. The person should be identified as early in the planning process as possible. The Project Manager should have strong experience with the transit agency, or some other assurance the person will stay committed to the project throughout the planning, procurement and implementation processes.

The Project Manager must be enthusiastic about and committed to the transit ITS deployment. A strong commitment is essential in order to endure the obstacles and setbacks that are inevitable in large technology projects. The Project Manager must be supported by management with the understanding that the path to successful implementation will not be perfectly smooth. The Project Manager must also have the willingness and ability to communicate frequently with executive decision-makers and operations staff.

RTC selected a Project Manager from its planning department. The RTC Project Manager has extensive knowledge of daily paratransit and fixed-route operations, as well as RTC budgeting and planning processes. The advantage of the planning Project Manager approach is that the agency was able to plan the transit ITS from the service-needs perspective. The Project Manager was able to help plan a system from the viewpoint of how operators, dispatchers, maintenance, planning and administrative staff use it to improve RTC's operations.

If a planning or administrative person serves as Project Manager, an agency needs to ensure his or her willingness and ability to understand the Information Technology (IT) needs of ITS. At RTC, the Project Manager is the daily administrator of the system and manages such technical issues as reformatting corrupt memory cards and administering user accounts.

Another approach to project management is to select a Project Manager from the IT side of an agency. This approach may be advantageous during planning and implementation because of the Project Manager's familiarity with the agency's network and hardware. A project manager from IT may be able to more directly work and communicate with a Contractor during the procurement and installation of the ITS.

The potential disadvantage of a Project Manager from IT is that his/her knowledge may not provide a full understanding of the needs of operators, dispatchers, maintenance, planning and administrative staff. The focus may be on making the system function rather than on meeting the needs of the agency staff.

Shortcomings of either an IT or Planning project management approach can and should be overcome through strong communications within the agency. If a planning person is selected, he or she must have a strong relationship and ability to communicate with IT staff throughout the transit ITS project. Similarly, an IT project manager must be able and willing to spend the time working with agency staff to understand their needs and responsibilities.

7.1.2 Identify Champions to Represent Each User Group in the Agency

Early in the planning process, a champion, or champions, should be identified in each user group at the agency. This may include planning, management, operators, dispatchers and maintenance staff. The champions should be people enthusiastic about technology and willing to incorporate it into their daily activities.

The purpose of the champions is threefold. First, the user group champions can serve as liaisons with the rest of the staff in their user groups. The champions can communicate the plan to the users and receive feedback and needs from them to relay to the Project Manager. Second, the champions can work with the Project Manager to refine the transit ITS plans and the required functionality. Third, the champions can generate enthusiasm within their user groups and help the agency staff understand how transit ITS will benefit them. Their participation in the planning process will engender a sense of ownership in the planned system that allows it to be accepted and utilized more quickly.

Also, the champions from each user group can help smooth the implementation process. Because they are enthusiastic and well-informed regarding the transit ITS, the champions will be ideal candidates to perform the testing and to help identify and resolve “bugs” during implementation.

Depending on the size of an agency, a formal working group of champions may not be necessary. However, it is important for the Project Manager to stay in contact with them and share information about the planning process. This may be through efforts as simple as group e-mails, a newsletter or monthly progress report. The champions help all the agency staff feel they are part of the planning process.

7.1.3 Know the Limitations of Your Agency's Labor Contracts

Transit ITS can provide a powerful set of tools to manage transit operations; however, their utility can be limited what agency staff are allowed to do. RTC has experienced instances where the transit ITS could not be fully utilized due to labor rules. Two examples are provided below.

RTC RIDE dispatchers now have the ability to monitor vehicle locations and schedule adherence in real-time. The transit ITS also gives them the ability to send text messages to vehicle operators. When a vehicle is off-route or schedule, the dispatchers can, in theory, alert the operator and give some instruction to help them get back on route or schedule; however, labor contracts define that directing vehicles in such a way is a supervisor's responsibility. Even though the dispatcher is usually the first to see such issues, he or she must contact a supervisor. In this case, the labor contracts prevent a dispatcher from directly using the transit ITS to resolve an on-street issue.

