Monterey-Salinas Transit ITS Augmentation Project
Phase III Evaluation Report

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16. Abstract

The purpose of this document is to present the findings from Phase II and Phase III of the Evaluation of the Intelligent Transportation Systems (ITS) Augmentation Project that was implemented at the Monterey-Salinas Transit (MST) in Monterey, California. This project, implemented using the Federal Fiscal Year 2003 ITS Integration Program Funds, originally included automated passenger counting (APC) technology, digital video surveillance, on-board automated vehicle annunciation (AVA), smart-card based fare payment, web-based trip planning, and real-time information systems. Although many of these systems were already implemented as of August 2008, deployment of some of these technologies has been delayed for institutional or technical reasons.

The goal of the evaluation was to determine the impacts of these technologies in performing daily functions such as operations, scheduling, service planning, and maintenance, and to gather and document any lessons learned by the MST throughout the process of the deployment and operation of the technologies. This report discusses impacts to date of the technologies that have been in place for at least one year as of June 2009. The findings from customer satisfaction surveys that were conducted in Phase III to observe the impacts of technologies, particularly real-time information, and web-based trip planning on MST, are also documented in this report.

As discussed in the Phase II report, the Evaluation Team was not able to derive conclusions on the direct impact of technology for certain expected changes (e.g., increased ridership, improved on-time performance). Further AVL data analyses were performed in Phase III, but the analysis results regarding schedule adherence remained inconclusive. However, anecdotal information obtained from MST staff during interviews conducted in Phase II provided significant evidence to show that technology has helped MST make significant improvements in operations and planning. Also, based on the customer surveys conducted in Phase III, it can be concluded that a significant number of MST riders are satisfied with the MST service which has been improved through the deployment of the technologies. The survey results reveal that nearly 70% of the riders surveyed are "satisfied" or "very satisfied" with the reliability of service, and nearly 80% of the riders surveyed are "satisfied" or "very satisfied" with MST service in general.

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GLOSSARY OF ACRONYMS

AADT	Annual Average Daily Traffic
AAS	Automated Annunciation System
ACS	Advanced Communication System
ADUS	Archived Data User Services
APC	Automatic Passenger Counters
AVL	Automatic Vehicle Location
AVA	Automatic Vehicle Annunciation
BRT	Bus Rapid Transit
CAD	Computer Aided Dispatch
COA	Comprehensive Operational Analysis
DDAM	Daily Dispatch and Attendance Management
FAMIS	Financial and Accounting Management System
FTA	Federal Transit Administration
GPS	Global Positioning System
ITS	Intelligent Transportation System
JPO	Joint Program Office
MMS	Maintenance Management System
MOE	Measures of Effectiveness
MST	Monterey-Salinas Transit
NTD	National Transit Database
RITA	Research and Innovative Technology Administration
RTIS	Real-Time Information System
TSP	Transit Signal Priority
USDOT	United States Department of Transportation

EXECUTIVE SUMMARY

The purpose of this document is to present the findings from Phase II and Phase III of the evaluation of the Intelligent Transportation Systems (ITS) Augmentation Project that was implemented at Monterey-Salinas Transit (MST) in Monterey, California. This project, implemented using Federal Fiscal Year 2003 ITS Integration Program Funds, originally included automated passenger counting (APC) technology, digital video surveillance, on-board automated vehicle annunciation (AVA), smart-card-based fare payment, transit signal priority (TSP), web-based trip planning, and real-time information systems. All of these systems were implemented as of June 2009 except for smart card fare payment and TSP. Deployment of these two technologies has been delayed for institutional and technical reasons.

Monterey-Salinas Transit (MST) is one of the three major transit providers in the Monterey Bay area and serves Monterey County and Southern Santa Cruz County. MST provides service to the 352,000 residents of Monterey County, including the RIDES curb-to-curb paratransit transportation service for residents of the MST service area who need specialized transportation. MST serves the Monterey Peninsula and Salinas Valley areas with 36 fixed routes and provides service between these two urban areas of Monterey County via Highway 68 and Highway 1. MST also operates trolleys that serve the area along the Monterey and Pacific Grove waterfronts.

Background on the ITS Augmentation Project

MST received Federal earmark funding in 2003 to procure and implement technologies to meet its daily organizational needs. These technologies were implemented under a project named the ITS Augmentation Project. The ITS Augmentation Project was primarily intended to assist MST in improving customer information and convenience, on-time performance, operational efficiency and management, and safety and security. Additionally, the project was expected to enhance reporting and implement automated passenger counting.

MST's goals for the ITS implementation as they relate to Federal Transit Administration (FTA)/USDOT goals were identified as follows:

FTA/USDOT Goals	MST Issues Addressed by ITS Technologies
Increased Productivity	Route performance and cost
	Maintenance scheduling and management
Improved Mobility	Customer information and convenience
Improved Efficiency	On-time performance
	Operational efficiency and management
	Enhanced reporting
	Automated passenger counting
Improved Safety	Safety and Security

The following technologies were selected by MST for implementation as part of the ITS Augmentation Project:

- On-board technology for automatic passenger counting (APC);
- Automatic vehicle Announcements (AVA);
- Upgraded transit management and planning software;
- Digital cameras on buses and in transit centers;
- Security images to local public safety agencies;
- Archived Data User Service (ADUS);
- Real-time information system (RTIS);
- Transit Signal Priority (TSP);
- Translink program (San Francisco Bay Area smart card fare payment system); and
- Upgraded MST website to provide trip planning and bus location information.

Some of the above technologies (e.g., passenger counting and AVA) were integrated with the existing Advanced Communication System (ACS) system, which was procured under a separate grant in 2002. The ACS is a global positioning system (GPS)-based computer aided dispatch and automatic vehicle location (CAD/AVL) system.

Most of the technologies identified in the ITS Augmentation project were implemented as of June 2009. MST has decided not to use the Translink program due to current institutional issues among participating agencies and the vendor. The agency plans to procure smart card fare payment technology in partnership with the Santa Cruz Metropolitan Transit District.

MST decided not to participate in the TakeTransit trip planner offered by the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area even though that was identified in the original scope of this project. Instead, MST launched the Google Transit trip planner in November 2008.

MST has not yet implemented TSP because all of the project stakeholders have yet to reach consensus regarding the benefits of this technology. The dynamic message signs (DMS) providing real-time information have been installed at two locations. Please refer to Section 1.2 of this report for further details on the deployment status of each technology.

MST has procured other technologies since the implementation of the ITS Augmentation Project to reduce manual process and improve efficiency, including implementing a financial accounting and management software (FAMIS)[1] in 2006, a new payroll system in 2008 and maintenance management system (MMS) in 2006. MST has also installed on-board internet access on vehicles serving the two commuter routes.

Background on the MST ITS Evaluation

The USDOT's ITS Joint Program Office (JPO), housed within the Research and Advanced Technology Administration (RITA) established a National ITS Evaluation Program to determine the impacts of ITS deployments across the country. The objective of these evaluations is to document findings that can be used by a wide variety of external audiences such as planners, engineers, and managers. The results of

[1] "FAMIS" is a term used by MST to refer to its financial and accounting system. This is not an official product name for the system.

these evaluations assist in the planning and implementing of future ITS projects with help of lessons learned from systems already implemented.

The ITS/JPO selected the MST ITS Augmentation Project for an evaluation to be conducted by an independent Evaluation Team comprised of SAIC and TranSystems (referred to as the Evaluation Team in this report). The two-fold purpose of this evaluation is to evaluate the use of archived ITS data for improving service planning and operations and to evaluate the costs and benefits of implementing the MST ITS Augmentation Project. The ACS was evaluated along with the technologies that are part of the Augmentation Project since these technologies were integrated with the ACS. Further, the ACS was evaluated because it contributes significantly to achieving the ITS Augmentation Project goals (e.g., on-time performance). Also, the Evaluation Team analyzed the impact of other technologies that were not procured with the Federal earmark funding (e.g., FAMIS and MMS) but have made significant contributions to improvements at MST.

The evaluation was conducted in three phases. Phase I of the evaluation was an initial assessment of the implementation of the Augmentation Project by the Evaluation Team. This Phase was completed in October 2005 when the Evaluation Team submitted its Phase 1 findings to the ITS/JPO. These findings assisted the ITS/JPO in deciding to proceed with a full evaluation of MST's Augmentation Project. Phase I results are not included in this Evaluation Report.

Phase II, completed in December 2008, focused on a "before and after" analysis of the technologies that had been fully deployed as of August 2008. Additionally, the Phase II report provided information on technologies that were planned to be deployed in the future.

In Phase III, the impacts of real-time information and the Google Transit trip planner were evaluated by analyzing results of the customer intercept surveys that were conducted. Since TSP and smart card payment were not deployed at the time of Phase III evaluation, an analysis was not performed for these technologies. Further, all inconclusive hypotheses from Phase II were revisited in Phase III.

The evaluation approach adopted for Phases II and III is discussed in Section 2 of this report.

Conclusions of the Evaluation

This report describes the findings from both Phase II and Phase III of the evaluation. The evaluation was conducted by testing the hypotheses identified in the Evaluation Plan submitted to USDOT in January 2007. Data collection and analysis were conducted according to the Test Plan submitted to USDOT in June 2007. The evaluation was based on six key hypotheses and nine secondary hypotheses. These hypotheses were tested by analyzing quantitative data obtained from MST and qualitative data obtained by interviewing MST staff (staff interviews were conducted in Phase II), and by conducting intercept surveys of MST customers at two major transfer centers (surveys were conducted in Phase III). The Evaluation Team would like to thank MST staff members since they have made significant contributions to this evaluation by providing data and anecdotal information, and by assisting with the planning for the customer survey.

The evaluation of ITS deployment at MST has resulted in the identification of key factors about MST's experience related to the procurement, implementation, management, and utilization of ITS technologies. Also, the evaluation identified the impacts of the technology on various departments at MST. Further, the customer satisfaction survey conducted in Phase III of the evaluation helped measure customer perception of the impacts of the deployment of technology at MST.

The following paragraphs provide a summary of the evaluation findings with respect to both key and secondary hypotheses. The results of testing the hypotheses revealed that they were either supported or inconclusive. For example, a few of these hypotheses (e.g., related to the improvement of on-time performance, and increase in ridership) were not supported by the data. The contribution of related technologies was not obvious due to the involvement of external factors (e.g., service change and operational improvements). Further, given that it takes considerable time for technologies such as those deployed at MST to stabilize, to become integral to agency operations and management, and to be accepted by staff, all hypotheses were re-examined in Phase III. However, as discussed below, in many cases, the conclusions were not markedly different from those that were determined in Phase II. Also, some hypotheses did not require retesting in Phase III since quantitative or anecdotal evidence obtained in Phase II had already provided sound conclusions.

The key hypotheses for this evaluation are:

- Hypothesis: The project will result in a reduction in operations and planning costs and improved service planning. In Phase II, the Evaluation Team found increases in annual revenue and annual revenue per passenger-mile from the time of the technology implementation. However, it was not obvious that the improvements were due to technology. Also, quantitative estimates of benefits perceived by MST departments were not available for most technologies. MST provided some basic estimates of savings from the deployed technologies, such as the HASTUS scheduling software, and fuel management systems highlighted in Section 3.7.5 of this report.

  Also, as part of the staff interviews conducted in Phase II, MST provided anecdotal evidence of benefits perceived from ITS implementations (as of August 2008), which provides the basis for the fact that technology contributed to service planning and operations improvements. MST reported improvements in service planning due to the accuracy and reliability of the archived ACS data used in recent comprehensive operational analysis (COA) studies. Also, MST has been able to reduce the cost of data collection by reducing the manual effort required by COA studies (e.g., recruitment of temporary staff). Among other benefits, MST utilizes archived data from the ACS for analysis with the help of other tools such as ArcView and Microsoft Excel and Access for planning needs (e.g., using passenger count data for determining stop and shelter needs and appropriate locations).

  This hypothesis was not revisited in Phase III since anecdotal evidence obtained in Phase II led to the conclusion that new technologies played a significant role in improving MST service. MST staff considers these improvements to be a result of changes made in the service based on recommendations resulting from ACS data analyses.

- Hypothesis: The project will result in improved on-time performance of MST operation. The intent of this hypothesis was to determine if there were improvements in schedule adherence due to the availability of real-time vehicle information for dispatchers and supervisors. Also, the Team wanted to evaluate the impact of MST's ability to adjust schedules by utilizing the archived ACS data. However, *this hypothesis could not be supported with the results obtained from the quantitative data analysis.* The results were inconclusive in Phase II because MST had made several changes in planning and operations during the time period selected for analysis. Therefore, this hypothesis was re-examined in Phase III of the evaluation.

In Phase III, the Team analyzed a larger amount of AVL data (daily schedule adherence data from March 2005 through June 2009) but, similar to Phase II, the analysis results did not suggest any consistent trends for schedule adherence (i. e., consistent improvement after AVL deployment). It should be noted that, in most cases, vehicles were found to be on-time per MST standards (less than 5 minutes late). Also, the variability across the evaluation timeframe was well within two minutes. However, as concluded in Phase II, it cannot be confirmed that the use of the ACS system alone had an impact on MST's on-time performance. Various changes in the system implemented by MST during the evaluation timeframe could have contributed to the trends as well (Figure ES1).

2009	Fares changed from $2.00 to $2.50 (Jan 2009)
2008	• Google Transit went live (Nov 2008) • Bus Stop Shop (customer service center) opened in Monterey Downtown (Aug 2008) • Minor service change (May and Aug 2008) • Real-time information system went live at Salinas Transit Center (Feb 2008) • Minor Service change (Jan 2008)
2007	• Real-time information system live at Marina Transit Exchange(Oct 2007) • Service change in Monterey area (Jan 2007)
2006	• Service change in Salinas area (Oct 2006) • Started to charge for transfer at $0.25 (Aug 2006) • On-time performance standard changed (Jan 2006) • HASTUS/ ACS integration (Jan 2006)
2005	• Routes resurveyed and trigger zones modified (2005) • Fare change from $1.75 to $2.00 (Jul 2005) • 41A and 41B renamed as 41 and 42 (Jul 2005)
2004	Large amount of missing ACS data (2004)
2003	Large amount of missing ACS data (2003)
2002	ACS implemented (Oct 2002)

Figure ES1. Timeline of Events Related to ACS Deployment

Even though the hypothesis cannot be supported with the results from the quantitative analysis, MST staff input obtained during Phase II interviews provided an understanding of the positive impacts of ACS. MST staff believes (see their detailed input in Section 3.1.2.2.3) that on-time performance has improved since the technology implementation and technology has contributed directly or indirectly to this improvement (e.g., by providing data for COA analysis and subsequent service restructuring).

- Hypothesis: The project will result in an increase in the reliability of services. In Phase II, the Evaluation Team concluded that the reliability of MST service should be measured by performing a qualitative assessment of customers' perception of on-time performance. Based on the customer survey, it can be concluded that at least 70 percent of the riders who were surveyed in Monterey and Salinas are "satisfied" or "very satisfied" with the on-time performance of MST service. Also, a similar percentage of riders are "satisfied" or "very satisfied" with the ease of making transfers. These statistics indicate that a significant number of MST riders find MST service reliable.

- Hypothesis: The project will enhance system productivity. This hypothesis is supported by several statistics that serve as indicators of productivity improvements (e.g., revenue per passenger mile and passenger miles). These statistics were calculated in Phase II of the evaluation; however, these statistics are inconclusive since it is not clear from the productivity indicator data whether the improvements are due to technology implementation or other changes in the organization.

  This hypothesis was revisited by examining productivity data for fiscal years 2008 and 2009. A trend indicating some improvement in productivity was based on several of the statistics (e.g., revenue and revenue-hours), but in most cases, the statistics (e.g., boarding/revenue-hour) showed inconsistencies when compared to the trends observed in Phase II. These inconsistencies were mostly due to a decrease in MST ridership in fiscal years 2008 and 2009. Thus, the results of the quantitative data analyses were inconclusive.

  However, as reported in Phase II, based on staff interviews, MST staff believes that the technology has assisted them in increasing their productivity by carrying more passengers during the same service hours with improved scheduling. MST also pointed out during staff interviews that a productivity increase may not be an absolute indicator of service improvements since a decrease in productivity sometimes benefits the organization by contributing to on-time service. For example, reducing the number of passengers on overcrowded buses can reduce dwell times at stops and subsequently improve schedule adherence of those buses.

- Hypothesis: The project will result in an improvement in maintenance scheduling and planning. This hypothesis is supported by the information provided by the maintenance department during on-site interviews conducted as part of Phase II of the evaluation. MST staff believes that the MMS has enabled them to track daily maintenance activities such as inventory control, maintenance-workflow management, and fuel management. Other systems such as the ACS and video surveillance system assist MST by enabling the agency to review on-board system performance logs and by to monitor the quality of maintenance work (through reviews of recorded videos), respectively.

  As reported in Phase II, the Evaluation Team also wanted to evaluate the capabilities and impact of the remote diagnostics system implemented as part of the ACS. However, MST discontinued the remote diagnostics feature after initial use since the diagnostics were completely unreliable. MST was receiving an overwhelming number of false alarm messages, which led maintenance supervisors to ignore the remote diagnostics.

  We did not revisit this hypothesis in Phase III since anecdotal evidence obtained from Phase II interviews were sufficient to conclude that there are positive impacts of the deployment of MMS and ACS on managing maintenance activities at MST.

The secondary hypotheses for this evaluation are:

- Hypothesis: The project will result in improved customer satisfaction. Customer intercept surveys were conducted at the Monterey Transit Plaza and Salinas Transit Center locations in mid-September 2009. The overall satisfaction with MST was found to be very high with riders at both locations — they provided ratings that averaged a score of 4 out of a possible 5. Also, this overall average was reflected in riders' perceptions of MST's on-time performance, the ease of making transfers, the frequency of service, the hours of service, and the number of routes served. In fact, almost three-fourths of the survey respondents said that they were "satisfied" or "very satisfied" with each of the system attributes discussed above.

  Further, riders were very positive in their views of the AVA system with 7 out of 10 (from both locations) reporting that they "agree" or "completely agree" that the announcements are loud enough, help them find their stop, and give them enough time to get ready before the stop. Salinas riders were positive in their views of the electronic signs. Again, almost three-fourths of surveyed riders reported that they "agreed" or "completely agreed" that the signs were useful, accurate, easy to understand, and conveyed the correct bus status information.

  However, although a majority of riders appear to be satisfied with many aspects of the MST bus service, it appears that many of the riders are not yet making use of the benefits of (or have access to) the most recent MST technological advances such as real-time travel information and automated trip planning.

  Thus, it can be concluded, based on the results of the intercept surveys, that the technology implementation has resulted in improved customer satisfaction.

- Hypothesis: The project will result in an increase in ridership. The data provided by MST shows an increasing trend in ridership since 2003. However, this information does not support the hypothesis as it is not clear if the ridership increases have been due to just technology implementations.

  This hypothesis was revisited during Phase III by analyzing customer satisfaction obtained from intercept surveys. As discussed above, a large number of MST riders are satisfied with the service.

- Hypothesis: The project will result in an improvement in driver and passenger security. The Evaluation Team obtained several anecdotal references that support this hypothesis through MST staff interviews conducted in Phase II. The general perception at MST is that security systems have helped them create a safer environment for MST riders and coach operators.[2] MST has posted placards on-board vehicles that inform riders that they are under video surveillance.

  The local police consider MST buses as "mobile surveillance units." MST's ability to provide video evidence of criminal activities that involve MST buses with the help of on-board cameras has helped improve MST's relationship with the local police.

  The on-board security cameras assist MST primarily in capturing evidence of any criminal activity. Additionally, these cameras have continually assisted MST in reducing the number of insurance claims

[2] "Coach Operators" is the term used by MST for bus drivers.

submitted by passengers (e.g., related to slip and falls). Also, the video evidence assists MST in protecting drivers from being victims of false customer complaints.

Since the Phase II results discussed above provided evidence regarding the impact of surveillance systems on driver and passenger security, this hypothesis was not revisited in Phase III.

- Hypothesis: The project will result in a reduction in the travel times of specific routes where TSP is deployed. This hypothesis was not tested in Phase III since MST has not yet implemented TSP.

- Hypothesis: The project will help reduce response time for incidents and emergency management. The hypothesis can be supported by information provided by operations and maintenance staff from interviews conducted during Phase II. However, the Team did not receive any quantitative estimates of improvements in response time.

  It was reported in Phase II that the availability of the ACS assists MST staff to track vehicle locations in real-time and enables them to send a supervisor to the accident site immediately. Also, MST drivers can select a specific text message from the list of canned messages on mobile data terminals (MDTs) and send that to the dispatcher to notify operations that there has been an incident enabling drivers to avoid making a voice call, if necessary. Text messaging capability has helped MST reduce the voice radio traffic by 60 percent. Also, starting fall 2008, MST supervisor will be able to connect remotely to the ACS to obtain any additional information that is needed while responding to an incident.

  The ACS enables MST to provide and monitor evacuation services in the event of natural disasters such as the wildfires that happened during summer 2008. For example, during the recent wildfire event in Big Sur, MST was able to develop and manage task forces using MST vehicles through the use of the ACS.

  Also, the number of incidents has been reduced in recent years subsequently contributing to reduced insurance premiums.

  Since anecdotal and quantitative evidence obtained in Phase II provided sufficient information to conclude that there are improvements in incident response time, this hypothesis was not re-examined in Phase III.

- Hypothesis: The project will result in a reduction in vehicle hours. The intent of this hypothesis was to test whether the technology has assisted MST in reducing the number of revenue hours since 2003. Since annual revenue-hour statistics do not show a consistent increasing or decreasing trend, this hypothesis could not be supported. The number of revenue-hours decreased between 2003 and 2005, but an increasing trend can be seen since 2005. This inconsistency could be due to operational changes (e.g., addition of more trips to a route) implemented by MST throughout the evaluation timeframe.

  This hypothesis was not re-examined in Phase III since the trend of revenue vehicle-hours alone does not provide a reasonable indication of the impacts of technology on overall MST operations. Trends in revenue vehicle-hours need to be examined in conjunction with the number of passengers carried by those vehicles.

A reduction in deadhead-miles or deadhead-hours may be a reasonable indicator of improvements in transit operations, but the Team did not have access to the data required to measure the non-revenue miles or hours experienced by MST vehicles.

- Hypothesis: The project will reduce the number of customer complaints. This hypothesis was not tested completely in Phase II since MST did not have a record of the number of customer complaints for the "before" and "after" cases. However, it was indicated by MST during the Phase II interviews that the reduction in the number of complaints should not be an absolute indicator of improved customer service. They have noticed that the number of complaints have increased since MST developed an efficient process to track and respond to a customer complaint. It is evident that customers like to provide more comments and feedback only when they are assured of receiving a response.

  This hypothesis was not revisited in Phase III since no additional data could be obtained to make additional conclusions.

- Hypothesis: The project will result in improved facility security. This hypothesis is supported by the facts and anecdotal references obtained during on-site interviews as part of Phase II of the evaluation. The physical facilities are equipped with cameras and the closed circuit television (CCTV) technology that enable the real-time video monitoring of facilities by the safety and security group. MST staff believes that the video monitoring capability has assisted MST in reducing vandalism activities and creating a more secure environment for MST riders waiting at transit centers.

  Also, MST has implemented controlled access to its facilities with. The access is restricted to MST staff with a valid proximity card-based identification. This implementation is assisting MST in securing its physical facilities (headquarters and the transit centers) by restricting entrance to only authorized employees.

- Hypothesis: The project will establish a comprehensive reporting system. This hypothesis cannot be supported with the available information as the reporting process could not be evaluated "before" and "after" the technology.

  However, MST staff believes that the current reporting needs to be improved. The standard reports provided by various deployed systems (e.g., ACS, MMS, FAMIS) do not necessarily provide the information needed by MST employees. MST had hired an outside consultant to conduct a needs assessment for reporting; however, it was reported by MST during the Phase III onsite visit that the project could not be completed. Thus, this hypothesis is not supported with currently available information.

- Hypothesis: The project will result in reduced cases of false financial claims. Through the staff interviews conducted in Phase II, MST provided several anecdotal references (see Section 3.3.2.2) that serve as evidence of financial savings due to the implementation and use of technologies, primarily the video surveillance system. The video playback component of the ACS also assists MST in responding to customer complaints related to late arrivals or departures.

  The on-board cameras have helped MST save money in various false complaints and accidental damage claims from passengers. MST reported that it recovered $70,000 during fiscal year 2007. However, before the installation of the video surveillance system, cost recovery was only in the order of

$800 – $1800. Also, MST had to pay $3 million in settlements due to lack of sufficient evidence, which could have been mitigated with the help of an additional exterior camera on the bus.

Since the findings from Phase II were sufficient to support this hypothesis, it was not re-examined in Phase III.

Figure ES2 highlights the overall benefits found from this evaluation. Even though the Evaluation Team was not able to derive conclusions regarding the direct impact of technology for specific expected changes (e.g., increased ridership, improved on-time performance), anecdotal information obtained from MST staff has provided significant evidence to show that, so far, technology has made significant improvements in operations and planning. Also, survey findings reveal a high satisfaction among MST riders that can be partially attributed to changes in the system based on recent studies (which used ACS data for analyses), or new customer-centric technology implementations (e.g., AVA or real-time information signs). Generally, technologies have played a significant role in improving the efficiency of all departments as reported by the MST management. Improved efficiency has helped MST achieve cost savings as well. It is expected that even more benefits will be realized as these technologies are increasingly relied upon to perform specific operational and management functions.

Summary of Overall Benefits

Improved decision-making based on facts/information available from ACS and other systems.

Organizational Improvements:

- Availability of archived ACS data for analysis by service planning department
- Improved scheduling with scheduling and operations software
- Video evidence of boardings and alightings helped defend operational changes (e.g., discontinuation of a route)
- ACS and other technologies helped identify routes that are not cost-effective

Current benefits have generated management support for future technology deployments (e.g., MST Board of Directors adopted technology as a priority).

Return on Investment:

- $1 million/year savings from scheduling and operations software by incorporating meal and rest breaks (per new contract rules) and improved pay-to-platform ratio
- Efficient resource usage - purchased only 15 buses as replacement for 17 buses
- Improved inventory control and warranty tracking from MMS using CCTV monitoring
- Reduction in false insurance claims with video evidence
- $15,000/year savings from new payroll system

Figure ES2. Summary of Overall Benefits

Technologies have primarily helped MST operations by enabling the agency to track vehicles in real-time and respond to incidents and emergency situations quickly. Also, HASTUS and the ACS, along with other tools, have helped MST improve planning which has subsequently helped the agency to run better operations (e.g., improved on-time performance resulting from route changes and schedule adjustments). The impact of the video surveillance system is significant as well because it has created a safer rider environment and has enabled MST to defend itself against lawsuit claims and reduce insurance-related costs. The maintenance department has experienced benefits through the MMS as it assists MST in improving the workflow process and quality control.

Figure ES3 highlights the overall lessons learned identified during this evaluation. The technology implementations provided an opportunity for MST to learn several lessons that will help them in future procurements. As MST plans to replace some of their systems (e.g., the ACS) with upgraded and better technologies, they believe that the prior deployment experience gives them enough confidence to procure from and negotiate with vendors, and manage the implementation of those technologies.

Summary of Lessons Learned

- Need good process management during procurement and implementation
- Should be willing to increase staff
- Should be flexible in embracing benefits of technology
- Should consider timely technology upgrade
- Should factor both ITS data and anecdotal information in decision-making
- Need good training plan for successful technology implementation
- Need “culture of change” for successful technology implementation
- Need technology standardization across agency

Figure ES3. Summary of Lessons Learned

1 Introduction

1.1 Overview of the Monterey-Salinas Transit

Monterey-Salinas Transit (MST) is one of the three major transit providers in Monterey Bay area. MST was formed in 1981 after the merger of the Salinas Transit System with the Monterey Peninsular Transit. Currently, MST serves an area of approximately 280 square miles in Monterey County and Southern Santa Cruz County. MST provides service to the 352,000 residents of Monterey County. MST also provides curb-to-curb paratransit transportation services, called RIDES, to the residents of the MST service area who need specialized transportation. RIDES is operated by MV Transportation.

MST serves the Monterey Peninsula and Salinas Valley areas with 36 fixed routes. MST provides service between these two urban areas of Monterey County via Highway 68 and Highway 1.

In addition to the Monterey-Salinas area, intercity routes connect MST with the Santa Cruz Metropolitan Transit District. MST also provides rural transit service to Carmel Valley and seasonal service to Big Sur. Recently, MST has added express commuter routes to its service on two corridors: Monterey – San Jose and Salinas – King City.

In addition to regular and express routes, MST operates trolleys that serve the area along the Monterey and Pacific Grove waterfronts.

MST recently reviewed and modified its routes based on recommendations from the Monterey Peninsula and Salinas Service Area Studies completed in 2005 and 2006, respectively.

Nine new routes were introduced in July 2009 to serve active duty service members and Department of Defense (DoD) employees who commute to work from (outside of the Presidio in Monterey) communities throughout Monterey County and from San Jose.

MST operates its services from the following five transit centers or transfer centers located across its service area:

- City of Monterey: Monterey Transit Plaza;
- City of Salinas: Salinas Transit Center;
- City of Sand City: Edgewater Transit Exchange;
- City of Marina: Marina Transit Exchange; and
- City of Watsonville: Watsonville Transit Center.

MST serves 36 fixed routes that include approximately 1,250 bus stops. Table 1 provides information on specific operational characteristics of MST.

Table 1: MST Operational Characteristics

Category	Directly Operated Services	Contracted (Fixed Route and Demand Response)
Number of coach operators*	123	28
Number of road supervisors	9	3
Number of dispatchers	4	3
Number of revenue vehicles	76	21
Number of non-revenue vehicles	31	Not applicable
* "Coach Operators" is the term used by MST for bus drivers.		

MST operated approximately 3.6 million revenue-miles and just under 230,000 revenue-hours annually in fiscal year 2009 (which ended in June 2009). Other operating statistics and performance measures are as follows for fiscal year 2009:

- Annual operating and capital budget = $25.2 million;
- Passengers per revenue-mile = 1.23;
- Annual boardings per capita = 12.5;
- Operating cost per passenger = $5.72;
- Passengers per revenue-hour = 19.6; and
- Operating cost per revenue-hour = $112.1.

Figure 1 is a regional map of the MST service area.

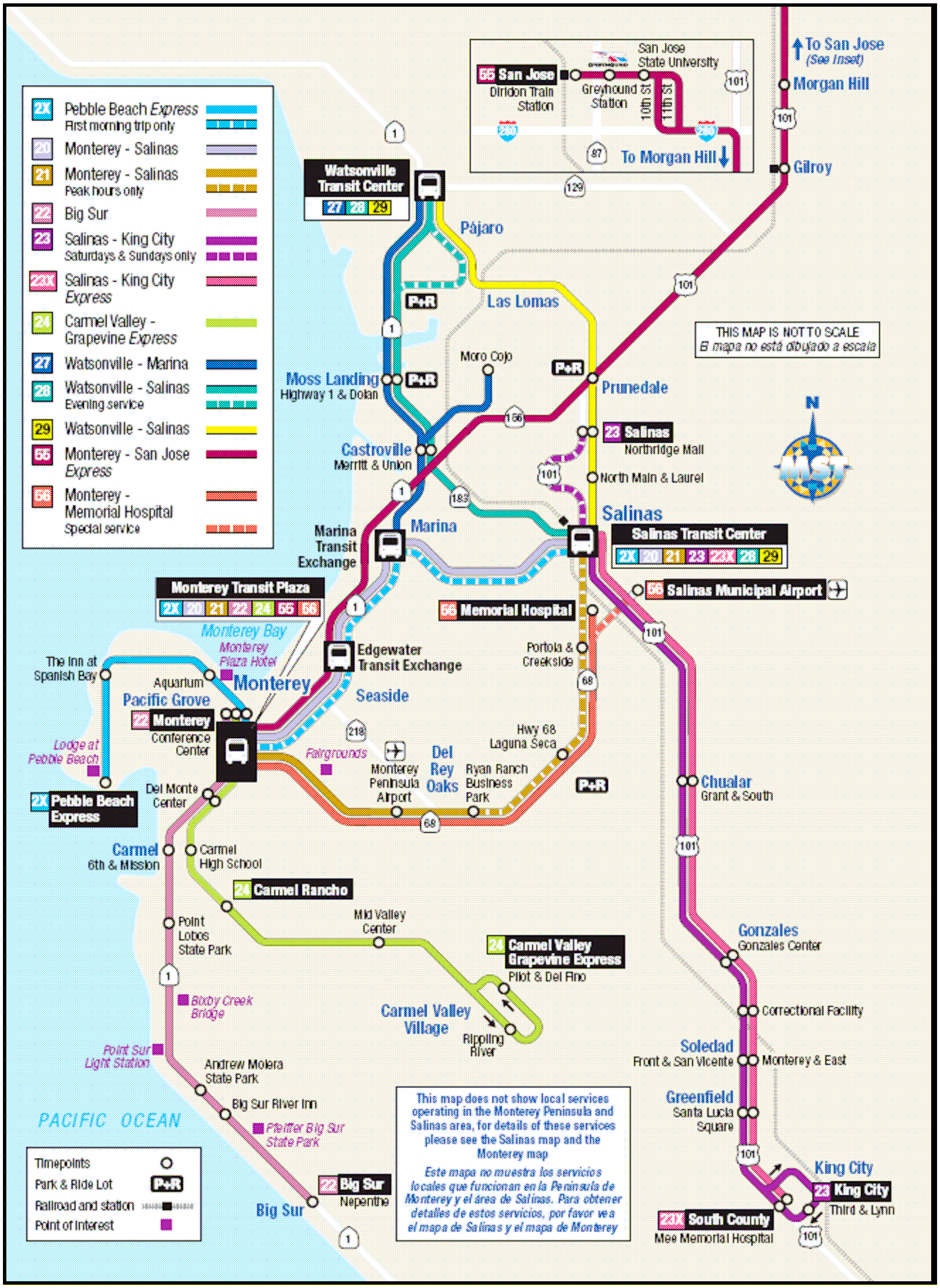

Figure 1. Regional Map of MST Service Area

1.2 Monterey-Salinas Transit ITS Augmentation Project

The TransitMaster system was implemented at MST in October 2002 as part of a $3.5 million MST Advanced Communication System (ACS) project. The TransitMaster system was installed to provide MST operations with computer-aided dispatch/ automatic vehicle location (CAD/AVL) and digital voice/data communications. Later in 2006, a maintenance management system (MMS) was installed. MST also procured financial management and accounting software (FAMIS) in 2006. MST has plans to integrate the MMS with the FAMIS. They will not integrate the ACS with the MMS. In 2007, MST procured and installed on-board internet access system on buses serving commuter routes.

In fiscal year 2003, MST received Federal earmark funding for the implementation of the ITS Augmentation Project to address the following areas:

- Customer information and convenience;
- On-time performance;
- Route performance and cost;
- Automated passenger counting;
- Operational efficiency and management;
- Maintenance scheduling and management;
- Safety and security;
- Integration with the regional emergency services communication system; and
- Enhanced reporting.

Like many other transit agencies, MST was faced with challenges in keeping track of its fleet and personnel, monitoring the performance of its services, and complying with the Americans with Disabilities Act (in terms of providing next-stop and major intersection announcements). MST procured its Advanced Communication System (ACS) system, consisting of new radio and a GPS-based CAD/AVL system, to meet these needs. The ITS Augmentation Project continues to meet the additional needs of MST, such as providing a high level of safety and security both on-board and in transit facilities, providing passengers with real-time information and trip planning capabilities, facilitating the collection of passenger counts, and ensuring service reliability. In meeting these needs, one key element of the Augmentation Project is to ensure that all aspects of the ACS are fully integrated.

MST has completed the deployment of most of the ITS systems as part of the ITS Augmentation Project, with the TSP, smart card fare payment, and additional real-time information signs yet to be deployed. The following sections describe the basic features and the deployment status of each of the technologies identified as part of the ITS Augmentation Project.

1.2.1 Passenger Counting

The implementation of a passenger counting system was accomplished using a technique that was different than what was originally intended. The agency has elected to gather passenger counting information by having MST coach operators record (via their MDT) the number of passengers boarding (see Figure 2).

MST coach operators do not enter any alighting data. Daily alighting figures are estimated based on the number of boardings. Also, alighting data is verified using information from on-board surveys[3] when National Transit Database (NTD) data is being collected.

Figure 2. On-board MDT

1.2.2 Automated Vehicle Announcements (AVA)

All vehicles are equipped with on-board light emitting diode (LED) dynamic message signs (DMS) and a public address system for making visual and audio next-stop announcements. These announcements are made per the ADA. Figure 3 shows DMS installed inside an MST vehicle showing a “stop requested” message. When a stop has been requested, the DMS alternates to a next-stop announcement message as the vehicle approaches a major stop, landmark or street-intersection.

Figure 3. On-board DMS for Making Visual Next Stop Announcements

[3] On-board surveys refer to having MST staff or a consultant count the number of passengers boarding and alighting.

1.2.3 Transit Management and Planning Software

The existing scheduling and runcutting software, called Gsched, was upgraded and replaced with HASTUS Scheduling Software from Giro, Inc. in 2005. The Daily Dispatch and Attendance Management (DDAM) timekeeping module of HASTUS was purchased from Giro in 2007.

1.2.4 Surveillance System

All MST revenue vehicles are equipped with digital cameras. MST completed the initial installation on 38 vehicles in 2003 and installed cameras on the remaining vehicles in 2007. These cameras are installed both on the interior and exterior of MST vehicles. The video is recorded by a digital video recorder (DVR) which is connected to the on-board cameras. The on-board DVR can store up to 72 hours of data. Data is overwritten once the DVR memory disk reaches its capacity.

The surveillance system has enabled MST to develop an excellent relationship with the local police department by sharing video data when necessary.

1.2.5 Archived Data User Service

The implementation of the ACS has enabled MST to store, archive, and retrieve historic logs of daily vehicle events. The data archived by the ACS can be exported and analyzed by MST planning and operations staff. MST staff utilizes Microsoft Access and Excel to analyze the archived ACS data.

1.2.6 Real-time Traveler Information

The DMS that provide real-time information were installed by MST at the Marina Transit Exchange and Salinas Transit Center in 2007. Additional DMS were installed at the "Bus Stop Shop," a new customer service center which was opened near the Monterey Transit Plaza in 2008. MST plans to install additional DMS at other major bus transfer points, including downtown Monterey, the Del Monte Shopping Center, Northridge Mall, and the Crossroads Shopping Village in the future.

Figure 4 provides an example of the LED DMS installed at the Salinas Transit Center. One DMS has been installed in the center of each bus bay providing the scheduled departure and estimated arrival time for each bus.

Figure 4. DMS Displaying Real-Time Information at Salinas Transit Center[4]

[4] Photograph provided by Monterey Salinas Transit.

Figure 5 shows a liquid crystal display (LCD) sign with a summary of the arrivals at and departures from the Marina Transit Exchange. The LCD DMS was installed inside the customer service kiosk at the Center to avoid vandalism.

Figure 5. DMS Displaying Real-Time Information inside Customer Service Kiosk at Marina Transit Exchange

MST believes that the DMS, which were tested extensively before installation in both locations, have been working as expected. The Evaluation Team assessed the impact of real-time information on MST operations in Phase III of this evaluation by conducting customer intercept surveys.

1.2.7 Transit Signal Priority (TSP)

MST vehicles have been equipped with transit signal priority (TSP) transponders[5] since 2001, but TSP has not been implemented yet because of institutional issues. MST has been negotiating with the City of Salinas and other jurisdictions to achieve consensus for the implementation of TSP along the proposed bus rapid transit (BRT) corridors. Currently, only the City of Monterey has approved the use of TSP. Thus, MST is not certain about the timing of TSP deployment.

1.2.8 Integration with Translink[6]

MST had planned to implement smart card fare media on buses traveling to the Bay area, which is currently using the Translink smart card fare payment system. MST runs eight buses on the long distance commuter route to San Jose. However, due to delays caused by institutional agreements between the vendor and agencies in the region, MST has decided not to use the same Translink fare media.

[5] Transponders are installed on-board transit vehicles to emit signals to receivers installed at traffic intersections. These receivers process the signals to extend priority to transit vehicles.
[6] Translink is a Contactless smart card based fare collection system being implemented in the San Francisco Bay Area.

MST will be investing in a separate smart card fare payment system in partnership with the Santa Cruz Metropolitan Transit District in the future by utilizing a grant received from the State of California.

1.2.9 Improvements in MST website

Originally, MST planned to participate in the TakeTransit trip planner program offered by the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area. However, MST had discussions with Google, Inc. and decided to implement a regional trip planner for the Monterey-Salinas and Santa Cruz regions. After evaluating several other options, MST decided to deploy the Google Transit trip planner, which went live in November 2008. The Google Transit trip planner for MST enables MST riders to plan regional travel in the Bay Area.

Displaying the real-time location of buses on their website is not a high-priority requirement for MST since their customer service representatives do not receive a large number of calls requesting information on the real-time location of buses. However, MST is interested in surveying customers regarding their interest in using such a capability in the future.

Table 2 provides a summary of the current (as of June 2009) status of each technology deployment as part of the ITS Augmentation Project.