The playback feature of the transit ITS allows a user to view a "replay" of a vehicle on any specific time and route or route segment. RTC uses the feature for many purposes, including examining customer complaints or grievances against particular vehicle operators. The complaints and grievances usually concern late or early vehicles. While the replay tool is considered "very reliable" by supervisors, dispatchers and management, it is not allowed to be used as evidence in grievances. Regardless of whether it proves or disproves a grievance, the labor contract does not allow use of AVL data for grievances.

During the planning process, transit agencies considering ITS should review and be knowledgeable about the labor contracts that define the jobs of each potential ITS user group. If the labor contracts may adversely affect the use of ITS, the agency should consider whether to attempt to change the labor contract, or whether to modify its ITS plans to accommodate the existing agreement.

7.1.4 Conduct a Review of Your Existing Technologies

During the planning process, a transit agency should conduct a thorough review of its existing hardware, software and networks. If a detailed inventory does not exist, one should be made that documents the capabilities of all systems in terms of processor speeds, radio and wireless communications capabilities, network configurations, storage capacities and backup processes.

Performing this review will allow your agency to be better able to identify systems that may need to be replaced due to lack of technical support or outdated technologies. It will also help identify the limitations of your system that may impact how ITS is implemented, or what will be needed to fully utilize ITS.

A detailed technology review is valuable information to provide to potential ITS contractors. They will be able to identify how their systems can work with your existing technologies, and help you identify changes necessary that will be above and beyond the cost of their systems.

RTC procured all-new hardware with its transit ITS implementation, and that simplified the process by eliminating interfacing with legacy equipment. Some software used by the agency was not as compatible with the proposed ITS as expected. In order to fully utilize the transit ITS, RTC had to procure new paratransit scheduling and fixed-route scheduling systems. The need for these applications was not determined until transit ITS implementation had begun, and resulted in delays and additional unanticipated costs to RTC.

7.1.5 Perform Detailed Cost/Benefit Analysis

During the planning process, RTC conducted a cost/benefit analysis. RTC IT staff now believe that agencies would benefit from doing a detailed analysis of costs. In fact, the IT department stated that the ongoing cost of the ITS system still surprises the agency because many costs were not identified before procurement and implementation. RTC IT staff stated that they will not enter into a project of this magnitude in the future without a detailed cost/benefit analysis.

7.2 RTC Procurement Lessons Learned

The procurement process includes the review of proposals, selection and negotiations with a contractor. Despite rigorous preparation, RTC experienced several unexpected opportunities from this process. The following lessons learned are intended to help other agencies as they procure transit ITS.

7.2.1 The Agency Project Manager Should be a Single Point of Contact for the Contractor

Once an agency selects a Project Manager for the transit ITS, that Project Manager should serve as a single point of contact for the contractor, not only for procurement but also implementation and operation. This is not to say that the Project Manager is the only person within the agency that the contractor should speak to. Rather, it means that the Project Manager should be aware of, and authorize communication between the contractor and other individuals within the agency.

The reason for making the Project Manager the single point of contact is to insure consistency and that all contractor activities are coordinated. Because of the complexity of a transit ITS implementation, the contractor may need to work with several departments of an agency. Without a single point of contact, decisions may get made between the contractor and departments that are not consistent or coordinated with the other departments.

The Project Manager must be kept aware of each action of the contractor and the agency departments, and track them to be aware of how they may impact the overall implementation, budget and schedule. The Project Manager can then work with the contractor to make decisions on changes or scheduling in order to make them beneficial to the agency as a whole.

To repeat the planning lesson, *select an agency Project Manager with the right skill set*. Because the Project Manager will be a single point of contact, the person must be knowledgeable about all systems and operations at the agency, and must be able to communicate with both the contractor and the many user groups within the agency.

Although RTC has had the same project manager committed to this project since initial planning, the agency prepared for the possibility of a transition. The Project Manager should document interaction with the contractor throughout the project. While the ideal is for the agency to have a single project manager from beginning to end, it must be prepared for the possibility of a change. Documenting all interaction and decisions will provide a new project manager a background to help understand the current project status and what is expected from each involved party. The documentation will make a project management transition less disruptive. It also provides a “paper trail” in case of any disputes.

7.2.2 Demand Consistent Support from the Contractor

During the procurement and implementation process, RTC's contractor changed its project manager four times. It changed the Project Engineer six times. RTC believes that these changes caused delays in the project because each new contractor staff person had to become familiar with RTC staff and the status of the ITS implementation.