Table 2. ITS Augmentation Project Deployment Status

Technology	Deployment Status
On-board Passenger Counting	Completed in 2003
Automated Annunciation System	Completed in 2003
Upgrade of Transit Management and Planning Software	Completed in 2005
Digital cameras on buses and in transit centers	Completed in 2007
Archived Data User Services (ADUS)	Completed in 2003
Real-time Traveler Information System	Completed in 2007
Trip Planner	Completed in 2008
Transit Signal Priority (TSP)	Deployment timeframe uncertain
Smart Card Payment System	Deployment timeframe uncertain

1.3 Overview of MST ITS Evaluation Project

The USDOT's ITS Joint Program Office (ITS/JPO), housed within the Research and Advanced Technology Administration (RITA), established a National ITS Evaluation Program to determine the impacts of ITS deployments across the country. The objective of these evaluations is to document findings that can be used by a wide variety of external audiences such as planners, engineers, and managers. The results of these evaluations assist in the planning and implementing future ITS projects with the help of lessons learned from systems already implemented.

The ITS/JPO selected the MST ITS Augmentation Project for an evaluation to be conducted by an independent Evaluation Team comprised of SAIC and TranSystems (referred to as the Evaluation Team in this report). The two-fold purpose of this evaluation is to evaluate the use of archived ITS data for improving service planning and operations and to evaluate the costs and benefits of implementing the MST ITS

Augmentation Project. The ACS was evaluated along with the technologies that are part of Augmentation Project since these technologies were integrated with the ACS. Further, the ACS was evaluated since it contributes significantly to achieve the ITS Augmentation Project goals (e.g., on-time performance). Also, the Evaluation Team analyzed the impact of other technologies that were not procured with the Federal earmark funding (e.g., FAMIS and MMS) but have made significant contributions to improvements at MST.

The evaluation is being conducted in three phases. Phase I of the evaluation was an initial assessment of the implementation of the Augmentation Project by the Evaluation Team. This Phase was completed in October 2005 when the Evaluation Team submitted their Phase 1 findings to the ITS/JPO and the FTA. These findings assisted the ITS/JPO in deciding to proceed with a full evaluation of MST's Augmentation Project. Phase I results are not included in this Evaluation Report.

Phase II, completed in December 2008, focused on a "before" and "after" analysis of the technologies that had been fully deployed as of August 2008. Additionally, the Phase II report provided information on technologies that were planned to be deployed in the future.

In Phase III, the impacts of real-time information and the Google Transit trip planner were evaluated by analyzing results of the customer intercept surveys that were conducted. Since TSP and smart card payment were not deployed at the time of Phase III evaluation, an analysis was not performed for these technologies. Further, all inconclusive hypotheses from Phase II were revisited in Phase III.

1.4 Document Organization

The remainder of this Evaluation Report is organized as follows.

- Section 2 discusses the evaluation approach;
- Section 3 discusses the impact of the deployed systems and sub-systems on various departments at MST (e.g., Planning, Operations and Security);
- Section 4 describes the implementation challenges faced by MST during the deployment of ITS technologies;
- Section 5 identifies several lessons learned from MST's experience with the deployments; and
- Section 6 provides a summary of the results of Phases II and III of the evaluation.

2 Evaluation Approach

A kick-off meeting was conducted in Monterey, California at MST headquarters on November 1, 2006, to begin preliminary discussions and lay the foundation for the overall evaluation process as discussed later in this section. The following steps were proposed for conducting the evaluation:

- Develop Evaluation Plan;
- Develop Test Plan;
- Collect data;
- Conduct data analysis;
- Conduct on-site interviews at MST; and
- Prepare and submit final evaluation report.

The last four steps (i.e., data collection through the final report) were proposed to be conducted separately for Phases II and III of the evaluation. The final report for Phase III (this document) also includes findings from Phase II.

2.1 Evaluation Plan

2.1.1 Evaluation Phases

USDOT-sponsored ITS evaluations are traditionally divided into phases. During Phase II, the Evaluation Team collects data before the technologies are deployed and summarizes the "before" data in a Phase II Report. Phase III occurs once the technologies have been deployed (after the approval of Phase II results), when the Evaluation Team collects the "after" data and presents the findings of the "before and after" analyses in a Phase III Report. In the case of the MST ITS Augmentation Project, many of the technologies were deployed during Phase II, presenting the Evaluation Team with an opportunity to document the findings of the "before and after" analyses earlier, in the Phase II report. However, there were project components that were deployed during Phase II, namely real-time information and Google Transit trip planner. To allow the timely publication of evaluation results for the technologies already deployed, the Evaluation Team proposed that the scope of both phases be conducted in the following manner:

- **Phase II:** The "before and after" analyses were performed for those technologies that were fully deployed and operational. For those technologies that did not have a definite deployment frame, only the "before" analysis was performed. The Phase II Report was prepared with results from these analyses.

- **Phase III:** This phase consisted of evaluating the technologies that were deployed by the end of 2008. The Evaluation Team collected the "after" data and customer satisfaction surveys during 2009.

For this Phase III report, the Evaluation Team performed the following activities:

- Collected data for the "after" analysis following the implementation of the new technologies;
- Collected customer satisfaction survey data at the Monterey Transit Plaza and Salinas Transit Center;

- Performed data analysis and tested the hypotheses associated with Phase III technologies;
- Developed the Draft Evaluation Report for Phase III and provided the report to FTA/FHWA for review and comment; and
- Incorporated FTA/FHWA comments, revised, and finalized the Final Evaluation Report for Phase III and submitted to FTA/FHWA for final review and approval.

2.1.2 Evaluation Hypotheses

The evaluation hypotheses and measures of effectiveness (MOEs) were developed in the initial phase of this evaluation project. The hypotheses that were submitted and approved in the Evaluation Plan were identified in two distinct categories: "key hypotheses" and "secondary hypotheses."[7]

Both key and secondary hypotheses were tested in the in Phase II report based on test procedures identified in the Test Plan. Section 6 describes results obtained from test of these hypotheses.

The key hypotheses for this evaluation are:

- The project will result in a reduction in operations and planning costs and improved service planning;
- The project will result in improved on-time performance of MST operation;
- The project will result in an increase in the reliability of services;
- The project will enhance system productivity; and
- The project will result in an improvement in maintenance scheduling and planning.

The secondary hypotheses for this evaluation are:

- The project will result in improved customer satisfaction;
- The project will result in an increase in ridership;
- The project will result in an improvement in driver/ passenger security;
- The project will result in a reduction in the travel times of specific routes where TSP is deployed;
- The project will help reduce response time for incidents and emergency management;
- The project will result in a reduction in vehicle hours;
- The project will reduce the number of customer complaints;
- The project will result in improved facility security;
- The project will establish a comprehensive reporting system; and
- The project will result in reduced cases of false financial claims.

Please refer to Appendix A for a detailed list of measures of effectiveness (MOEs) for all hypotheses.

[7] Secondary hypotheses are those that address goals that are relatively less significant in improving daily operations at MST in comparison to key hypotheses.

The evaluation of these hypotheses can be categorized based on their contribution to individual operational departments at MST. Hence, the evaluation (including both Phase II and Phase III activities) was conducted by studying each of the following topics:

- Transit Planning and Operations;
- Maintenance and Incident Management;
- Safety and Security;
- MST Reporting Capabilities;
- Finance; and
- Customer Service.

The preceding categories were defined by considering the complexities of the evaluation based on the MST goals for technology implementation, the nature of data analyses for this evaluation, and the types of data and data collection methods needed for analyses.

The hypotheses related to the real-time Information, trip planner and customer satisfaction were tested in Phase III of the evaluation. The hypotheses related to the TSP and smart card payment could not be investigated because the deployments were not completed during the evaluation period.

2.2 Test Plan

2.2.1 Data Collection

Phase II of the evaluation project required collecting data for both quantitative and qualitative analyses. Archived data from the ACS was collected for the time period from April 15 to May 31 for each year from 2003 through 2007 to test the hypothesis related to on-time performance. In addition to the ACS data, information such as operational statistics (e.g., vehicle revenue-miles and passenger-miles), cost and revenue data, information on performance measures, accident or incident statistics, and financial claim/recovery data was collected to test other hypotheses. Further, the Evaluation Team conducted several interviews during a 2-day on-site visit at MST in August, 2008. These interviews were conducted with representatives from planning, operations, finance, maintenance, customer service, management, safety and security, and information technology. Please refer to Appendix D for a detailed list of questions asked in these interviews.

In Phase III, the quantitative analysis was conducted by collecting a larger amount of automatic vehicle location (AVL) data over a more specific timeframe (i.e., starting in 2005) as compared to Phase II dataset. As part of the Phase III data collection, the Evaluation Team exported raw AVL data directly from the database of the CAD/AVL system during the site visit in June 2009. This data was further processed and imported into a SQL Server database and Microsoft Excel in order to perform data analyses. Further, a qualitative analysis was performed on data collected through intercept surveys. The customer survey was primarily focused on evaluating real-time information and MST's service reliability. However, the results of the survey complement the findings from the quantitative analysis of AVL data, which was conducted to determine if there were any on-time performance trends.

2.2.2 Analysis

A quantitative analysis was performed on ACS data to calculate on-time performance of MST vehicles for selected time periods in both Phase II and Phase III. Since on-time performance measurement standards were changed by MST during the selected time periods (see Section 3.1.1.1.1), the Evaluation Team measured on-time performance based on new MOEs. The on-time performance was measured based on the positive or negative deviation (in number of minutes) of the actual arrival time from the scheduled arrival time. A detailed approach for this analysis is discussed later in this report (see Section 3.1.1.1.1 for Phase II approach and 3.1.1.1.2 for Phase III approach). Also, the annual trends for other statistics (e.g., ridership, revenue, productivity and accidents) were calculated.

In addition to performing quantitative analysis, a qualitative assessment of the impact of technologies on daily activities of all MST departments was performed in Phase II. The qualitative analysis was conducted based on information obtained from MST staff during the interviews conducted in August 2008.

Finally, data obtained from customer intercept surveys were analyzed in Phase III to measure customer perceptions of the impact of technology on MST Service.

Section 3 summarizes findings obtained from the data analyses, on-site interviews (conducted in Phase II), and intercept surveys (Phase III) to describe the impact of various technologies on MST.

3 Impact of Technology

3.1 Impact on Transit Planning and Operations

As reported in Phase II based on information obtained from staff interviews, there have been significant improvements in daily operations and planning activities since the implementation of the ITS technologies at MST. These improvements can be attributed directly to the use of the technologies and tools in both departments.

The following technologies are being used by the planning department at MST:

- HASTUS scheduling system;
- The ACS;
- Video playback system;
- ArcView geographic information system (GIS); and
- Microsoft Office products (e.g., Microsoft Excel and Microsoft Access).

The operations department uses the following technologies in addition to the above technologies:

- HASTUS-DDAM, the timekeeping module of HASTUS; and
- Trapeze Pass and Mentor-Ranger on the MST RIDES paratransit system (operated by MV Transportation, a contractor).

HASTUS assists MST in preparing fixed route schedules and daily driver assignments. The DDAM module of HASTUS allows MST to track driver attendance with respect to assigned schedules. These systems are installed in the Communications Center[8] (see Figure 6).

The ACS system is primarily accessible in the Communications Center but can be accessed remotely over the MST virtual private network (VPN) by authorized staff. The ACS system includes a voice and data communication system (see Figure 7 for a photograph of the radio equipment in the Communications Center), a performance monitoring screen, and a real-time vehicle tracking screen (see Figure 8).

[8] "Communications Center" is the term used by MST for their dispatch center.

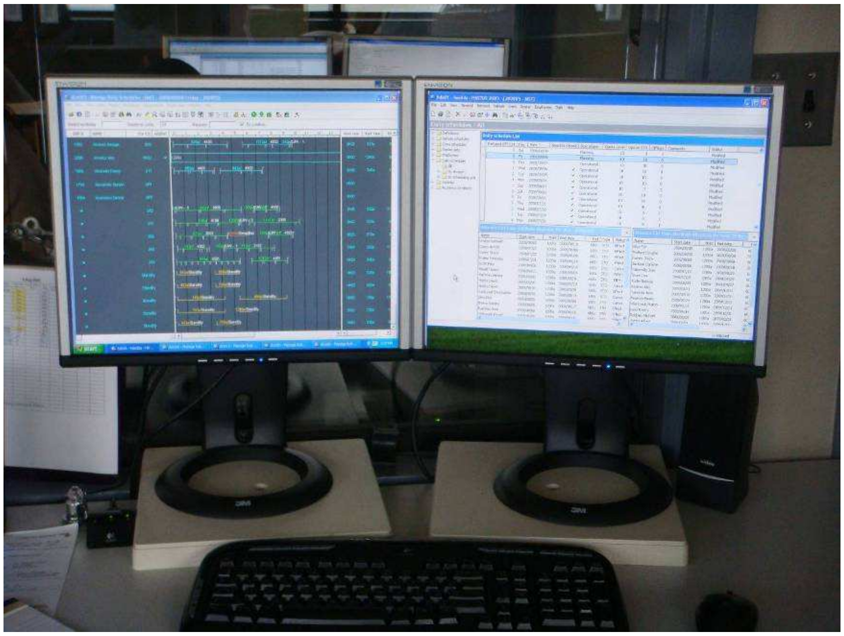

Figure 6. HASTUS Scheduling and DDAM Workstation in the Communications Center

Figure 7. Radio Equipment in the Communications Center

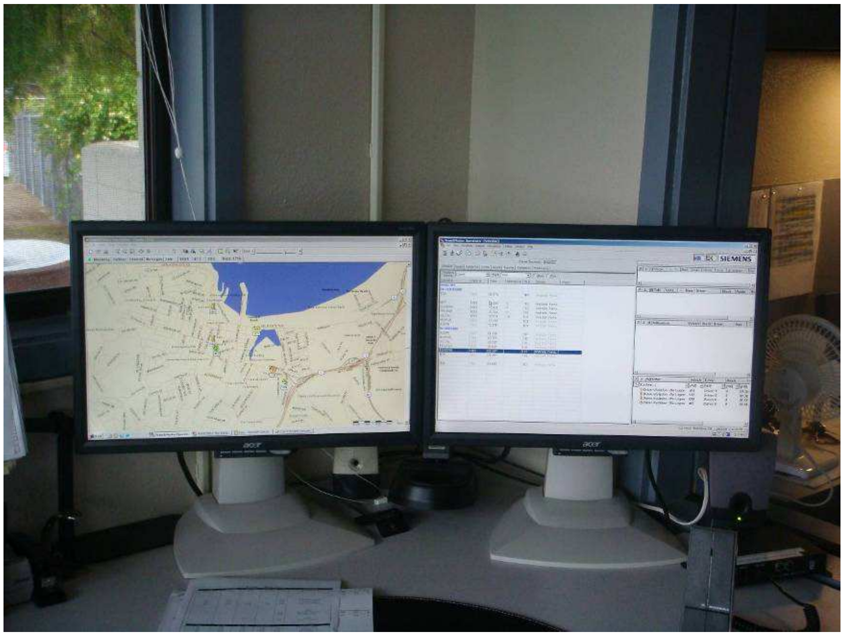

Figure 8. The ACS Workstation in the Communications Center

The ACS assists MST in daily operations by providing various capabilities to manage its fleet and coach operators in real-time. The following features of the ACS have been critical in improving operations at MST:

- Real-time Vehicle Tracking: The coach operators and dispatchers receive schedule adherence warnings when the vehicles are running early or late based on a configurable threshold.

- Text messaging: Both dispatcher and coach operators send data messages to each other as needed. The store and forward feature of the ACS provides the capability of sending messages to an employee (via their ID number) from a dispatch workstation. These messages pop up when the employee receiving a message logs onto a workstation.

- Covert alarms: The coach operators can send emergency alarm messages to the dispatch center. MST reports that covert alarms typically occur once or twice a month. Sirens go off at the Communications Center when covert alarms are received.

- Automated Vehicle Announcements (AVA): The AVA system (with support from the ACS) makes visual and audible announcements at major stops and intersections.

- Route Adherence Monitoring: The dispatchers can monitor vehicles that stray from their routes using the ACS.

- ACS System Control Log: The control log provides a record of daily events and can be searched using a text/keyword search feature.

- Reporting: The ACS provides several standard reports. Along with the standard reports, the ACS system provides several monthly summary reports which are used to provide summary information to the MST Board.

- Archived Data: The ACS provides data for review by the planning staff as needed. The planning department exports and analyzes archived data using external tools (e.g., Microsoft Excel). Archived data is also used for planning studies. For example, the comprehensive operational analysis study done for the Salinas area in 2006 used data from the ACS.

The ACS provides a playback feature to review vehicle operation at desired time durations in the past; however, this feature is not used much by the planning department. Rather, the planning staff relies on data exports from the ACS for manual review and analysis of operational data with the help of Microsoft Excel and Access tools.

The AVL playback feature, however, has been very helpful to the operations department. The ability to review vehicle activities within a given time period allows operations staff to investigate customer complaints about early or late arrivals and departures of MST vehicles. Before the implementation of this feature, MST could not validate customer complaints regarding vehicles failing to arrive or leave the stop on time (e.g., when customers referred to their own watches). Further, this feature assists in investigating situations in which MST may have a valid complaint against a coach operator. MST has trained all its coach operators to use the time displayed on the MDT to avoid any conflicts with other time sources.

3.1.1 Operational Data Collection and Analysis

3.1.1.1 AVL Data

3.1.1.1.1 Recap of Phase II Data Analysis

In the earlier analysis conducted as part of Phase II, the Team had analyzed data for a subset of the MST route system. The dataset consisted of routes that operate in Monterey and Salinas. Also, those routes carried nearly 80 percent of MST riders and had not experienced any significant shift in ridership since the installation of ACS.

ACS data was analyzed for Routes 4, 5, 9, 10, 20, 24, and 41 for the time period of mid-April to end of May for the years 2003 through 2007. The Evaluation Team did not use MST's on-time performance definitions for our analysis since MST had used two different on-time performance standards during the evaluation timeframe. These two standards were as follows:

- From 2003 to 2006, on-time performance was three minutes or more being defined as "late"; and
- From 2006 to the present, on-time performance was five minutes or more being defined as "late."

In Phase II of the evaluation, the Evaluation Team calculated on-time performance statistics using the above standards, but the results were not conclusive. Even though the Team noticed improvements in on-time performance since the technology implementation, the reasons for the improvements were not obvious (i.e., whether it was due to ACS implementation or the change in on-time performance standards). Hence, the Team decided to use an indicator of on-time performance called "lateness," which was calculated as the deviation of the actual arrival times from the scheduled arrival times. Lateness was analyzed across the years by the following:

- Route and direction;
- Time of day; and

- Day of week.

Generally, the analysis did not show any clear trend in average lateness over time for the selected routes, thus leading to inconclusive results. This situation was based on the following:

- Data-related issues that included a low sample size (approximately 12 percent) as data from a period of mid-April to the end of May was used for analysis;
- Inconsistencies in lateness trends were noted in 2003 and 2004 due to large percentages of missing data on the routes selected for analysis;
- The presence of a large number of outliers in the dataset resulted in biased results. In Phase II, the Team had not rejected lateness values less than 30 minutes since that would have reduced the size of sample dataset even more;
- Several operational changes made throughout the evaluation timeframe, including schedule changes, changes in fares in 2006 and 2007, and timepoint adjustments in 2005; and
- External factors, including traffic conditions.

Phase III of the evaluation analyzes on-time performance taking the above issues into consideration. In this phase, the Team has addressed the issues mentioned earlier by utilizing a larger dataset for analysis, minimizing missing data, and removing exceptions from the dataset. Also in this phase, the Evaluation Team analyzed data by schedule periods (i.e., a time period corresponding to a specific operational schedule; e.g., fall 2006) since summary statistics aggregated by year did not provide conclusive results in Phase II.

3.1.1.1.2 Phase III Data Analysis Approach

Having learned from the experience of Phase II, the Evaluation Team collected and analyzed a larger amount of schedule adherence data from the ACS database for a more restricted timeframe (i.e., 2005 onwards). Data was collected from March 29, 2005, through June 16, 2009. This dataset included daily schedule adherence data for all routes within the MST system except for express routes.

As discussed earlier, the Evaluation Team used schedule periods to differentiate the impacts of service changes on on-time performance from the impacts caused by deploying the ACS. For example, MST made major modifications to its service that resulted in schedule changes in October 2006 and January 2007. These changes were found to be one of the reasons behind the inconsistent trends in lateness noticed in Phase II. Hence in this phase, the summary statistics were calculated by schedule periods to determine whether or not there were any on-time performance trends.

However, a preliminary analysis of missing schedule adherence data revealed major data deficiencies in the data that we collected. A preliminary analysis was conducted to identify missing data for each route across various schedule periods (see Table 7 in Appendix B). More than 20 percent of the adherence data was missing on most routes. In fact, in several cases, more than 60 percent of the data was missing (see highlighted cells in red in Table 7).

The routes that the Evaluation Team analyzed in Phase II were not necessarily appropriate for our Phase III analysis because of the high percentage of missing data on those routes. For example, Table 8 in

Appendix B shows a significant amount of missing data on Routes 4 and 5 during 2007. Route 20 has a considerable proportion of missing data before mid-2007. Also, Route 24, a contracted route, is missing a lot of data across all schedule periods.

Only a few routes offered a consistent sample size across the analysis timeframe. Thus, we selected Routes 1, 9, 10, 41 and 42 since these routes had the least amount of missing data. Also, these routes are designated as primary routes in the MST system and together account for a large share (40-50%) of the total ridership.

We observed that buses arrived earlier than the scheduled time on a number of instances on all routes. It could be due to excess running time that has been built into the schedule between timepoints. In Phase II, all early arrivals were treated as on-time to be consistent with MST's operational practice. MST treats early arrivals as on-time since early buses are supposed to wait until the scheduled departure time before leaving the stop. In Phase III of the evaluation, the Team conducted a separate analysis for early and late arrivals at timepoints (referred to as "earliness" and "lateness") since treating earliness and lateness separately reduces any potential bias when summarizing the data at the trip level. Also, this approach avoids the potential of these values cancelling each other out, which may happen when both early and late timepoints on a trip are included when summarizing data at the trip level.

Before estimating schedule adherence, the data was evaluated to exclude outlier adherence values, which exhibit large deviations from the mean values (e.g., lateness values higher than 15 minutes). The timepoints for all routes were sorted into datasets representing a range of earliness and lateness values (e.g., 0 to 5 minutes late and 5-10 minutes late). This analysis was useful in determining the general trend of earliness and lateness noticed in the data, and assisted in identifying and eliminating outlier values. Table 3 and Table 4 present this analysis for the routes used in the analysis.

Table 3. Percentage of Early Timepoints

Route	Total number of timepoints	Percentage of missing timepoints	Percentage of Early Timepoints						
			5 min or less	5-10 Min	10-15 Min	15-20 Min	20-25 Min	25-30 Min	30+ Min
1	313,097	11.18%	28.87%	1.59%	0.03%	0.01%	0.02%	0.03%	1.80%
9	390,800	4.45%	19.99%	3.28%	0.09%	0.02%	0.01%	0.00%	0.04%
10	491,122	3.61%	20.79%	1.07%	0.06%	0.01%	0.00%	0.00%	0.02%
41	429,128	10.28%	27.80%	2.83%	0.12%	0.02%	0.03%	0.03%	0.02%
42	329,807	8.87%	28.91%	3.86%	0.27%	0.05%	0.01%	0.00%	0.05%

Table 4. Percentage of Late Timepoints

Route	Total number of timepoints	Percentage of missing timepoints	Percentage of Late Timepoints						
			5min or less	5-10 Min	10-15 Min	15-20 Min	20-25 Min	25-30 Min	30+ Min
1	313,097	11.18%	46.48%	6.54%	1.43%	0.53%	0.24%	0.09%	0.90%
9	390,800	4.45%	61.95%	8.61%	0.94%	0.19%	0.08%	0.02%	0.13%
10	491,122	3.61%	63.33%	9.25%	1.21%	0.21%	0.08%	0.02%	0.09%
41	429,128	10.28%	44.10%	10.71%	3.14%	0.36%	0.23%	0.07%	0.08%
42	329,807	8.87%	43.22%	11.64%	2.53%	0.28%	0.04%	0.01%	0.05%

It is evident from Table 3 and Table 4 that most timepoints are either early or late within the range of zero to ten minutes. Very few trips are early or late beyond 10 minutes, and should be treated as exceptions. Hence, only timepoints with earliness or lateness within 10 minutes were considered for the analysis in order to obtain an unbiased summary of schedule deviations

3.1.1.2 Other Data

In Phase II, other information resources were collected in addition to AVL data to test the hypotheses related to COA studies, ridership, and productivity measures.

3.1.2 Findings

3.1.2.1 Impact on Comprehensive Operational Analysis

As reported in Phase II, based on MST staff interviews, the Comprehensive Operational Analysis (COA) studies conducted after the technology implementation (e.g., Salinas Area COA study in 2006) have taken less time to complete compared to earlier studies. The accuracy of the analysis results obtained from these COA studies is also more reliable as compared to earlier studies (e.g., COA study in 1999). Due to the availability of ACS, now MST has access to a larger volume of more reliable data for analyses. MST can respond to the data needs of its consultants in a better and more timely manner. Previously, MST had to hire temporary staff to meet the data collection needs for COA studies.

The availability of the ACS provides the flexibility to consider different scenarios for operational analyses (e.g., seasonal ridership and monthly ridership). MST believes that such flexibility is very useful, especially for analyzing seasonal patterns (e.g., patterns of ridership and the on-time performance) in their system.[9]

The accuracy and reliability of the ACS data assists MST in defending information that is presented to the Board of Directors and the general public in implementing recommendations of COA studies. Before the ACS implementation, MST could not provide enough information to support Board requests. For example, the service improvement plan proposed after the COA study in 1999 faced a lot of questions and concerns during the public meetings. It was challenging for MST to defend those results since the data was collected manually and could not be validated using additional data. Also, the validation process would have demanded extra resources in terms of time and money. Now, the ACS can provide additional data if needed. For example, in 2006, MST proposed to eliminate service on Route 21 due to poor performance and was able to defend their proposal based on an analysis conducted using archived ACS data.

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[9] MST ridership is the highest in the summer season due to tourism and is the lowest during the school season.

Even though MST believes that the cost of data collection has been reduced as a result of the ACS, it does not have any quantitative information to show the actual change in the cost of conducting COA studies.

3.1.2.2 Impact on On-Time Performance

3.1.2.2.1 Results of Phase III Data Analysis

In order to understand the analysis results, the Team revisited several operational and policy changes implemented by MST that could have had a direct or indirect impact on its on-time performance and reliability (or customer perception of reliability). Figure 9 shows a list of the changes implemented between 2002 (at the time of ACS implementation) and June 2009. Further, Figure 9 lists several activities related to ACS implementation and operation (e.g., missing data and trigger zone modification) and implementation of other technologies related to ACS.

2009	Fares changed from $2.00 to $2.50 (Jan 2009)
2008	• Google Transit went live (Nov 2008) • Bus Stop Shop (customer service center) opened in Monterey Downtown (Aug 2008) • Minor service change (May and Aug 2008) • Real-time information system went live at Salinas Transit Center (Feb 2008) • Minor Service change (Jan 2008)
2007	• Real-time information system live at Marina Transit Exchange(Oct 2007) • Service change in Monterey area (Jan 2007)
2006	• Service change in Salinas area (Oct 2006) • Started to charge for transfer at $0.25 (Aug 2006) • On-time performance standard changed (Jan 2006) • HASTUS/ ACS integration (Jan 2006)
2005	• Routes resurveyed and trigger zones modified (2005) • Fare change from $1.75 to $2.00 (Jul 2005) • 41A and 41B renamed as 41 and 42 (Jul 2005)
2004	Large amount of missing ACS data (2004)
2003	Large amount of missing ACS data (2003)
2002	ACS implemented (Oct 2002)

Figure 9. Timeline of Events Related to ACS Deployment

The implementation of the real-time information system would not have directly impacted MST operations but is listed in the figure since this implementation could have impacted the customer perception of service reliability (before and after its implementation). Customer perception of reliability was measured as part of the qualitative analysis.

Analysis results for lateness and earliness by trip are discussed in Sections 3.1.2.2.1.2 and 3.1.2.2.1.1. Section 3.1.2.2.1.3 includes a discussion about earliness and lateness trends by timepoint.

3.1.2.2.1.1 Earliness Analysis by Trip

Average earliness by trip for the selected routes was calculated as follows. First, all early timepoints were identified on a trip. Then, the sum of earliness across these timepoints was divided by the number of early timepoints on that trip to calculate the average earliness for an individual trip. The average value of earliness for all trips on a particular route for a given time period was calculated by dividing the sum of earliness by trip for all trips within the time period by the number of early timepoints in that time period. Hence, the calculation of earliness can be represented by the following equation:

$$\text{Earliness} = \frac{\sum_{j=1}^{NS} \frac{\sum_{i=1}^{NE} Eij}{NE}}{NS}$$

The variables used in the equation can be defined as follows:

Eij= Earliness value at Timepoint i on Trip j

NE= Total number of timepoints on a trip at which buses arrived early

NS= Total number of trips within a schedule period on a route

Average earliness by trip was calculated by time of day and day of week to observe the impact of traffic on earliness trends. In this section, the earliness analysis for three scenarios is presented, including earliness values for all trips, all weekday off-peak trips, and Saturday trips. The results are presented separately for inbound and outbound trips. Analysis results for additional scenarios are provided in Appendix B.

Figure 10 and Figure 11 represent average earliness for all trips in the analysis timeframe for inbound and outbound directions. In the inbound direction, Routes 1, 9, and 10 show a gradual increase in earliness over the study time frame. Routes 41 and 42 show a decrease in earliness from the end of January 2006 to June 2007, followed by an increasing trend. Further, a sharp decrease can be noted on Routes 41 and 42 from July 2008 through May 2009. The change in earliness around July 2008 coincides with the service change that was made in August 2008 which resulted in the elimination of a timepoint located at the intersection of Del Monte and Sanborn Streets. Also, the variable patterns on Routes 41 and 42 across the evaluation timeframe could be attributed to operational changes made on these routes in 2005 and 2008.

In the outbound direction, earliness does not vary significantly for any of the routes in the analysis over the time period. These routes show a slight increase from July 2008 through May 2009. However, this pattern cannot be attributed to any operational changes.

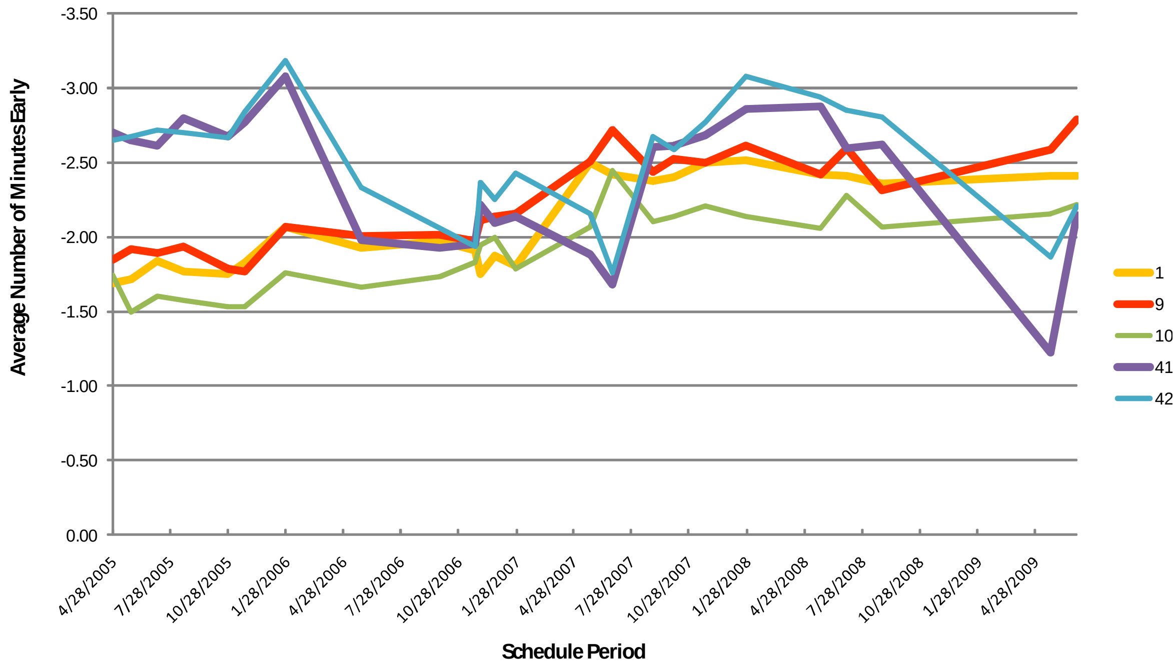

Figure 10. Average Earliness by Route for the Inbound Direction

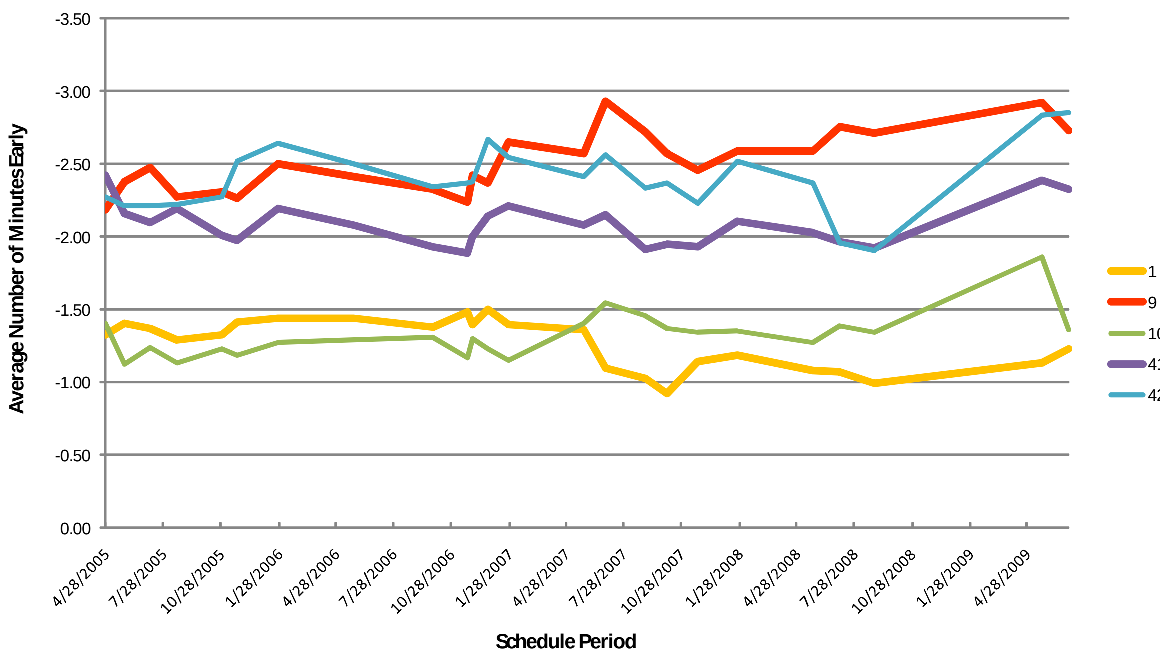

Figure 11. Average Earliness by Route for the Outbound Direction

Figure 12 and Figure 13 show average earliness for weekday off-peak trips, which are not affected by rush hour traffic. However, no consistent trend in earliness was found. Inbound trips on Route 1 show an increase in earliness starting in January 2007, which could be due to changes made in the route in January 2007. Average earliness values for Routes 9 and 10 do not vary by more than 1 minute between consecutive schedule periods but at the same time they do not follow any trend across the study timeframe. Routes 41 and 42 show a more variable trend of earliness due to the operational changes mentioned earlier. No significant change in trends was recognized for outbound trips.

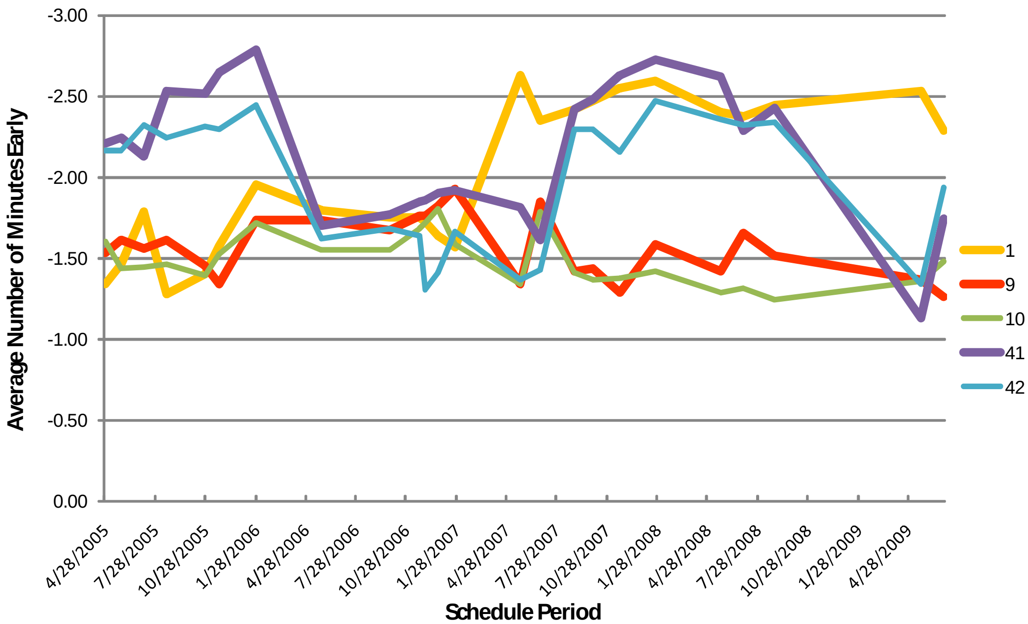

Figure 12. Average Earliness by Route in Inbound Direction during the Weekday Off-peak Period

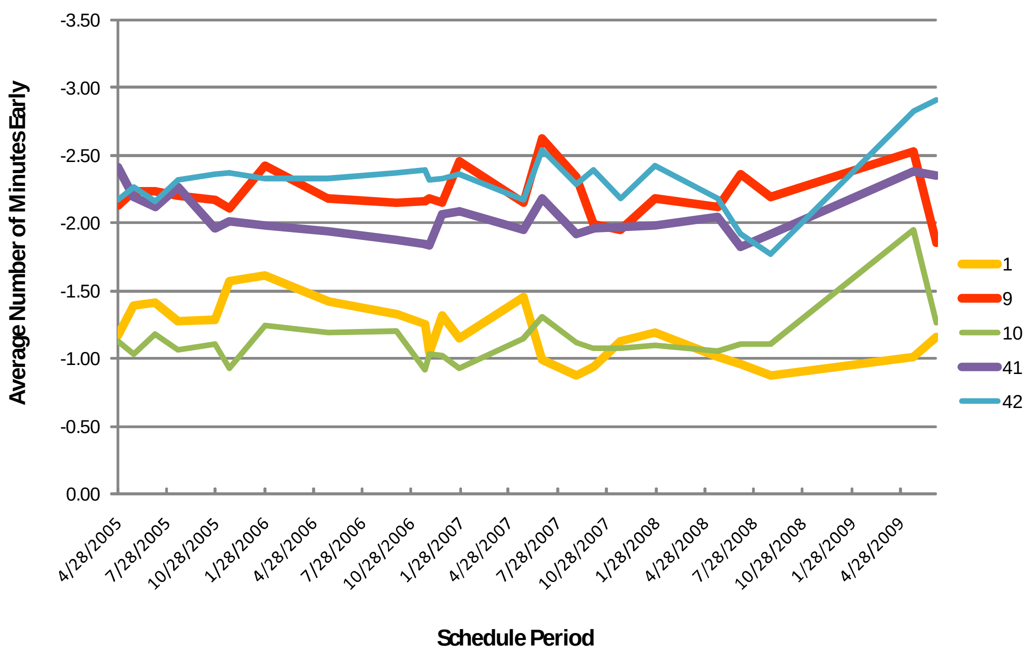

Figure 13. Average Earliness by Route in the Outbound Direction during the Weekday Off-peak Period

Figure 14 and Figure 15 present average earliness by trip for Saturday trips. Saturday trips were considered for analysis since data for these trips could assist in analyzing an earliness trend without a bias, which could be caused by commuter traffic when Saturday trips are analyzed along with weekday trips. However, no consistent trend in earliness was noted.

In the inbound direction, Routes 9 and 10 show a significant increase in average earliness from January 2007. This increase was not seen in weekday trips. This can be attributed to service changes that went into effect that eliminated service to some areas on Routes 9 and 10 during weekends and holidays. No significant trend in earliness was noted in the outbound direction.