While RTC placed requirements in its RFP to specify that contractor project management changes must be approved by RTC, the contractor has often sought approval after the fact. RTC recommends that agencies carefully review and develop their contractor staffing requirements to minimize disruptions resulting from contractor staffing changes.

During the selection process, RTC would recommend placing emphasis on each bidder's recent project history and the project management within each. Consider giving added weight in past experience to those bidders who have had consistent and satisfactory project management and engineering on recent projects.

7.2.3 Review Your Requirements Immediately Before Requesting Proposals

Developing system requirements can be a time-consuming process. There are many user groups who will provide input, including technical and non-technical staff, before the requirements are released to potential contractors. Reviews can delay the release of an RFP, and during that delay the underlying transit ITS technologies may change.

At RTC, the procurement process from RFP to contracting was delayed by a series of factors that resulted in the agency requesting some functionality that had become unnecessary or not state-of-the-art. A specific example of this was the requirement for a wireless data network to communicate between vehicles in the maintenance yard and the ITS servers. The wireless network supplied by the contractor was PROXIM, a proprietary wireless protocol. While it was suitable at the time the requirements were written, an open standard (IEEE 802.11b/g/n) has emerged. The rapid success of the open standard resulted in the PROXIM system quickly becoming obsolete. RTC had difficulty getting technical support or buying replacement PROXIM hardware.

RTC eventually converted its network to the open standard at its own expense. Had RTC been able to make last-minute changes and perform a review of its requirements immediately before release to potential contractors, the additional expense of the conversion may have been avoided.

Also, as this example illustrates, the use of open and widely-accepted standards should be used wherever possible in the development of requirements. The developer of the requirements should be knowledgeable of the National ITS Architecture and any other network or communications standards that will be affected by transit ITS. The requirements should clearly identify where contractors will be expected to use open standards.

7.2.4 Independently Procure Computer and Network Hardware Separately When Feasible

RTC worked with its contractor to identify the computer and network hardware requirements for running the transit ITS. The requirements included servers, workstations, network routers and switches and other communications hardware. The contractor provided requirements to RTC, which allowed the agency to procure the hardware itself. *(Note that this does not include system-specific hardware such as GPS antennas, MDTs and IVLUs.)*

Being able to procure its own hardware gave RTC several advantages. First, it allowed RTC to procure the hardware using relationships and advantageous pricing it had access to. Second, it allowed RTC to procure the brands of equipment with which it felt comfortable. It also allowed the agency to better manage the procurement through a process that tracks the inventory better. Finally, it allowed RTC to procure hardware that could be locally supported. A key potential disadvantage of this approach is that the transit ITS contractor may not provide technical support for hardware-related problems as they would if they provided the hardware.

At RTC, all transit ITS servers and communication hardware were procured new. This gave the advantage of not requiring interfacing with legacy hardware and software, such as machines that used different operating systems or databases. If an agency chooses to procure its own hardware, it should follow the requirements of its contractor and procure new hardware when recommended.

7.2.5 Procure the Right-Sized Systems

RTC procured separate servers for each of the following transit ITS components: TransitMaster™, WebWatch™, DataMart™, HASTUS™, Trapeze™ and the radio system. Individual servers add capital cost at procurement and at replacement and retirement. The cost of servers also goes beyond the price of the hardware. The addition of these servers and other network switches and routers necessitated the addition of at least one rack in the RTC computer room. More air conditioning was added to the room to keep the servers at the correct operating temperature, increasing the cost of electricity usage. The space they occupy has a cost because it now cannot be used for other purposes.

RTC IT staff believe that many of the servers it procured are underutilized. In fact, the WebWatch™ server is currently unused. The functionality of the servers could be combined on fewer machines running virtual servers. Virtual server allows a single machine to operate virtually as two or more separate servers, thereby reducing the needed amount of hardware, rack space and cooling.

The reduction in machines would have resulted in a savings in capital acquisition and ongoing costs. Having fewer machines also simplifies the tasks of monitoring servers, performing data backup and disaster recovery.

As servers become faster and more powerful, agencies should consider ways, such as virtual servers, to minimize the amount of hardware it must buy and maintain.

7.2.6 Plan for Operations and Maintenance Costs

It is critical to understand the total capital cost of transit ITS. As previously discussed, the cost includes the system proposed by the contractor and the cost of any modifications or additions that will be required to make the transit ITS work properly. As important as capital costs are the costs for ongoing operations and maintenance. While an agency's RFP will likely ask the contractor for estimated operation and maintenance costs, there are costs besides the contractor's to consider.