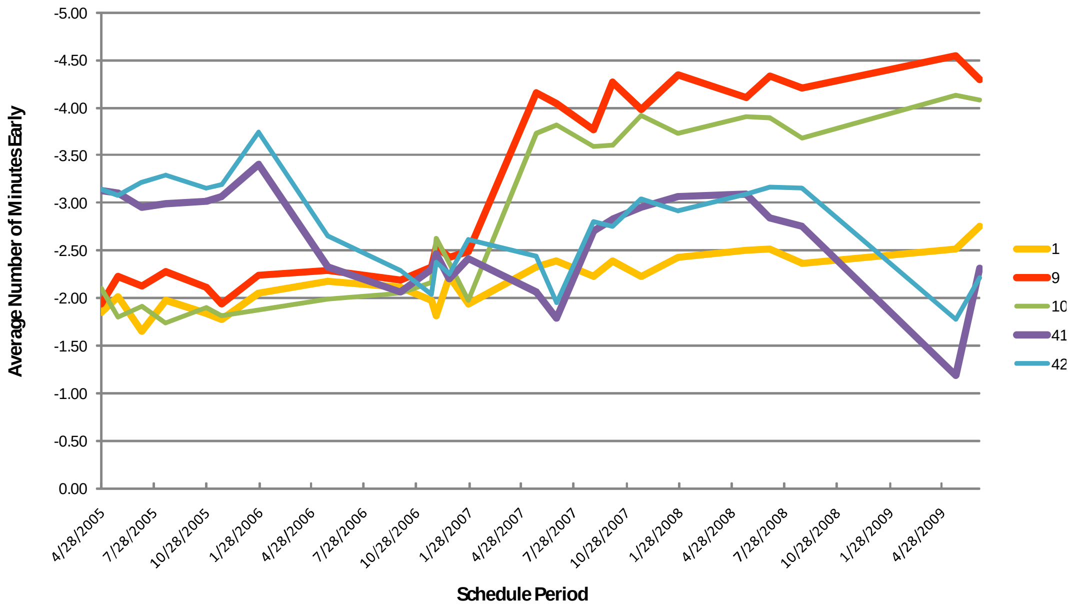

Figure 14. Average Earliness by Route in the Inbound Direction on Saturdays

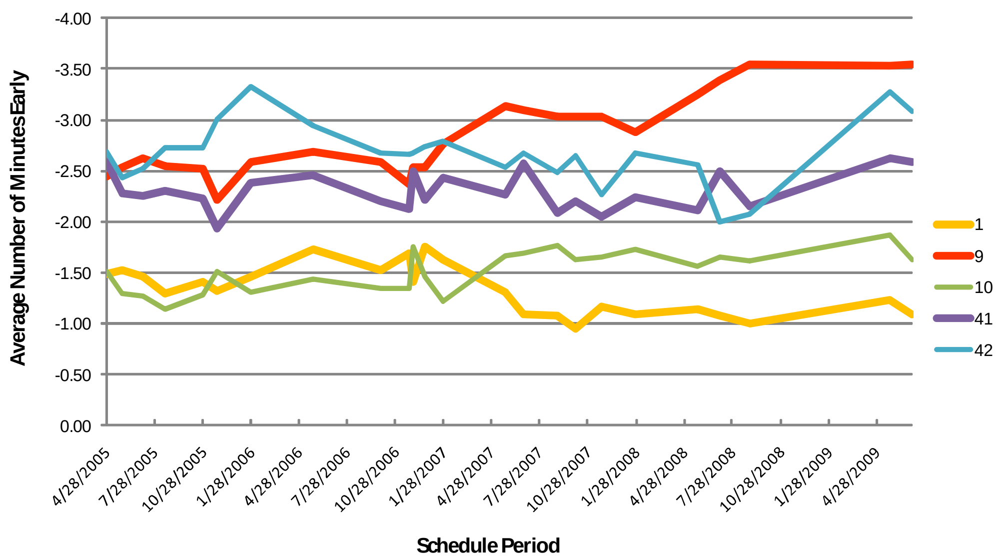

Figure 15. Average Earliness by Route in the Outbound Direction on Saturdays

While no clear trends in earliness are seen across the study timeframe, average earliness in the outbound direction does not show large changes between any consecutive schedule periods. A large number of early arrivals suggest that some additional running time was built into the schedules for all routes selected for the analysis.

In the inbound direction for Routes 41 and 42, the decrease in earliness is noted between January and May 2006, followed by an increase from June 2007 through the beginning of 2008. Then, there was another sharp decrease from January 2008 through May 2009.

Average earliness for weekday off-peak trips in the inbound direction on Route 1 increased from January through May 2007, and then remained constant. MST implemented a schedule change on the same route on January 27, 2007 (that rerouted Route 1 at both downtown Pacific Grove and downtown Monterey). This may have resulted in travel time savings that are more significantly evident during the off-peak periods.

3.1.2.2.1.2 Lateness Analysis by Trip

Average lateness was calculated in a fashion similar to average earliness and can be represented by the following equation:

$$\text{Lateness} = \frac{\sum_{j=1}^{NS} \frac{\sum_{i=1}^{NL} Lij}{NL}}{NS}$$

The variables used in the equation can be defined as follows:

Lij= Lateness value at Timepoint i on Trip j

NL= Total number of timepoints on a trip at which buses arrived late

NS= Total number of trips within a schedule period on a route

Figure 16 and Figure 17 show the trends for average lateness per late trip for selected routes in inbound and outbound directions. In these charts, it is evident that Route 1, 9, and 10 have a more or less constant lateness with a variability of less than 1.5 minutes over the timeframe. Routes 41 and 42 experienced an increase in lateness from the end of January 2006 to the end of July 2007, and then again from the end of January 2008 to mid-May 2009. Outbound trips on these routes do not display any well-defined increases or declines, but exhibit smaller changes during the evaluation timeframe as compared to trends seen with inbound trips.

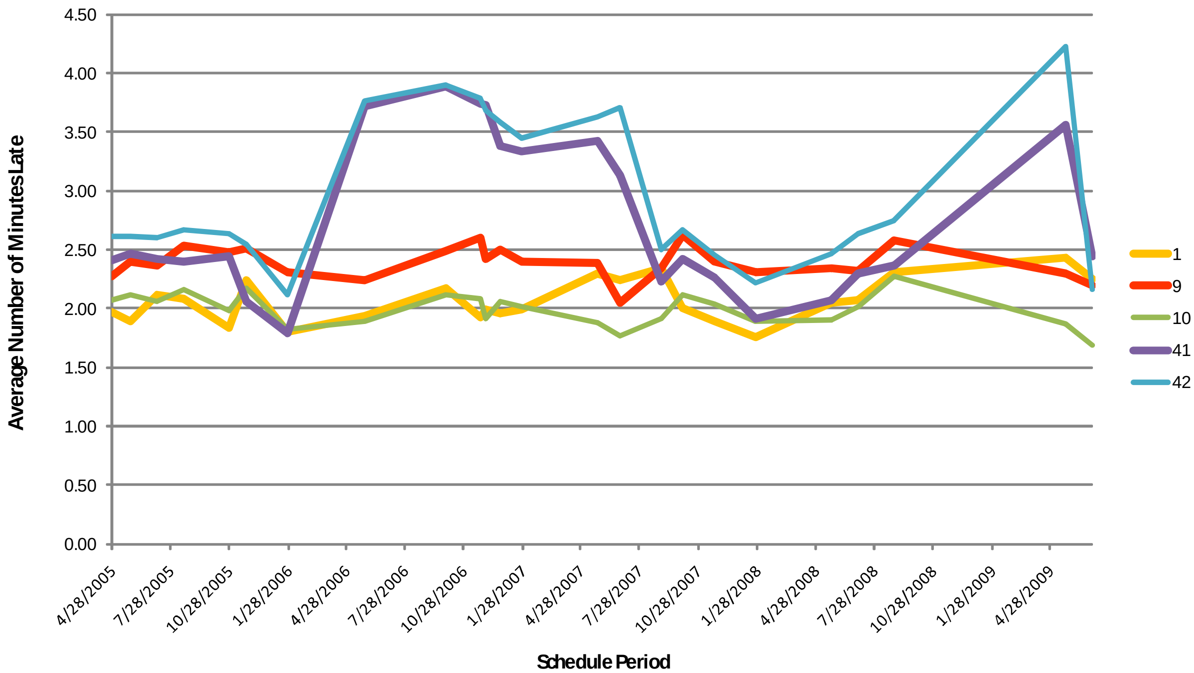

Figure 16. Average Lateness by Route in the Inbound Direction

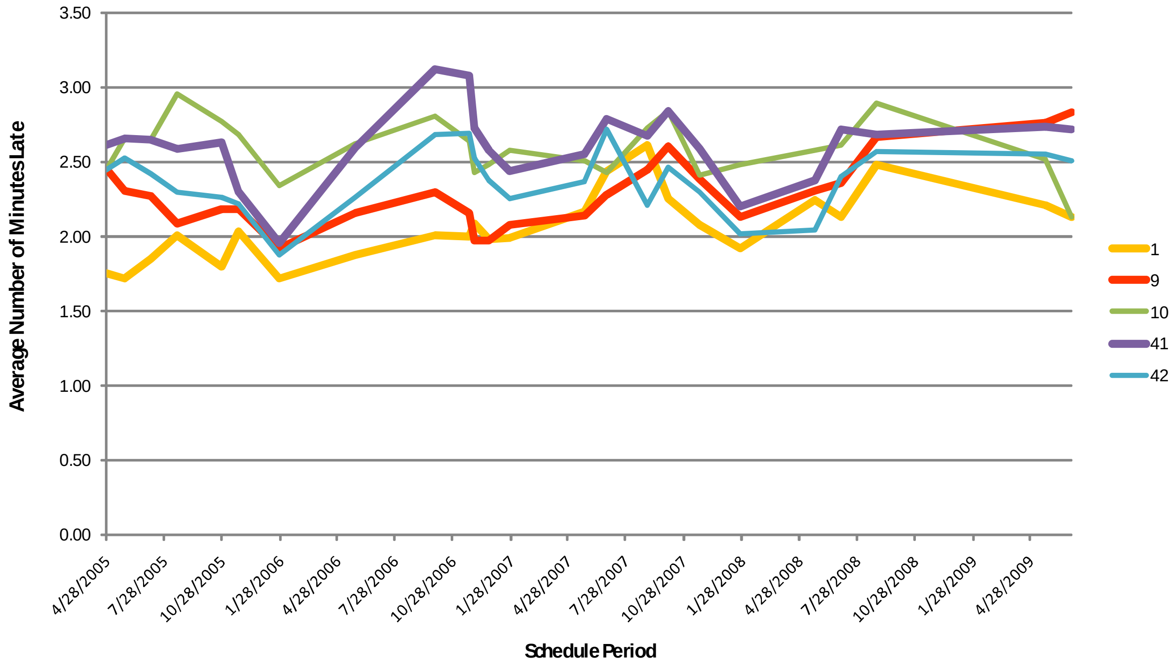

Figure 17. Average Lateness by Route in the Outbound Direction

The inbound and outbound trips in the weekday off-peak period have similar trends (see Figure 18 and Figure 19) as discussed above. This means that the factors responsible for inconsistent schedule adherence were not impacted by rush-hour traffic during a weekday.

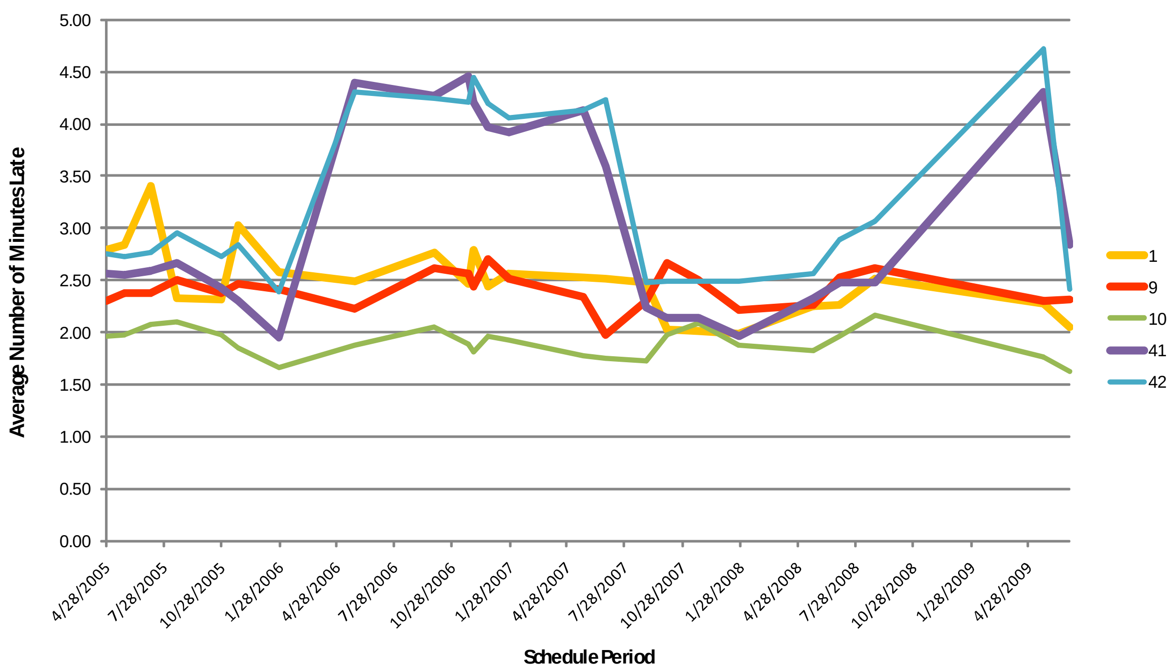

Figure 18. Average Lateness by Route in the Inbound Direction during the Weekday Off-peak Period

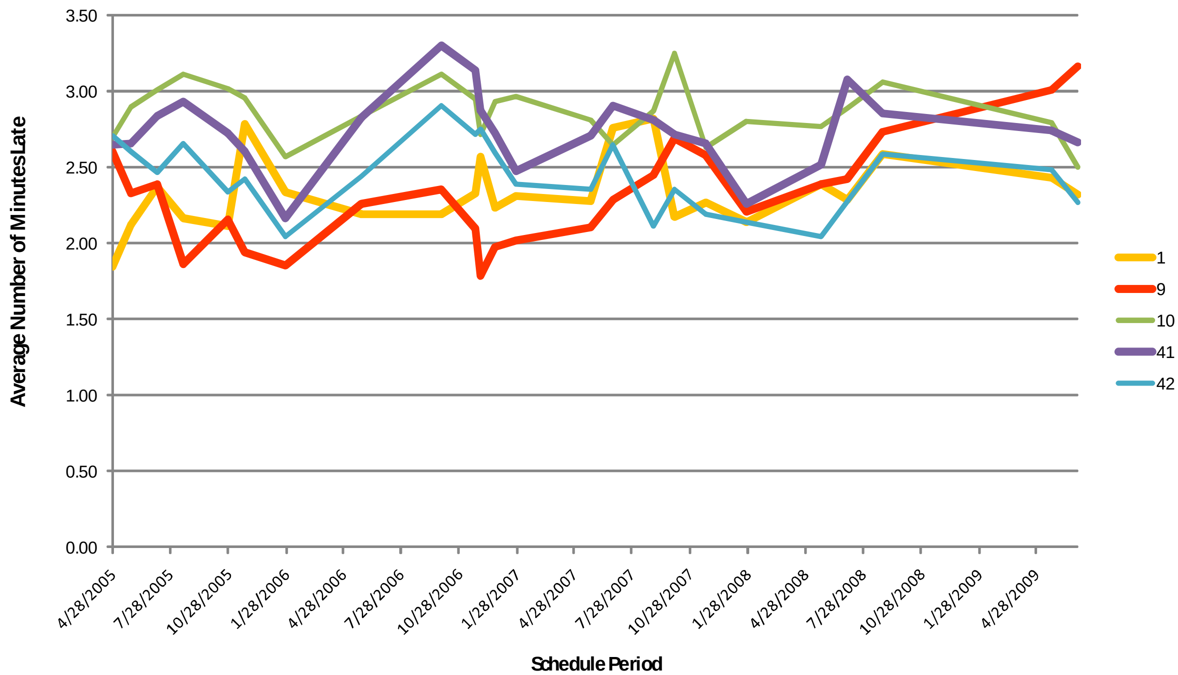

Figure 19. Average Lateness by Route in the Outbound Direction during the Weekday Off-peak Period

Trends for Saturday only trips are provided in Figure 20 and Figure 21. The Saturday trips also show similar trends as seen in Figure 16 through Figure 19, apart from minor fluctuations noticed over certain schedule periods. This observation seems to suggest that commuter and school-related travel, and/or peak traffic do not bear a significant impact on the on-time performance for these bus routes. Also, elimination of weekend and holiday trips going into certain parts of the MST service area on Routes 9 and 10 did not have any significant impacts on the lateness trends of these routes.

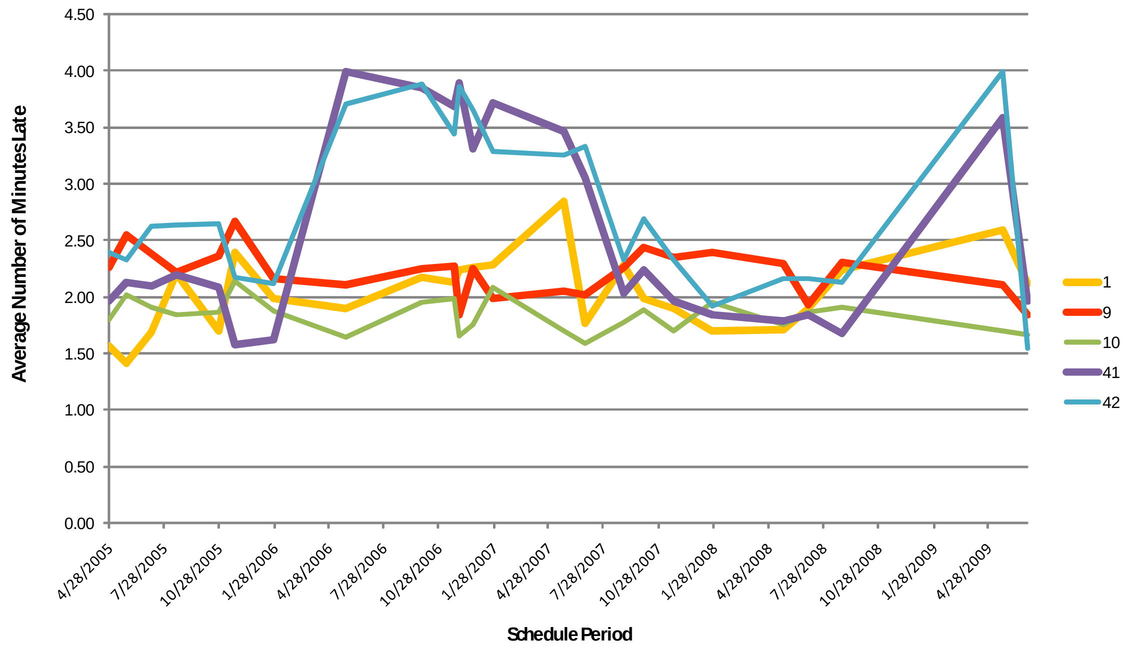

Figure 20. Average Lateness by Route in the Inbound Direction on Saturdays

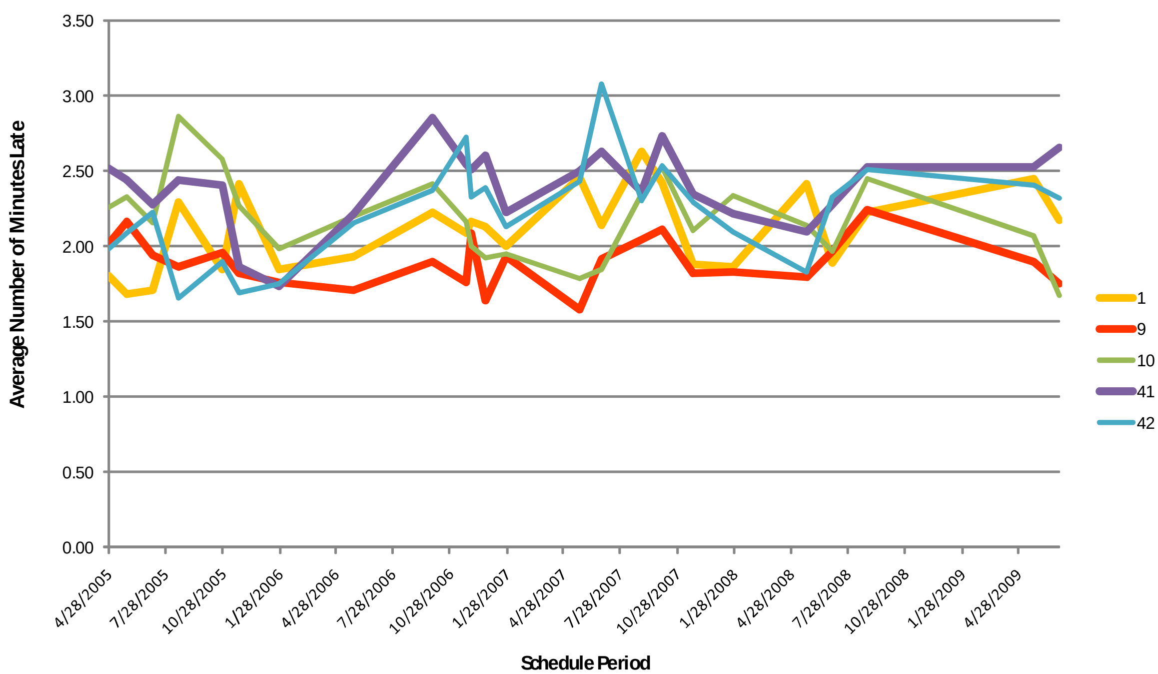

Figure 21. Average Lateness by Route in the Outbound Direction on Saturdays

Observations that can be made on the basis of the above analysis results are as follows:

- Routes 9 and 10 show similar trends in average lateness to each other. The same is true for Routes 41 and 42. In both route pairs, individual routes run on the same corridor for a significant length, which may explain similar on-time performance values since several timepoints are common.

- Routes 1, 9, and 10 in the inbound direction do not exhibit high variability in average lateness - they vary in a range of 1 to 1.5 minutes. However Routes 41 and 42 display two prominent peaks during the study time frame.

- Outbound trips present a constantly fluctuating trend of lateness throughout the timeframe suggesting seasonal variations.

- We also reviewed ridership numbers to determine if schedule periods with higher boarding counts (e.g., during tourist season in August) were resulting in lateness as larger number of boardings at stops would increase bus dwell time at those stops resulting in higher values of lateness. Routes 41 and 42 experienced high ridership during May 2006 through August 2006, and again in May, August and October 2007, with ridership dipping in January and February 2007. This may have contributed to high average lateness seen in the graphs for 2006 for both inbound and outbound direction.

3.1.2.2.1.3 Average Lateness and Earliness by Timepoint

While all of the previous analyses aggregate lateness and earliness by trip, the Evaluation Team also evaluated average lateness and earliness by timepoint to understand whether the geographic location of timepoints was correlated to schedule adherence at those timepoints. This analysis identifies timepoints that incur greater earliness or lateness and offers a further explanation for earliness and lateness trends at the trip level.

All five routes' trips were separately analyzed in the inbound and outbound directions. For each timepoint, average lateness is calculated by summing all adherence values that indicate a late arrival. This value is divided by the number of late arrivals. Average earliness is calculated in a similar manner (i.e., total number of minutes early divided by total number of early arrivals). Some key observations based on this timepoint level analysis are summarized in Sections A and B along with supporting graphs. Analysis results for other scenarios which were not as significant are provided in Appendix B.

A. Salinas Transit Center

The Salinas Transit Center serves as the starting point of outbound trips on Routes 41 and 42. As shown in Figure 22 and Figure 23, there is a significant fluctuation in the average earliness at the start point of outbound trips. However, other timepoints in do not show such variability. We are not aware of why this significant fluctuation exists.

In the legend for Figure 22 through Figure 25, timepoints are numbered (shown within parentheses in the charts) according to their order in the direction of travel.

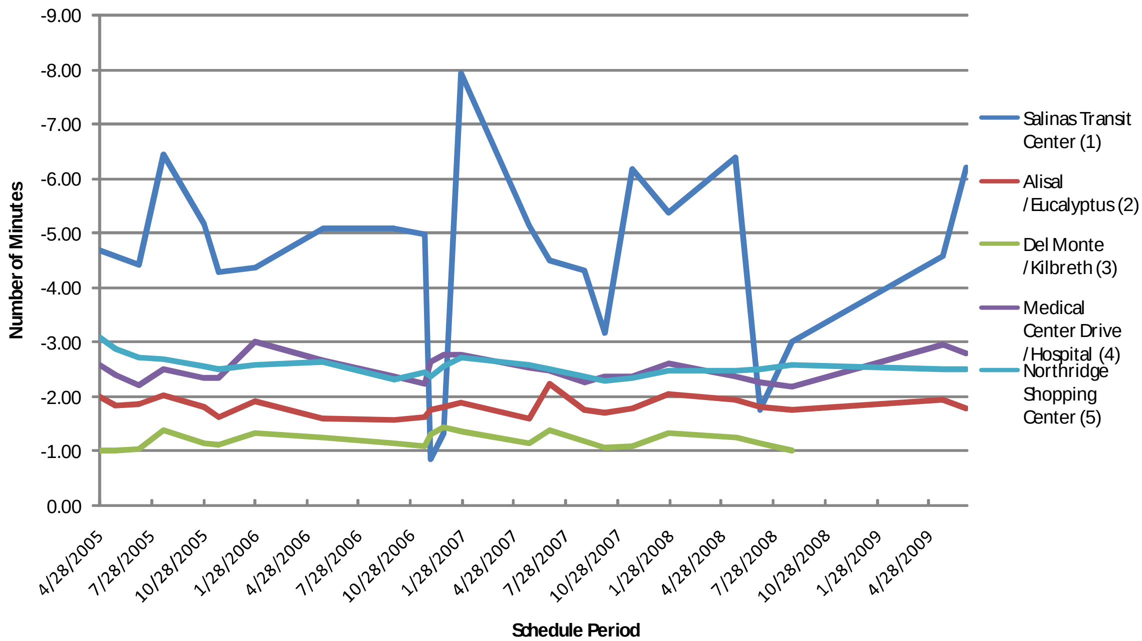

Figure 22. Average Earliness at Timepoints on Route 41 (Outbound)

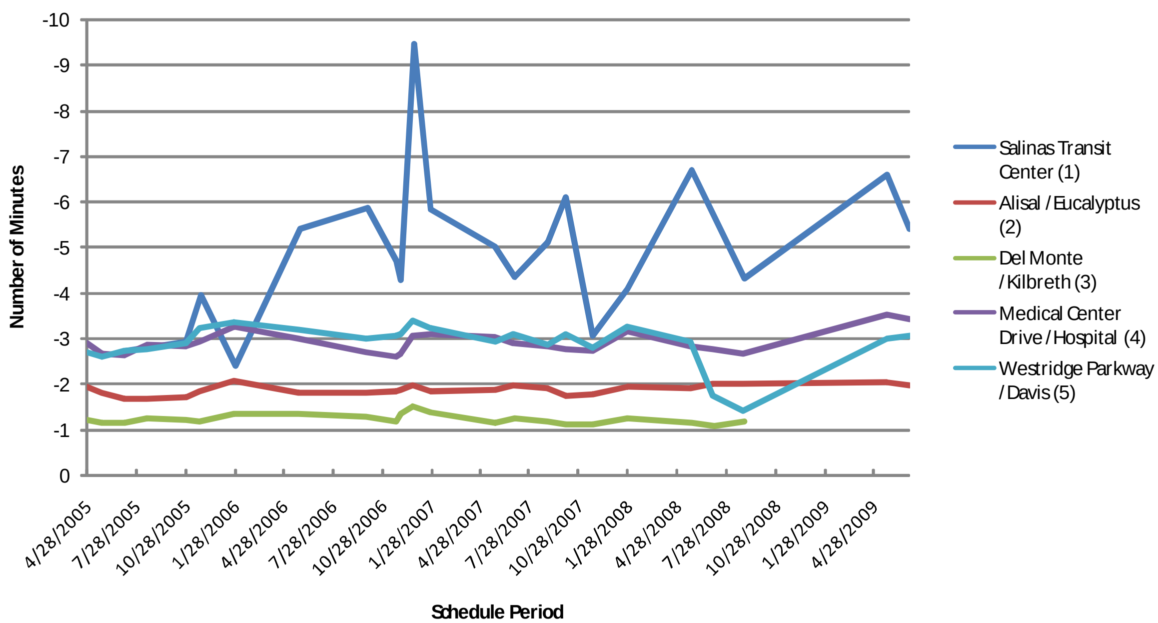

Figure 23. Average Earliness at Timepoints on Route 42 (Outbound)

As shown in Figure 24 and Figure 25, the average lateness of the inbound trips on Routes 41 and 42 at Salinas Transit Center (the last timepoint) indicate a significant increase of approximately 4 minutes between January 2006 and May 2007. This decreases sharply from May to August 2007 and then begins to increase from the end of August 2008 through May 2009. The pattern of lateness seen at the timepoint level is similar to that at the trip level for Routes 41 and 42. This pattern suggests that a significant delay occurs at the end of the trip in Salinas, possibly due to higher levels of traffic in this urban area. Also, it may be due to high boarding counts and, therefore, higher dwell times at this location. Other timepoints have a fairly constant level of lateness throughout the analysis time frame.

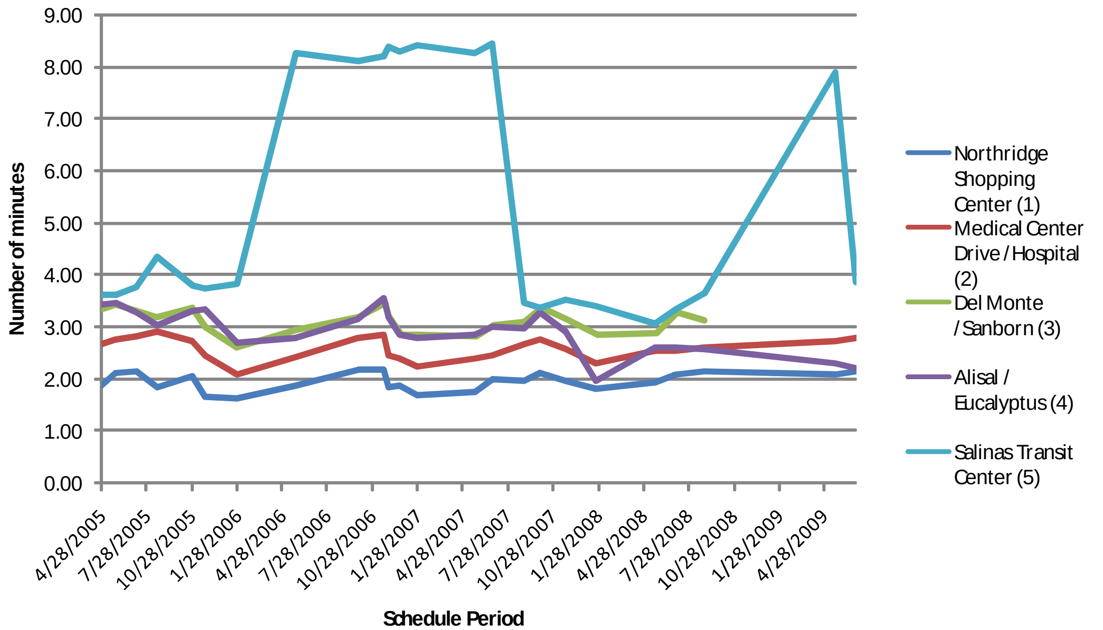

Figure 24. Average Lateness by Timepoints on Route 41 (Inbound)

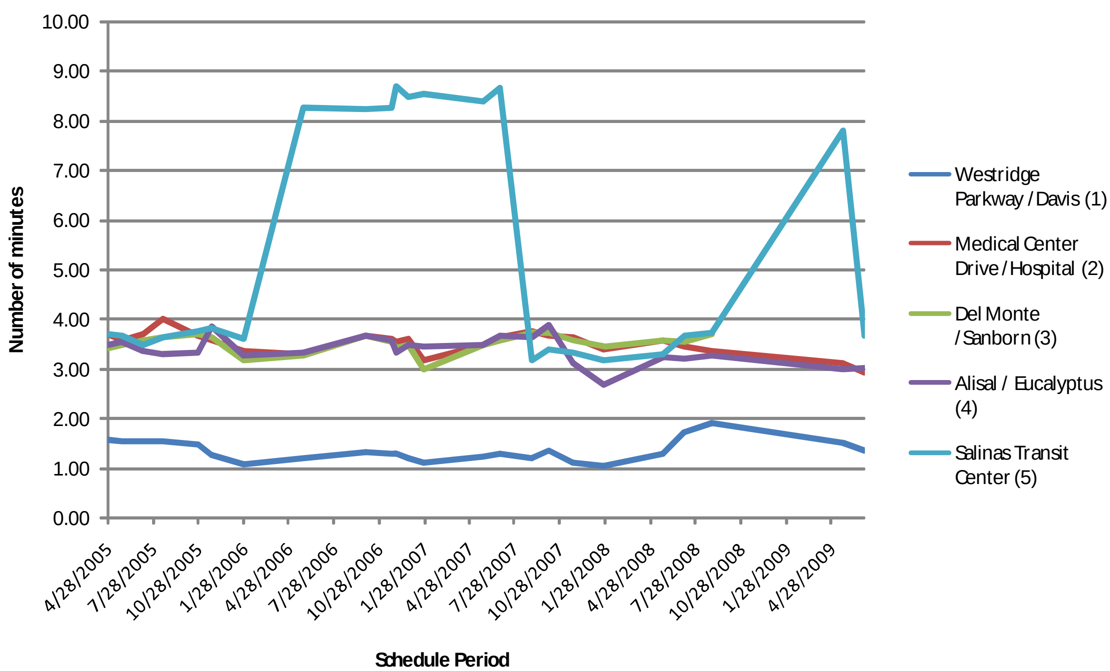

Figure 25. Average Lateness by Timepoints on Route 42 (Inbound)

B. Monterey Transit Plaza

Monterey Transit Plaza is the starting point of all outbound trips on Routes 1, 9, and 10. Surprisingly, the average earliness trends show significant fluctuations at this timepoint (similar to Salinas Transit Center). These trends are shown in Figure 26, Figure 27 and Figure 28. These fluctuations are not observed at other timepoints.

In the legend in Figures 26 through 28, timepoints are numbered (shown in parentheses in the charts) according to their order in the direction of travel.

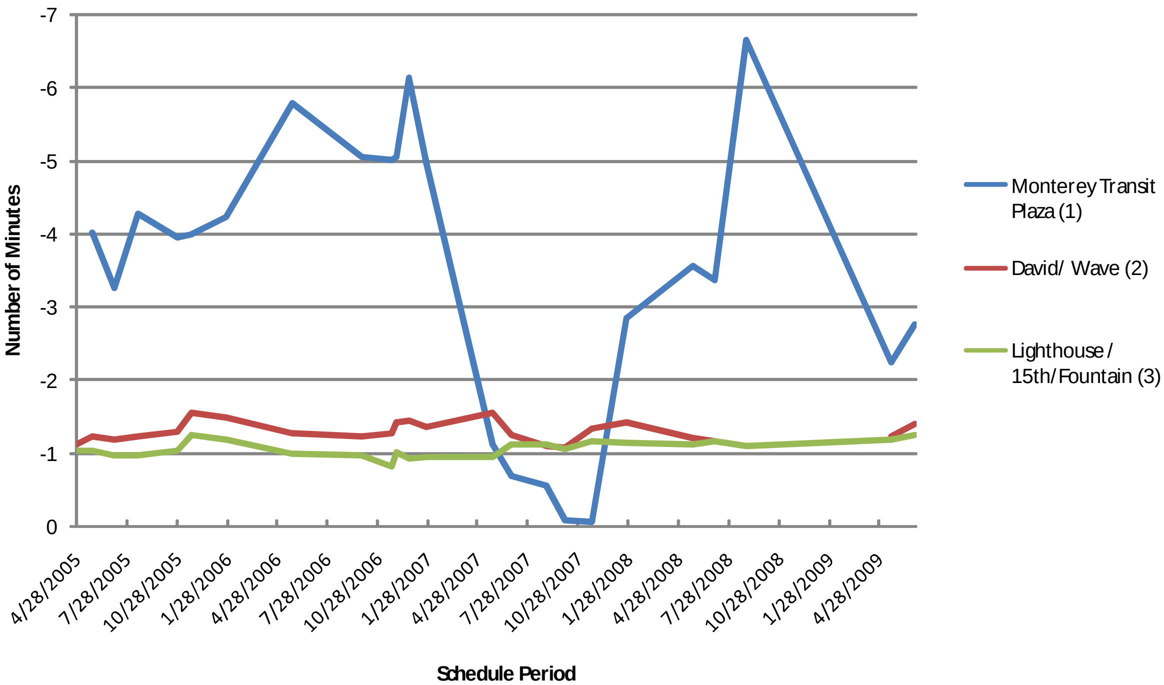

Figure 26. Average Earliness for Timepoints at Route 1 (Outbound)

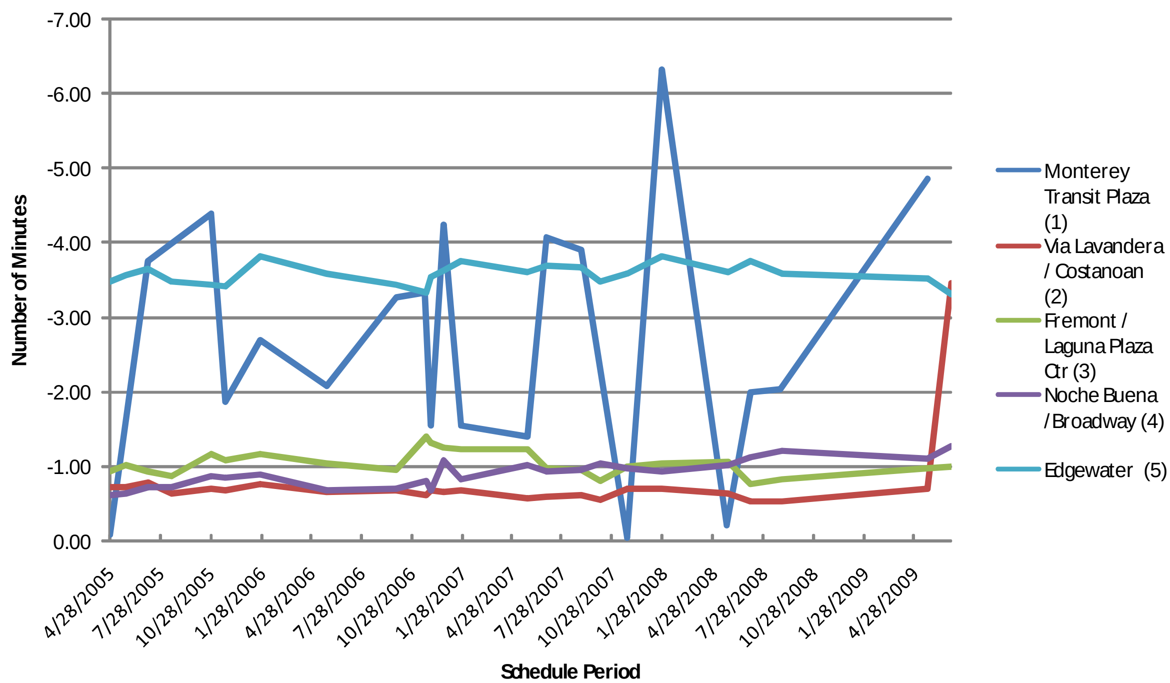

Figure 27. Average Earliness for Timepoints on Route 9 (Outbound)

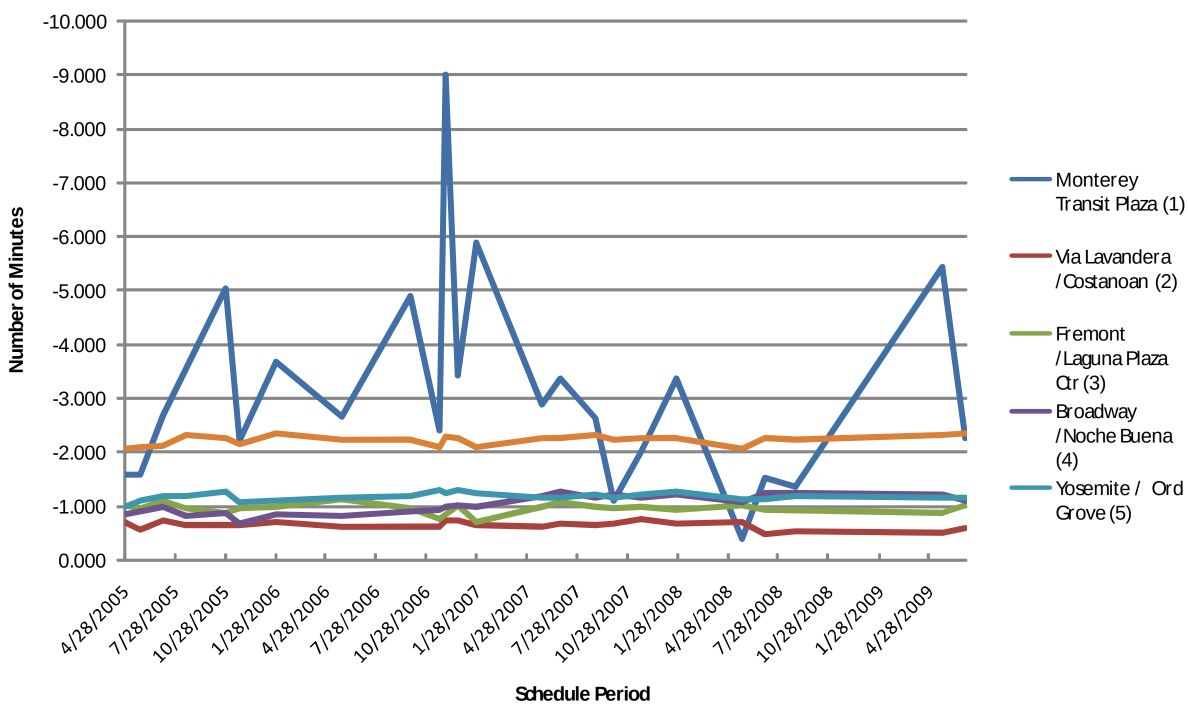

Figure 28. Average Earliness at Timepoints on Route 10 (Outbound)

The timepoint analysis of earliness and lateness led to the following observations:

- Monterey Transit Plaza, Salinas Transit Center, and Edgewater Transit Exchange are among the timepoints that have the most variable and broad windows within which earliness and lateness is seen to vary.
- The trend in lateness observed at the Salinas Transit Center between 2006 and 2007 and between 2008 and 2009 is similar to what we observed in the analysis of Routes 41 and 42 at the trip level. This observation indicates that significant lateness at the Salinas Transit Center alone could have contributed to the significant lateness observed at the trip level. It is likely since high boarding counts at the Salinas Transit Center could have resulted in high dwell times, and hence, late departures from this location, resulting in significant lateness values for trips on Routes 41 and 42.
- The average earliness of outbound trips at timepoints other than the start of the trip did not vary significantly over the analysis time frame. However, the variation at starting points, as discussed above, is significant and suggests that schedule adherence is unreliable at these timepoints.
- As seen in the trip level analysis, the average lateness for the routes in the outbound direction fluctuates periodically throughout the timeframe but does not show any significant changes. Lateness follows the same pattern at all timepoints on individual routes demonstrating that no geographic factor is significantly contributing to the changes in on-time performance.
- The average lateness in the inbound direction varies significantly at the timepoint level, particularly for Routes 41 and 42.
- The average earliness of inbound trips generally is higher at the last timepoint, which is Monterey Transit Plaza for Routes 1, 9 and 10, and Salinas Transit Center for Routes 41 and 42. There is no clear trend for average earliness at any of the other timepoints along these routes.