At RTC, operations and maintenance costs directly related to the transit ITS implementation, but not covered by the contractor, include digital maps, hardware the agency procured, space and cooling for that hardware, and additional applications required to interface with the transit ITS.

RTC provides its own digital map backgrounds for the AVL workstations. Because Washoe County's population has grown so rapidly, new streets and subdivisions have developed since the transit ITS implementation. Updating the digital maps costs approximately $8,000 annually. This cost was not planned for and RTC has not updated its base maps for approximately four years. Both RTC RIDE and RTC ACCESS staff note that the maps are not current with the road network on which RTC operates.

As mentioned previously, RTC has incurred additional cost in space and cooling for transit ITS servers and communications hardware. While not significant, the cost was not anticipated and planned for as part of the transit ITS operations and maintenance.

RTC had to procure two additional software applications that were not anticipated when it procured its transit ITS. In order to fully utilize its transit ITS, RTC purchased an upgraded version of Trapeze™ paratransit scheduling software, and shared the cost of the HASTUS™ fixed-route scheduling application with the contractor. Both of these systems require ongoing costs for training, support and licensing that are in addition to the direct costs of the transit ITS.

7.3 RTC Implementation Lessons Learned

The implementation process includes the portion of a transit ITS project after the selection of a contractor, until the system is accepted as operating and meeting its requirements by the agency. For RTC, the implementation process was approximately four years in duration. The lessons learned during that time are divided into operations and IT.

7.3.1 Operations

<u>Require the Contractor to Remain on-site after Installation</u>

Because of the complex nature of a transit ITS implementation, RTC recommends that agencies require the contractor to have staff on-site for a reasonable period of time after installation, depending upon the complexity and size of the implementation. The time the contractor should stay on-site to monitor the system after installation should be long enough to give both the agency and contractor assurance that all systems are stable and robust. The transit agency should require the on-site contractor staff be experienced and knowledgeable about all aspects of the transit ITS.

While the components of transit ITS may work well in a factory setting, their transition to the real-world environment may require numerous calibrations and adjustments. Most transit agencies have a variety of different vehicles and each may have slightly different characteristics that may not be anticipated during installation. Also, computer servers and communications hardware may integrate differently than expected with an agency's existing networks. Some data communication issues may not appear until after a system is in use.

While the RTC transit ITS mostly worked well after installation, and the RTC IT and maintenance staff said the installation was well done and correct, small issues still occurred. They included minor issues such as individual headsigns that didn't work correctly and automated passenger counters that were not well calibrated on some vehicles. Issues also included major problems such as a traveler information system that did not work. Many of these issues lingered because contractor staff were not present to address them.

Once transit ITS is installed, an agency will likely begin using it immediately. It will be relied on to perform many critical functions from the moment it is operational. For that reason, a failure of the system can be catastrophic for the agency, and must be remedied as quickly as possible. On-site contractor staff are essential for quick resolutions while the agency staff are learning the system.

Prepare Agency Staff for the Implementation Process

It is nearly impossible for a technical installation involving hundreds of vehicles, multiple communication networks, and dozens of computers, to happen flawlessly. The agency Project Manager should prepare agency staff for the potential that installation may be disruptive and challenging. As mentioned in the Planning Lessons Learned, having champions for each transit ITS user group would provide a way to maintain enthusiasm and communicate with the agency staff. Proper preparation would reduce potential staff frustration.

In many agencies, some transit staff members are reluctant to change their current practices, regardless of the potential benefits of a new system. When the system has shortcomings or failures, the reluctant staff members may become more hesitant to accept new technologies, even after they are working well. By preparing staff and making them aware that the system is likely to have some issues at startup, it will help to encourage staff acceptance.

RTC's staff was accepting of the new transit ITS. The agency Project Manager did an excellent job of involving staff in the planning and procurement process, and preparing them for potential issues. It was noted during interviews for this evaluation that dispatch and maintenance employees were fully accepting of the system from the beginning and expected debugging to be part of the implementation process. A small number of vehicle operators, however, did have technical issues with in-vehicle hardware. While those early issues have been resolved, the staff members that experienced them are still less likely to accept and fully utilize the transit ITS.