3.1.2.2.1.4 Overall Summary of AVL Data Analyses

We analyzed schedule adherence trends by both trip and timepoint, but were not able to support the hypotheses mentioned earlier. Similar to Phase II, the selected routes were changed throughout the analysis period. Variable trends in schedule adherence were recognized, and thought to be due to a variety of reasons.

Even though a clear trend was not evident, variability was within a range of one to two minutes in all cases for both earliness and lateness. Also, lateness was observed to be less than 5 minutes, which is within the threshold for lateness as defined by MST. Typically, MST dispatchers would take action and alert drivers about late arrivals and departures at a timepoint only when the vehicles are late by 5 minutes or more. Thus, schedule deviations of less than 5 minutes would have remained unnoticed by MST operations. Also, early arrivals are regarded as on-time by MST, so unusual early trends were not recognized as anomalies.

Thus, despite the fluctuating trends in our analysis, we can conclude that MST has been able to use ACS to their advantage in keeping their trips on time per their definition of on-time performance. Also, as indicated in Phase II, MST has been making many decisions regarding service planning and scheduling changes since 2005 by analyzing the on-time performance of routes (per their standards) using AVL data, along with incorporating feedback from other analyses. For example, changes such as restructuring certain routes, eliminating and adding certain timepoints, adding running times, and eliminating or adding certain trips (e.g., morning trips or express trips) were done primarily by reviewing the route performance using data from the ACS. The impacts of some of these changes on on-time performance trends have been discussed in earlier sections in the report.

However, as concluded in Phase II, the on-time performance and reliability improvements in MST service cannot be directly attributed to the implementation and utilization of the ACS.

3.1.2.2.2 Findings from the Customer Survey

In Phase III, the customer intercept survey data showed that nearly 70% of the surveyed riders in Monterey and Salinas (where service changes were made in 2006 and 2007, respectively) are “satisfied” or “very satisfied” with MST’s on-time performance. Also, a significant number of surveyed riders feel that the new improvements have resulted in making transfers at major transfer centers easier.

In addition, overall satisfaction with the routes selected for quantitative analysis in Phase III is 70 percent and 80 percent (see Figure 71 and Figure 72 in Section 3.8.3.4 for a detailed description).

3.1.2.2.3 Findings from MST Staff Interviews

As reported in Phase II, MST believes that the process of tracking on-time performance has become more efficient since the implementation of the ACS. Prior to the ACS deployment, the on-time performance was determined manually by supervisors by checking vehicle performance against timepoints. Now this process is automated in the ACS system. The ACS tracks vehicle on-time performance at every timepoint and alerts coach operators, dispatchers, and supervisors as needed.

Initially, there were issues with the data generated by the ACS system, but this system has improved over the past few years and has become more reliable in reporting on-time performance. Immediately following the ACS deployment, only 78 percent of timepoints were correctly defined in the ACS system. This problem was due to errors generated in surveying routes and was corrected after resurveying those routes in 2004. The routes were initially surveyed by the ACS vendor. After obtaining proper training, MST conducted the surveys again themselves for the routes with the highest volume of missing information. Resurveying has helped MST reduce the amount of missing data in the ACS. Consequently, the ACS has been collecting better on-time performance data for MST routes since the resurveying was completed.

Along with resolving issues related to resurveying, MST had to learn a lot about field conditions for setting the thresholds for on-time performance. The change in the on-time performance threshold in 2006 has helped MST in improving the percentage of their on-time performance. These thresholds for early and late arrivals were recommended by the COA study conducted by MST in 2005.

Generally, MST believes that the ACS has helped the agency to monitor and improve its on-time performance in recent years. They have noticed that the system-wide on-time performance has improved since the implementation of the technologies. Figure 29 and Figure 30 present the system-wide on-time performance statistics measured in FY 2004 and 2007, respectively. It is evident from these charts that MST’s on-time performance was more than 80 percent across FY2007, with monthly average on-time performance being approximately 84 percent. Earlier, in FY 2004, the monthly average on-time performance was only 74 percent. However, it is not evident from these charts that improvements have been due to the change in on-time performance standards or technology implementations. The impact of the change in early and late arrival thresholds on on-time performance standards discussed in Section 3.1.1.1.1 could be the reason behind this improvement.

The ACS has enabled MST to make coach operators more accountable. Now, reports can be generated in the ACS related to operator performances, so coach operators are aware that they will be held accountable for early or late departures. The on-time performance compliance reports for operators are provided routinely to supervisors who can be pro-active in monitoring the vehicles that are operated by specific coach operators.

MST believes that it has achieved significant travel time savings since the technology implementation but it does not have any quantitative information to support that claim. However, the results of the recent COA studies in 2005 and 2006 show some travel time savings. MST has been focusing on reducing travel time to some of its destinations by analyzing ACS data. The agency has already introduced certain express bus services (e.g., Seaside to Carmel). These changes have resulted in increased ridership and decreased travel times along those routes.

MONTH	TIME POINT COUNT	DELAYED ARRIVALS 3 + MINUTES	ON-TIME PERFORMANCE
July	58,224	15,379	73.59%
August	88,380	25,442	71.21%
September	60,611	17,083	71.82%
October	83,889	25,222	69.93%
November	75,735	20,252	73.26%
December	80,237	18,137	77.40%
January	77,264	16,484	78.67%
February	79,872	18,405	76.96%
March	79,751	20,703	74.04%
April	84,258	22,544	73.24%
May	88,240	23,606	73.25%
June	**94,703**	**22,256**	**76.50%**
TOTAL	951,164	245,513	
Monthly Average	79,264	20,459	74.15%
YTD Comparison	951,164	245,513	74.19%

FY 2004 On-Time Compliance
July - June

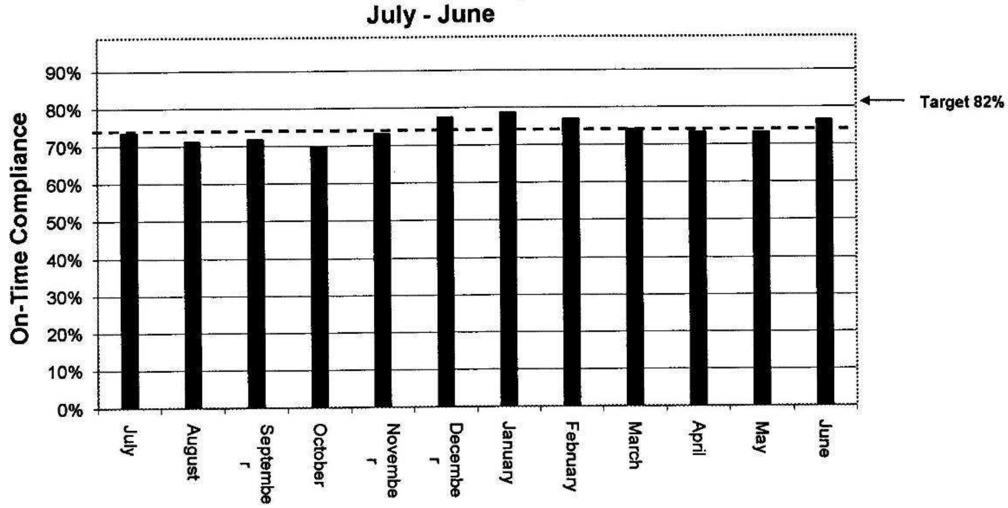

Figure 29. System-Wide On-Time Performance Statistics in FY 2004[10]

[10] Buses arriving three minutes or more after the scheduled arrival time were considered late in FY 2004

MONTH	FY07 ON-TIME PERFORMANCE	FY08 TIME POINT COUNT	FY08 DELAYED ARRIVALS 5 + MINUTES	FY08 ON-TIME PERFORMANCE
July	84.56%	96,770	16,779	82.66%
August	81.12%	100,678	18,982	81.15%
September	81.20%	86,598	15,803	81.75%
October	84.22%	94,293	14,844	84.26%
November	83.76%	89,268	14,020	84.29%
December	86.91%	87,703	12,621	85.61%
January	86.40%	91,318	9,947	89.11%
February	83.81%	89,071	12,078	86.44%
March	83.10%	97,350	13,008	86.64%
April	83.40%	96,780	13,498	86.05%
May	**82.67%**	**101,001**	**15,460**	**84.69%**
June	82.63%			
Total	N/A	1,030,830	157,040	N/A
Monthly Average	83.74%	93,712	14,276	84.79%

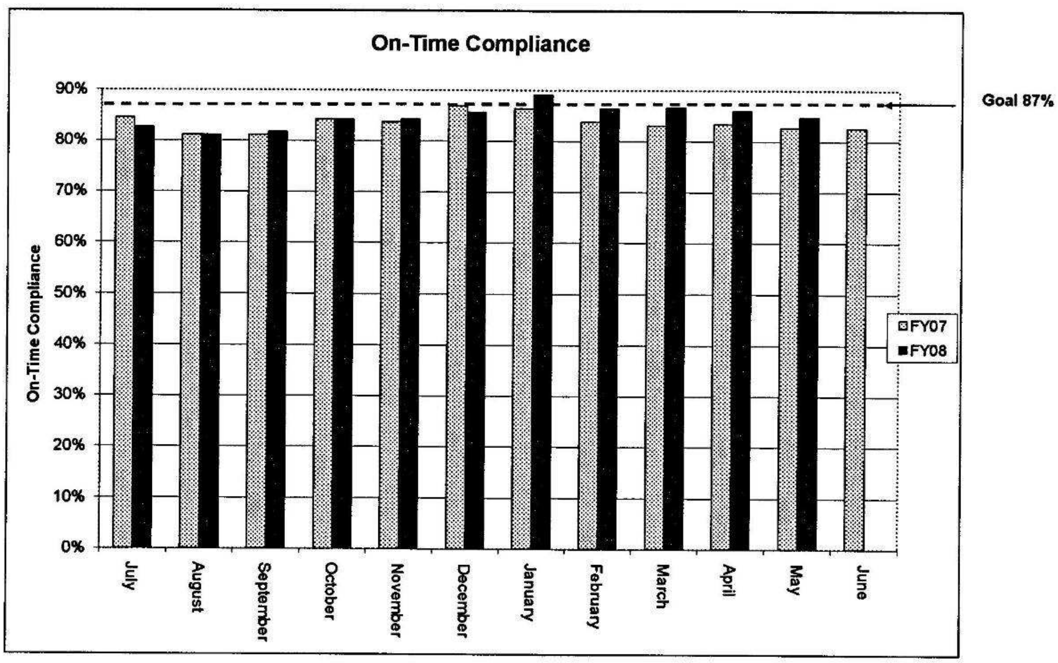

Figure 30. System-Wide On-Time Performance in FY 2007[11] and FY 2008

As stated earlier, the ACS data has helped MST understand seasonal patterns in on-time performance (also obvious in Figure 29 and Figure 30). MST recognizes that on-time performance is reduced during the summer season due to increases in road traffic. Also, MST believes that the rush hour traffic impacts on-time performance and, consequently, adjusts schedules to provide sufficient running time for vehicles operating during peak hours.

[11] Buses arriving five minutes or more after the scheduled arrival time were considered late in FY 2007.

3.1.2.3 Impact on Resource

As reported in Phase II, MST did not have a significant change in staff due to the technology implementation. Occasionally, MST hired interns for preparing maps while conducting COA studies, but interns mostly perform GIS analysis work (using ArcView).

MST believes that technology has provided limited help in saving resources. In fact, the technology implementation has generated the need for more staff to manage and use the data generated by the deployed systems. MST spends a large amount of time in managing and analyzing the additional information generated by the ACS and other technologies. Nevertheless, it takes less time to collect data now since MST does not have to rely completely on manual data collection.

MST has recognized several benefits from the scheduling system. HASTUS has allowed MST to perform runcutting in less time than it took using their prior product; currently, it takes 2 to 3 hours to perform the runcutting. In addition, MST can fine-tune blocking by bringing trips together more efficiently in the HASTUS system.

The technology has helped MST use its vehicle fleet efficiently. When MST retired 17 vehicles from its fleet, it purchased only 15 vehicles to replace them. Also, there has been a reduction in the number of coach operators from 132 to 123. While some of this reduction can be attributed to technology, a budget cut was partially responsible for this reduction as well.

3.1.2.4 Impact on Productivity

MST has noted that there have been improvements in productivity since the implementation of the ACS. However, MST does not consider the improvements in productivity to be an absolute indicator of good transit performance. For example, MST noticed that a reduction in productivity (e.g., passenger per revenue-hour or passenger per revenue-mile) on some routes also reduced overcrowding and resulted in faster boarding and improved on-time performance. The overcrowding on buses was reduced by restructuring some of the MST routes to reduce transfers based on results of an analysis of the ACS data. MST analyzed origin and destination information in the ACS system for routes that were overcrowded and had poor on-time performance. MST decided to add another service to provide direct routes and reduce transfers, which resulted in redistributing loads in the system.

3.1.2.5 Impact on Passenger Counting and Ridership

Before the ACS implementation, MST counted passengers using ride checkers, which required recruiting a dedicated staff. MST also used to obtain passenger counts from fareboxes. However, the passenger counts obtained from fareboxes were not thought to be very useful since the location and time of boarding was not available from the farebox. MST believes that the time and location of boardings from the ACS assists them in reducing operational costs and revenue-hours.

MST decided to approach passenger counting in a different way than many agencies that deploy automated passenger counting (APC) systems. MST was skeptical about the reliability of the APCs available in the market at the time of the ACS implementation. Instead it decided to implement an innovative solution for tracking the number of boardings with the help of the ACS system: MST designed and implemented an interface on the MDT for the coach operator to enter passenger counts. MST coach operators use this interface to enter the number of boardings at each stop. This interface also allows MST to associate numeric codes with boardings to indicate the fare type. For example, MST can capture boardings during special events using a special code for such events.

The boarding counts are sent to the ACS in real-time. While MST collects its passenger counts through the use of the ACS, spot checks are sometimes conducted on overcrowded buses to ensure that the counts are being recorded accurately. At times, MST had issues with training the coach operators in using the passenger counting feature on the MST. For example, the coach operators were found entering boarding information after leaving the departure zone and had to be retrained to use the feature while the vehicle was not in motion or after leaving the stop.

Information regarding the direct impact of the ACS implementation on ridership changes was not available. However, MST adjusted certain routes based on archived ACS data, resulting in a trend of increasing ridership since 2004 (see Figure 31). MST ridership declined in 2008 and 2009, and this decrease could be due to socio-economic changes in the MST service area (e.g., job losses in the Salinas area). This decrease in ridership could not be directly attributed to changes made in MST service.

Further, the on-board rider survey conducted by MST in December 2007 reported that 80 percent of MST riders agreed that MST service had improved since 2006. Also, MST service received an average rating of 1.7 (where, 1=excellent, 2= good, 3= fair and 4= poor) in the same survey. Also, as stated earlier based on intercept survey results, nearly 80 percent of the surveyed riders from Monterey and Salinas areas are satisfied or very satisfied with MST service.

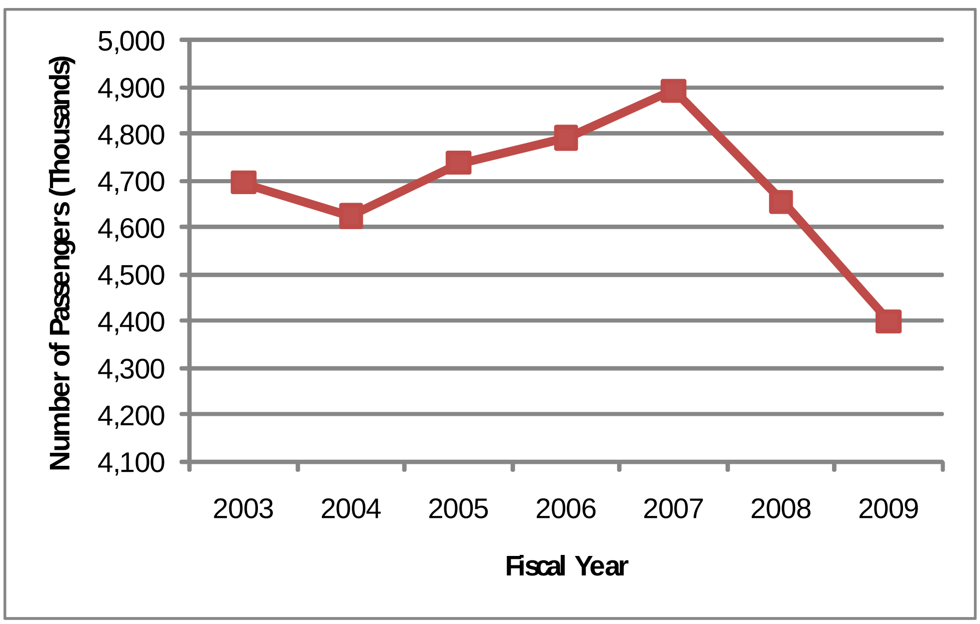

Figure 31. Annual Ridership

The passenger counting information obtained from the ACS has assisted MST in restructuring its services. For example, MST reduced service hours on certain routes that were found to have a low number of boardings during those hours.

MST experienced a ridership increase due to the deployment of on-board internet access on two long-distance commuter routes: the Monterey-San Jose express and Salinas-King City. MST conducted a survey in October 2007 to find out the response of riders to the Internet access. The survey results showed that riders consider this as an important amenity for commuters. The passenger survey showed that 55 percent of the respondents were aware of the on-board Internet access and 24 percent of the respondents had used the service before. Based on the initial positive response, MST is planning to install wireless Internet access at other locations such as transfer facilities and parking garages with the help of a local private partner.

3.1.2.6 Impact on Vehicle-Hours, Vehicle-Miles and Passenger-Miles

Figure 32 shows an increasing trend in the number of annual passenger-miles and serves as a positive indicator for increased ridership. Passenger-mile data for 2008 and 2009 could not be obtained from MST, so updated trend information is not available for this MOE.

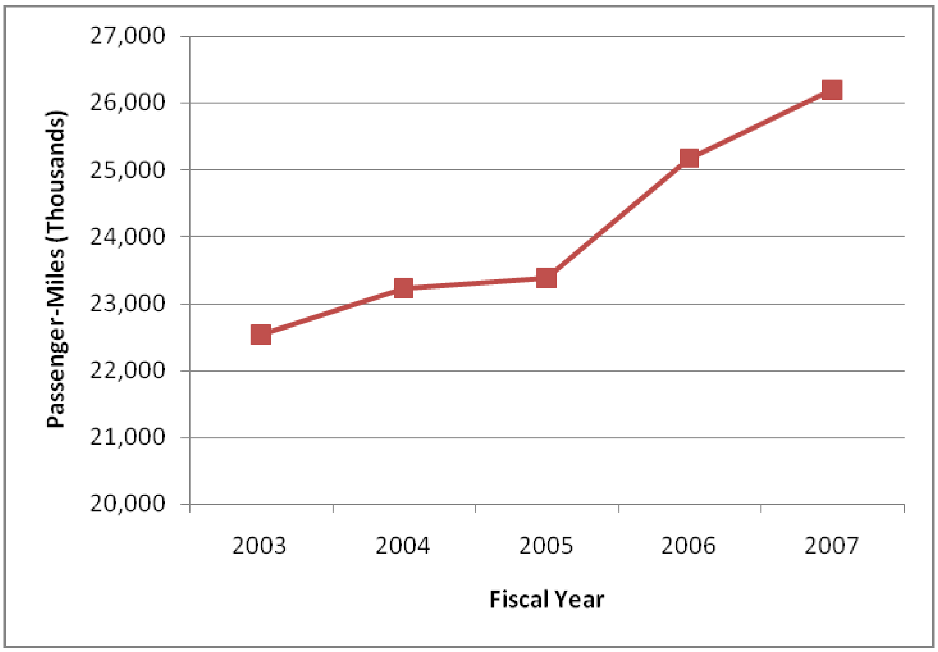

Figure 32. Annual Passenger-Miles

A review of annual vehicle revenue-miles shows an inconsistent pattern (see Figure 33). Revenue-mile statistics were the highest in 2007. An increasing trend can be seen in recent years. However, the increase in revenue-miles cannot be attributed directly to the impacts of technology deployment, as there is limited evidence to support this claim.