Some ways to prepare staff for the potential obstacles of the implementation process are to provide them with channels for voicing their complaints and frustrations. This can be a form for them to document system errors or functions that do not work properly. Such a form gives the contractor and agency Project Managers concrete examples to review and resolve. It also can help the staff feel a sense of ownership in the system because they are a part of the process to improve it.

Involve Maintenance and IT Staff in the Installation Process

Many agencies expect a transit ITS system to be fully installed by the selected contractor. During the installation, RTC's contractor worked side-by-side with RTC staff, and RTC believes it gave the agency a much better ability to diagnose and repair the transit ITS components on its own. As a result, the RTC RIDE staff are able to resolve many issues in-house. That ability reduces potential delays while waiting for the contractor to do repairs.

Two members of RTC RIDE's maintenance staff observed installations of hardware aboard all the fixed-route vehicles. They participated in the wiring, placement and testing of hardware, so they are familiar with how to remove, diagnose and replace equipment. RTC ACCESS Maintenance staff observed the installation on several buses, but did not participate. They frequently rely on the RTC RIDE Maintenance staff for support. The RTC RIDE expertise has also allowed them to inspect new vehicles that are shipped to RTC with the transit ITS installed. In some case, RTC RIDE Maintenance staff have been able to find and correct errors in the new vehicles.

Request a Contractor who Supports an Original Equipment Manufacturer (OEM) Process for Equipping New Vehicles

During the implementation of the transit ITS, RTC and its contractor installed new ITS equipment aboard RTC's existing fleet of vehicles. Since the initial implementation in 2002-2003, RTC RIDE has replaced approximately half of its fleet with new vehicles. RTC's contractor was able to work directly with the vehicle manufacturer to have the in-vehicle ITS hardware installed at the factory.

New vehicles arrive at RTC complete and do not require a trip by the contractor to install or oversee the installation of hardware. As previously noted, RTC RIDE Maintenance staff have corrected improper installations on a small number of vehicles, but the vast majority of vehicles arrive at RTC correct. The OEM process reduces the burden on RTC RIDE Maintenance staff, reduces costs by not requiring the contractor to be present for installs, and reduces delays in getting new vehicles into service.

7.3.2 Information Technology

Maintain an Asset Management List That Details New IT Inventory

When RTC procured its new hardware for transit ITS, it arrived as a single delivery with a single line item in the invoice. This complicated the tracking of the hardware and knowing where to assign each component. The issue of not being aware where each component belongs complicates future work. It is more difficult to track which components are operational and not in use, and which are due for lifecycle replacement.

RTC IT staff recommend that an agency request line item descriptions of all hardware, whether they are procured through the transit ITS contractor or a third party. An asset management list is a means to identify each component, how it will be used, when it was procured and put into use, its current disposition and its lifecycle. The asset management list will help in planning the ongoing cost of hardware replacement. It also makes maintenance easier because the location and purpose of each component is known. Finally, an asset management list allows an agency to identify components that are being utilized or underutilized.

Implementation Can Be Simplified by Procuring All New Hardware and Software

When it procured its transit ITS, RTC procured new servers and communications hardware to be installed as part of the implementation. The alternative would have been to resource or reuse existing equipment for transit ITS.

The primary advantage of new hardware is that it allowed RTC to more quickly implement its transit ITS. Because it was new, the hardware was state-of-the-art and met all of the contractor's requirements. The hardware also did not come with any potential issues such as bad components or viruses, and it didn't require any reformatting or reconfiguring to prepare it for use in transit ITS. IT staff must plan for space and temperature management when implementing the system. Rack spaces can be reduced by utilizing a special switch with integrated monitor and keyboard to manage several servers at a time. New cooling requirements may be necessary with the additional equipment. IT staff may also want to purchase workstations with small form factor casing to minimize the desktop and below-desk space of the system at dispatcher and other key personnel stations.

Preparing existing hardware for transit ITS would have required additional IT staff time. Also, RTC's existing hardware was already partially through its lifecycle, so the equipment replaced no longer had full retail value.

7.4 RTC Ongoing Operations Lessons Learned

RTC has been using transit ITS to improve its operations since 2003. During this time, the agency has learned many lessons that have helped it more effectively operate its system and maximize the benefit of the ITS. The Ongoing Operations Lessons Learned are divided into three sections: Administrative, Operations and Information Technology.

7.4.1 Administrative

Do Not Expect to Observe Staff Reductions

RTC has not seen significant staff reductions as a result of implementing transit ITS. There are a few exceptions, such as RTC ACCESS reducing its reservationist staff from seven to five. That reduction was in part a result of the transit ITS's improved scheduling and dispatching capabilities; however, it is also the result of a change in the paratransit service contractor. Over the same period, RTC RIDE maintenance has increased its staff by dedicating two staff members to technology maintenance. The technology maintenance staff spend only one-third of their time on transit ITS, while the rest of its time is dedicated to other technologies, including fareboxes and video security systems.

It is noted that the service level and ridership have steadily increased on RTC RIDE and RTC ACCESS between 2003 and 2007, while staff have not increased. Overall, RTC's operations, maintenance, IT and administrative staff have not seen appreciable increases or decreases as a result of transit ITS. Every department at both RTC RIDE and ACCESS report that they are more productive as a result of transit ITS. The value at RTC of the transit ITS is not in cost reduction, but in service improvement using the same human resources.

Have or Obtain the Ability to Customize Reports

RTC's transit ITS was implemented with a series of "canned" reports for administrative and management staff to use to track operation performance and efficiency. Canned reports are those whose formats have been prepared in advance and that allow for little or no customization. The canned reports cover a small set of typical transit performance and operational efficiency data, including ridership, schedule adherence and passenger counts.

One of the strongest attributes of transit ITS is the large amount of data it creates. Data can be analyzed in a myriad of ways, including microscopic data analysis of single trips of a route on a specific day, and macroscopic analyses, such as all ridership on all routes for extended periods of time. RTC determined the canned reports gave access to only a small fraction of the data being generated by ITS. The canned reports also limited the ways the data could be analyzed. In addition, RTC indicated that many of the canned reports were not in a format that was easily usable for them.

The RTC transit ITS data is stored on a server acting in a database accessible through the Crystal Reports reporting application. Several RTC staff members have gone through Crystal Report training. This gave the staff the ability to access the transit data through customized reporting. However, report customization is a complex and time-consuming process. The staff's other responsibilities prevent them from having time to design customized reports to extract the needed data.

Recognizing the high value of the data stored within its transit AVL, RTC hired a consultant at additional cost to develop customized reports in the agency's preferred formats. The customized reports will provide data for analysis beyond that accessible through the canned reports.

Because transit ITS generates a very rich data set for analysis, It is difficult to anticipate how an agency will use it. RTC believes it would be difficult to predict and request all the report types needed during the procurement process. For that reason, RTC recommends that agencies plan to either have someone on staff who is properly trained in customizing reports and can spend the time creating them, or plan to hire a consultant who will work closely with agency staff to create customized reports. Report customization generation is a key to maximizing the benefit of the data generated by transit ITS.

Have an Independent Dialog with Other Agencies Using the Same Contractor

RTC's contractor provides annual conferences and user groups for transit agencies using their transit ITS components. This provides agencies with an opportunity to speak to each other and support each other through implementation and operations. It also allows the providers to speak as a group with the contractor to discuss system changes.

RTC has found additional value in speaking to the same agencies outside of the channels created by the contractor. An independent communications channel allows the agencies to speak without involvement of the contractor. Through direct communication, RTC has been able to identify problems that occurred in other agencies' implementations, but were not known or revealed by the contractor. It also provides RTC and other agencies the opportunity to share findings and information that may benefit the providers, but does not benefit the contractor.

The independent dialog should take place in addition to, and not instead of, participation in the contractor's formal channels and user groups. Agencies are encouraged to seek out and make contact with other agencies who have deployed similar transit ITS, and continue to stay in contact. E-mail lists or web site forums are two low-cost means for holding an ongoing dialog among transit ITS users.

7.4.2 Operations

Encourage Creative Uses of Transit ITS

RTC has found that the uses for its transit ITS go beyond the planned functions. For example, the person at RTC who schedules vehicle operator shifts uses the system to send text messages to operators while they are on duty. She is able to send them information about changes in their schedules, inform them of available shifts and ask if they would like to change existing assignments or accept additional assignments. Communicating this way is much simpler and more effective than leaving messages for operators, or waiting for them in the break room. It also gives the scheduler access to a much larger pool of operators than she could reach previously. This unplanned benefit of the transit ITS may be partially responsible for RTC's 30% reduction in overtime hours as a percentage of total operator hours since 2005.

The planning staff also use the system to plan stop facilities, such as benches and shelters. Because boarding and alighting data is now available for each stop, RTC is able to view activity at each stop and accurately determine what is needed to improve the transit experience for its passengers.

RTC Customer Service has also found a unique use for the system. When a customer calls to report a lost item, Customer Service staff can immediately identify the vehicle on which the passenger rode, and send a text message to the vehicle operator. The operator can then search the bus for the lost item at the next opportunity. This improves the chances the item will be found, and allows the operator to either hold the object or pass it to another operator or supervisor to return to the passenger.

Agencies should allow their staff to explore the potential uses of the transit data and new communications capabilities of transit ITS. Agencies should not only focus on using the system as planned, but encourage their staff to create their own uses.

Allow Supervisors to Use the AVL System

RTC's original plans called for a product called Mobile Supervisor that would give on-street supervisors the same ability as dispatchers to monitor real-time vehicle locations and schedule adherence. For the reasons described in **Section 4.11**, the Mobile Supervisor was not implemented, and RTC RIDE on-street supervisors use an MDT that provides them with limited capabilities to monitor bus activity.

During peak hours and special events, RTC RIDE supervisors prefer being at a desk using the AVL workstation over being in a vehicle on-street because they can monitor more vehicles in more locations. However, vehicle operators indicated they prefer for the supervisors to be on-street so that they are more accessible.

At RTC there are usually two supervisors on duty during the day. If one stays at the RTC RIDE office to monitor operations through the AVL workstation, the other supervisor must be the on-street supervisor for the entire RTC RIDE routes in operation. Clearly, the Mobile Supervisor application would have allowed RTC RIDE supervisors to be on-street while monitoring all vehicles. RTC is still interested in deploying this component of their ITS in the future. In the meantime, however, the agency allows its on-duty supervisors to decide whether both will be on-street, or split between on-street and at a desk using an AVL workstation.

Agencies are encouraged to develop a policy that maximizes the benefit of the transit ITS and the traditional responsibilities of supervisors. Besides the Mobile Supervisor, other solutions are to add a supervisor who is dedicated to monitoring vehicles from a workstation, and to give dispatchers some supervisor-duty authority to manage vehicles. As stated in the Planning Lessons Learned, an agency should review its labor contracts before determining the most effective use of the transit ITS in supervising its fleet.

***Note**: Since completion of this study's on-site review and evaluation, RTC IT staff have developed a vehicle-mounted laptop for supervisors to use on the road. The laptop remotely runs TransitMaster™ AVL and CAD modules over cellular broadband.*

Continue Learning and Training

When RTC staff were trained on the use of transit ITS, not all systems were implemented or fully functional. One result has been that RTC staff were trained in the classroom on functions that were not available in the vehicles or at workstations. Other working functions may not be used by an agency at implementation but may be needed later.

At RTC, the staff did not receive practical training of functions such as "transfer request." Transfer request is a function of the MDT where a vehicle operator may contact another operator of another bus with an alert that a passenger would like to transfer at an upcoming stop. Theoretically, the vehicle operator who receives the transfer request can review its schedule adherence information, along with passenger load, other needs and traffic conditions and either acknowledge or decline the request. During interviews with vehicle operators, few were aware of the transfer request function. One driver who was aware of it said he did not use it because other operators ignored it.

Ongoing training, on a formal or informal basis, can help an agency effectively use its transit ITS. An agency must plan to provide ongoing training and education in order to maximize the benefits of its transit ITS. The training may be occasional classroom sessions. Continuing education may also be encouraging user groups to share what they know among themselves. In both cases, the key is continuing to share knowledge about the transit ITS to prevent the users from only utilizing a small portion of its capabilities.

Ensure Your System's Critical Components Can Be Maintained Locally

One component of RTC's transit ITS implementation was a new radio system that resolved shortcomings of the previous system and provided more bandwidth for data communications. However, the procured radio system has only one authorized service representative in the Reno-Sparks area. RTC determined that the lone authorized service agent was prohibitively expensive and has selected a national service representative who is not local. While RTC has received acceptable and timely service from the national representative, the agency would prefer to use one that is local. In the case of a critical component of transit ITS such as the radio system, agencies are encouraged to ensure that there is appropriate local support to help maintain and repair the system.

Budget for Onboard ITS Hardware Components Upgrades

At the time of this report, Trapeze ITS had sent RTC product end-of-life notices for the original IVLUs installed in RTC vehicles. RTC has been replacing its IVLUs as it replaces vehicles; however, not all RTC IVLUs will be switched to the new type by the deadline established by the vendor. Therefore, a regular budget to upgrade the onboard ITS equipment is recommended to plan for end-of-life replacements.

7.4.3 Information Technology

Purchase Monitoring Software to Track the Health and Activities of the Transit ITS Servers

The procurement of transit ITS will likely significantly increase a transit agency's inventory of servers. The increase will require more effort from IT staff to monitor the health and activity of its systems. The servers must be monitored for multiple issues, including verifying they are fit to perform their functions, detecting intrusion from outside sources and tracking processor speed, processor usage and storage space.

RTC's IT staff purchased software that automates the monitoring of its servers. If the monitoring software detects an issue on a server, it can alert the IT staff via pager or text message. The alerts eliminate the need for IT staff to dedicate time to actively observe the servers and has helped them to maintain an increased amount of hardware with a relatively small staff. RTC IT staff believe the server monitoring software has provided far more benefit than its cost.

Expect the Agency's IT Budget to Increase

RTC deployed its transit ITS system at the same time that it increased the agency's overall use of information technology. As a result, the IT department increased in size, as did the networks and amount of hardware it manages.

Because managing the transit ITS technologies requires additional or advanced skills, such as database and network management, implementation of transit ITS requires staff with advanced expertise. This causes agencies to make a stronger effort to retain experienced staff resulting in salary increases for IT staff.

The RTC increased IT staff in anticipation of the ITS implementation. IT has indicated about one-quarter of one staff member's time is required for the maintenance and administration of transit ITS hardware and software. If an agency's IT staff is already overworked, it may have to contract for technical support or hire additional staff.

The network hardware and servers all have lifecycles and must be periodically replaced. For example, the servers used by transit ITS are scheduled to be replaced every three years. Agencies should plan for the cost of replacement hardware. As recommended in the Procurement Lessons Learned, overall hardware costs can be reduced if an agency uses virtual servers or consolidation to reduce the amount of hardware required by transit ITS.

Also note that RTC IT staff believe its costs for maintenance and operation of the transit ITS would be significantly higher if not for the technical expertise of its ITS project manager, RTC RIDE electronics maintenance staff, and RTC ACCESS IT staff. Agencies that do not have strong expertise in-house may see greater demands on their IT staff than RTC did.

An agency should budget the costs for a support and maintenance agreement separate from the normal software upgrade costs. Trapeze ITS does not include the costs of software upgrade in their regular support and maintenance contract. There will be a large technology gap and potential loss of contractor/vendor support if sufficient time lapses between regular software upgrades. In addition, the staff training efforts will be significantly more intensive if the software is not upgraded on a regular basis.

8. CONCLUSION

RTC's experience with transit ITS has been largely positive. All staff at RTC RIDE and RTC ACCESS indicated that the system improved their ability to do their jobs and provide better customer service. While the transit ITS has not reduced RTC's costs or staffing needs, it has allowed RTC to provide more service without increasing staff. RTC is, overall, satisfied with transit ITS.

RTC experienced many challenges during its planning, procurement, implementation and operation, but has been able to resolve almost all of them. Through this evaluation, it has been able to review its own experience with ITS and identify the benefits it provides. Specifically, transit ITS has helped the agency accommodate nearly 11% more passengers on RTC RIDE and 5% on RTC ACCESS, while increasing customer satisfaction and improving its service.

Through this evaluation, RTC hopes to help other agencies understand that transit ITS is a powerful and useful tool. However, RTC encourages agencies to have realistic expectations and to prepare for the challenges that are inevitable in technology implementation this large. Agencies must have the appropriate staff and inter-departmental coordination to manage a deployment. They must do a thorough cost analysis to understand all of the capital and operations costs associated with transit ITS. And they must prepare their staff for the transition period and "growing pains" associated with transit ITS implementation.

RTC staff have been very accommodating and helpful in documenting its system. Their intention is to help other transit agencies considering an ITS deployment to understand the benefits and learn from the real-world experience of RTC so that they can successfully plan, procure, implement and operate transit ITS.

RTC of Washoe County Transit ITS Implementation Study

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