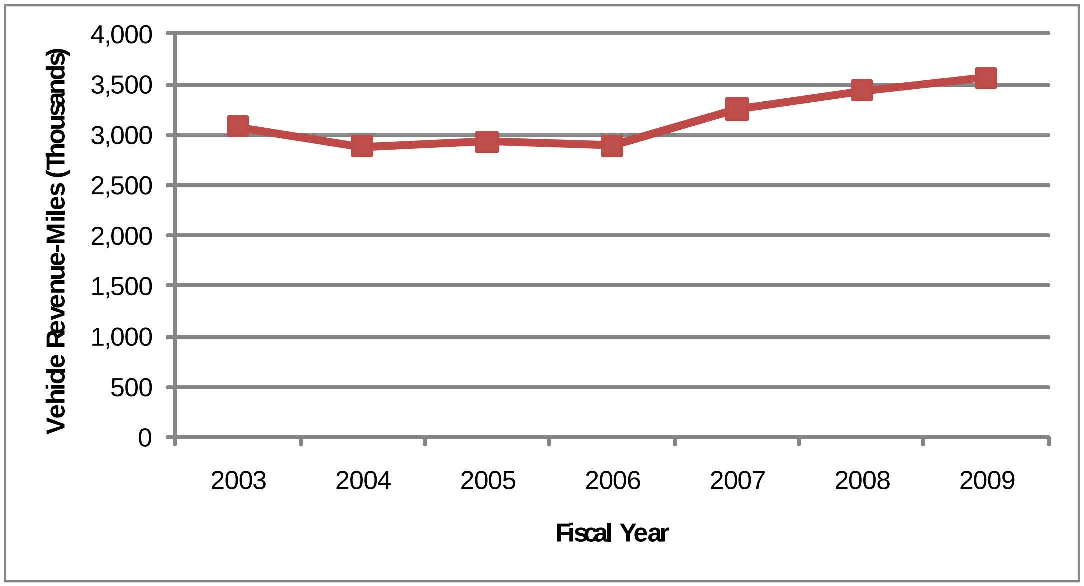

Figure 33. Annual Vehicle Revenue-Miles

Figure 34 shows an increasing trend in passenger-miles per employee since the technology deployment. This indicates that productivity has improved since the 2003. In summary, MST has served more passengers with existing resources through the use of technology. Passenger-mile data for 2008 and 2009 could not be obtained from MST, so updated trend information is not available for passenger-miles per employee.

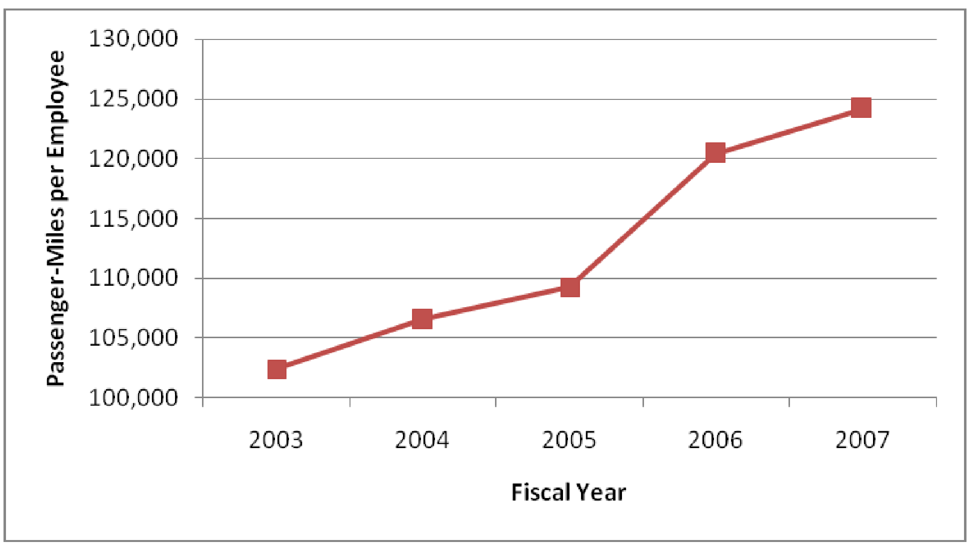

Figure 34. Annual Passenger-Miles per Employee

Figure 35 shows the trend in annual revenue-hours since 2003. This graphic shows that the annual revenue-hours have increased consistently since 2006 even though there was an inconsistent trend prior to that. This inconsistent trend prior to 2006 could be a result of operational changes implemented by MST. But, it is important to analyze vehicle revenue-hours in conjunction with the number of boardings. As seen in Figure 36, boardings per revenue-hour have consistently decreased since 2006. However, the decrease is less than five boardings per hour and can be attributed to various operational and policy changes (including a fare change) made during the evaluation timeframe. Also, external factors such as socio-economic changes in the area (e.g., an increase in unemployment) could have resulted in a decrease in ridership in 2008 and 2009.

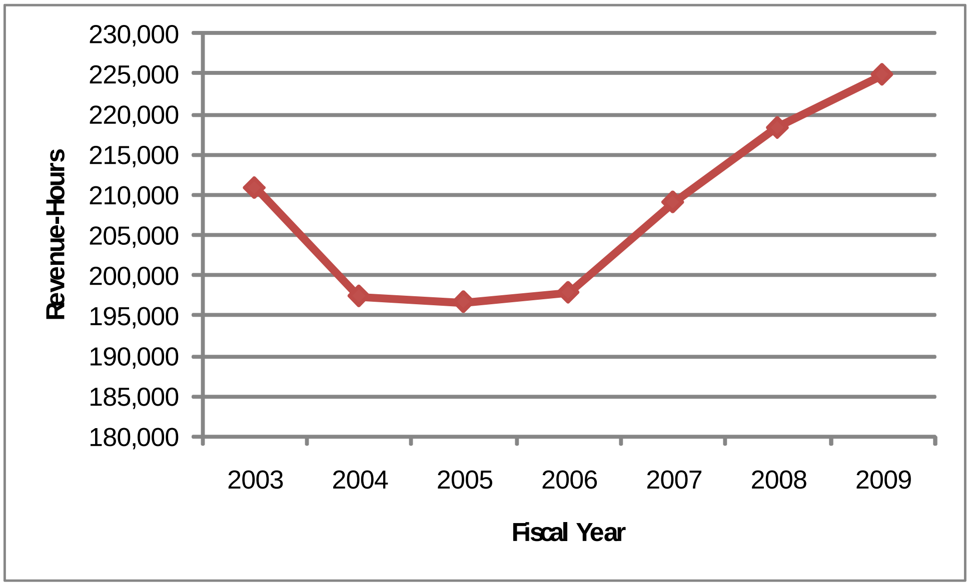

Figure 35. Annual Revenue-Hours

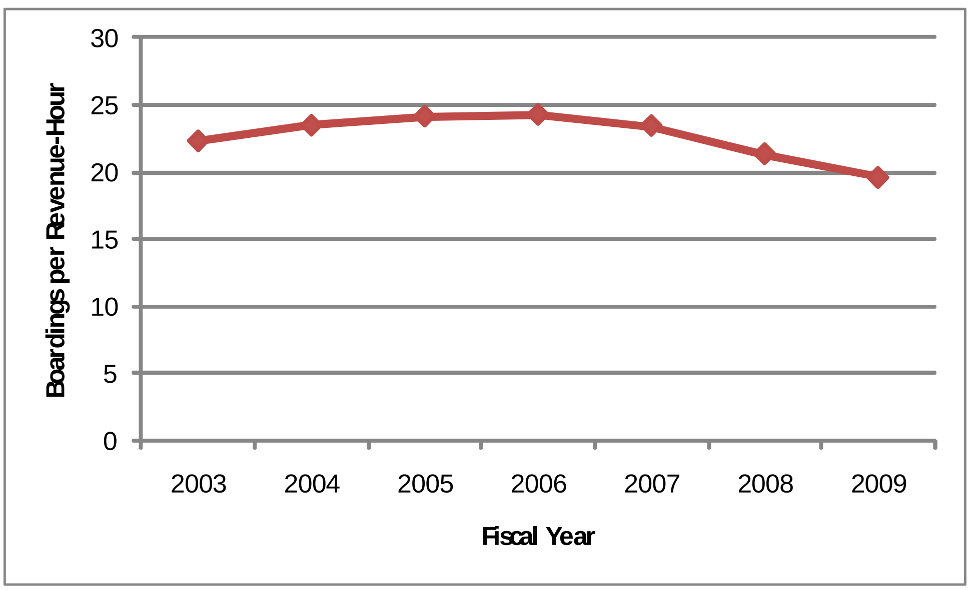

Figure 36. Boarding per Revenue Hour by Fiscal Year

3.1.2.7 Other Impacts and Perceived Benefits

As reported in Phase II, based on staff input, MST recognizes that the technology has, in general, resulted in efficiency improvements as well as increased MST's confidence in its ability to provide accurate information to customers. Beyond the major impacts described in earlier subsections, the ACS has assisted

MST in improving activities that take place in planning and operations departments. These impacts are as follows:

- Impact of Real-time Vehicle Data: MST believes that the ACS has had more impact on numerous departments than other technologies implemented at MST. Primarily, the capability of the ACS to provide real-time data from the field has been of great use to all departments. MST no longer has to rely on anecdotal information from supervisors or coach operators. Further, anecdotal information can be integrated with the field data generated by the ACS and the video surveillance system. This ability to integrate information enables MST to prioritize events or incidents and act immediately on those events or incidents that need urgent attention.

- Impact on Planning: MST has developed innovative ways of utilizing the data from the ACS for various planning needs. For example, MST uses boarding data from the ACS to determine the stops with high boardings for installing shelters. Also, the system assists MST in determining if shelters should be moved to more appropriate locations. For example, on one of the MST routes, shelters were placed next to each other at stops even though there were not enough boardings. MST decided to move the shelters and was able to use the boarding data to convince the City Council about the decision. The boarding data is used by MST to attract advertisers at shelter locations also.

- Impact of HASTUS: In 2005, MST implemented new contract rules which required scheduling software that would take these rules into account. At the same time it needed to replace the existing fixed-route scheduling software, so MST procured new the new HASTUS scheduling software from Giro, Inc. HASTUS is able to handle specific contract requirements such as meal and rest breaks and can perform better runcutting than the previous software.

  Also, as mentioned earlier, MST has decided to use Google Transit trip planner, which requires a data feed to reflect service changes at the agency. HASTUS will provide the data feed for Google Transit. The data feed will be sent to Google every 3 months (at the time of each schedule change).

- Improvements in Service through Data Analyses: The MST planning department built an interface between Microsoft Access and the ACS database to extract specific information by writing ad-hoc queries. MST uses data from the ACS to determine the routes that do not have sufficient run-time built in their scheduled runs. MST also uses the results obtained from the analyses to review and adjust the timepoints on routes that it found to be late consistently.

- Reduction in Voice Radio Traffic: Information on the average length of calls does not exist. However, MST believes that the number of voice calls has been reduced by 60 percent since the ACS implementation. One of the reasons the agency believes that the number of voice calls has been reduced is that the dispatchers know the real-time locations of vehicles from ACS and need to contact coach operators only on a by-exception basis. Also, the data messaging feature in the ACS can be used when a coach operator does not need to speak to the dispatcher.

  Prior to the implementation of the ACS; voice radio was the only mode of communication for coach operators, dispatchers and supervisors. At this time, the radio system was over capacity due to the high volume of voice traffic. Also, prior to the ACS implementation, every bus arriving at a transit center plaza used to call the dispatcher to hold the bus for transfer, resulting in constant voice radio traffic.

The number of such calls has decreased since coach operators call the dispatcher only when they need to hold the last bus for the day.

- Impact on Supervisors: The ACS system assists dispatchers in locating the supervisor nearest to a vehicle when there is an incident. Starting in September 2008, MST plans to equip supervisor vehicles with ruggedized laptops that will provide them with access to the ACS while they are working in the field. Remote access to the ACS will be provided over a virtual private network (VPN) connection.

  Originally, MST requested that the ACS vendor provide a quote for remotely accessing ACS, but the agency found the quote to be relatively high. Additionally, MST questioned the reliability of the vendor's remote access technology. Eventually, MST developed an in-house solution. The remote access capability over VPN also enables MST staff to access the ACS from home during emergency situations or non-business hours.

- Impact on Emergency Management: MST receives covert (or silent) alarms from coach operators when they indicate that there is an emergency situation. Usually, MST receives a very low number of these alarms (e.g., two alarms per month). A majority of the covert alarms received by MST are due to accidental activations. However, MST believes that this covert alarm feature has been valuable to the organization, even though it has had a very limited experience using it.

  As stated earlier, the ACS assists MST in managing the evacuation process during natural disasters such as wildfires in summer 2008. For example, during the recent Big Sur wildfires, MST was identified by the Office of Emergency Services (OES) as a secondary resource for providing evacuation services. MST developed plans to monitor the vehicles that would be part of the evacuation task-forces in the ACS.

- Impact on Coach Operators: There has been a noticeable change in the behavior of coach operator after the ACS deployment. They have become more responsive and accountable for operating their vehicles on time. This change can be attributed primarily to the real-time vehicle tracking capability of the ACS.

  Also, MST has improved their training of coach operators with the help of videos recorded by the on-board surveillance system.

3.2 Impact on Maintenance and Incident Management

3.2.1 Overview of the Maintenance Process and the Maintenance System

The maintenance department at MST maintains the fixed route vehicles fleet and relief units in-house. They follow up with contractors on the maintenance of MST RIDES vehicles and trolleys. Generally, contractors such as MV Transportation maintain their own vehicles and provide daily reports on the status of their vehicles to MST. MST is responsible for the maintenance of the major components of contracted vehicles.

The maintenance department purchased and installed a maintenance management system (MMS) in March 2006. The MMS has been implemented at MST by integrating the capabilities of both automated fuel management (e.g., automated fuel dispensing, tracking fuel consumption and efficiency) and fleet management (e.g., work order processing and preventive management) technologies. MST procured both fleet management (i.e., FleetFocus) and fuel management (i.e., Fuel Focus) systems from the vendor.

Contractors are using the MMS at a very basic level, mostly to generate preventive maintenance (PM) reports. Even though vehicles operated by contractors are set-up in the MMS at MST, maintenance systems at these organizations are not integrated.

Initially, MST had plans to integrate the MMS with the financial and accounting management software (FAMIS). MST developed an interface with help of the FAMIS vendor but the interface was not successful. Eventually, MST decided against integrating the two systems. Since there is no interface between the FAMIS and the MMS, MST cannot automate the initiation of purchase order. However, a manual workaround for generating purchase orders for required asset components (e.g., maintenance parts) is semi-automated.

Figure 37 shows the automated fueling system installed at the MST headquarters garage. The system, known as FuelFocus, consists of several automated features such as automatic vehicle identification and odometer reading with the help of radio frequency (RF) technology and overhead sensors (see Figure 38), electronic fuel dispensing, remote access to the fuel station hardware, and data logging and report generation. This automated fuel management system assists MST in tracking and controlling fuel usage by all MST vehicles.

Figure 37. Fuel Focus Hardware

Figure 38. Overhead Sensors for Automatic Identification of Vehicles

The FleetFocus component of the MMS assists MST in managing and controlling both preventive and corrective maintenance processes. FleetFocus captures labor in real-time and processes and monitors the status of all preventive and corrective maintenance works orders. The system can also store and report on various types of information such as equipment availability, warranty administration, and inventory control.

Preventive maintenance reports are run daily from the FleetFocus module of the MMS. MST performs vehicle servicing between 1 a.m. and 5 a.m., when all buses are parked at the MST garage. All vehicles scheduled for maintenance are held at the garage and the MMS generates work orders for these vehicles. Eventually, vehicle assignments are made to mechanics at the maintenance shop.

Further, vehicle inspections are conducted every night and the inspection data is entered into FleetFocus. The maintenance department uses laptops to run local diagnosis on ITS equipment installed on vehicles. The corrective maintenance reports are generated at night and any vehicle with a defect is taken to the maintenance shop.

Each corrective maintenance work order, identified based on vehicle inspection reports, is organized in the MMS by an individual task code. Since all maintenance tasks identified in the inspection report are coded, the maintenance reports generated by the MMS can be filtered by these task codes (e.g., which problem generated a particular work order).

The majority of the maintenance related data is collected and managed by the maintenance department electronically. Inspection data is typically entered in the MMS by a mechanic. The data-entry can take a long time for some mechanics to perform. MST believes that the data collection and reporting interface is appropriate for the end user but some of the data must be manually compiled for reporting purposes.

Figure 39 shows a vehicle undergoing maintenance in the headquarters maintenance shop.

Figure 39. An MST Vehicle in a Maintenance Shop

In addition to using the MMS, maintenance staff can access the ACS, which enables them to search for various types of vehicle alarms in the ACS control log. Typical alarms captured by the ACS system are related to incidents or accidents, wheelchair issues, and mechanical failures.

3.2.2 Findings

3.2.2.1 Impact of Remote Diagnostics Data Analysis

Initially, the ACS was implemented using an alarm monitoring system (also known as remote diagnostics) for monitoring mechanical alarms. Remote diagnostics were intended to provide staff with a list of vehicle component alarms in the event queue of the ACS (e.g., engine fire, and low oil-pressure). However, the remote diagnostics system did not work as expected and was generating a large number of false alarms. It was not practical to examine such a large amount of information in real-time, particularly since most of it was false. Also, the Communications Center had become insensitive to the remote diagnostics since so many alerts were false alarms.

The vendor was notified about the problem with remote diagnostics and provided one person on-site at MST for 8 months to resolve the problem. The vendor staff person attempted to filter the event queue based on certain criteria, but that did not resolve the problem. Eventually, MST decided to ignore the real-time monitoring of discrete alarms in 2005. Now, coach operators call the dispatcher if they notice problems with any of the on-board vehicle components. MST still refers to these alarm messages for maintenance by searching the ACS control logs but does not respond to these messages in real-time.

3.2.2.2 Impact on Maintenance Management

The Team found during the staff interviews in Phase II that the maintenance department has realized the following benefits since the implementation of the ACS and the MMS systems:

- Ability to Locate Vehicles in Real-time: The maintenance department has access to the ACS and uses it to locate vehicles in real-time. This capability helps maintenance department to locate a vehicle that needs to be replaced by a relief unit or is being used for a special event. Occasionally, the maintenance staff uses the playback feature of the ACS to review vehicle operations.

- Change in Resources: MST had plans to reduce the number of maintenance staff, especially the parts staff, after the implementation of the MMS in 2006. This was due to the fact that the most of the maintenance information was being captured electronically. However, due to the problems with the system, MST did not make any changes in the number of staff. In fact, the technologies have resulted in more responsibilities and a necessity for data management.

- Improvement in Work-Process: The MMS has improved the maintenance work process by providing better control of the maintenance workflow. The MMS allows the maintenance manager to monitor the ongoing work. Also, the performance of individual mechanics can be monitored in the MMS.

- Reporting: The reports in the current MMS have proved to be very useful to the maintenance department. For example, a certain type of report that was needed for a Board meeting could be produced quickly with the assistance of the MMS.

- Monitoring Using the Video Surveillance System: The video surveillance system was initially procured to enhance the security and safety of drivers and customers, but it is also being used for various other purposes. For example, the maintenance department uses the video playback feature to monitor the quality of vehicle servicing in the maintenance shop. The maintenance department also uses facility surveillance cameras to view the buses being serviced in the shop in real-time with the help of closed circuit television (CCTV) technology.

- Secured Access to Facilities: As stated earlier, MST is planning to control access to all its facilities using a proximity card. Currently, doors at MST facilities are secured with the help of numeric code-based locks, the codes for which have to be changed very often.

  MST has already implemented a proximity card to enter the facility at the Marina Transit Exchange. The system is very useful and provides control to identify only those employees who should have access, determine the times at which specific employees should have access, and to create a log of all facility entries and exits.

3.3 Impact on Safety and Security

3.3.1 Overview of the Security System at MST

MST procured a video surveillance system from General Electric Security in FY 2002, and buses are now equipped with interior and exterior cameras. MST equipped its buses with cameras in phases, as stated previously in Section 1.2.4. Both interior and exterior cameras were installed. The exterior cameras are located in the front of the vehicle (facing outside the window) and on the left and right sides of the vehicle (see Figure 40).

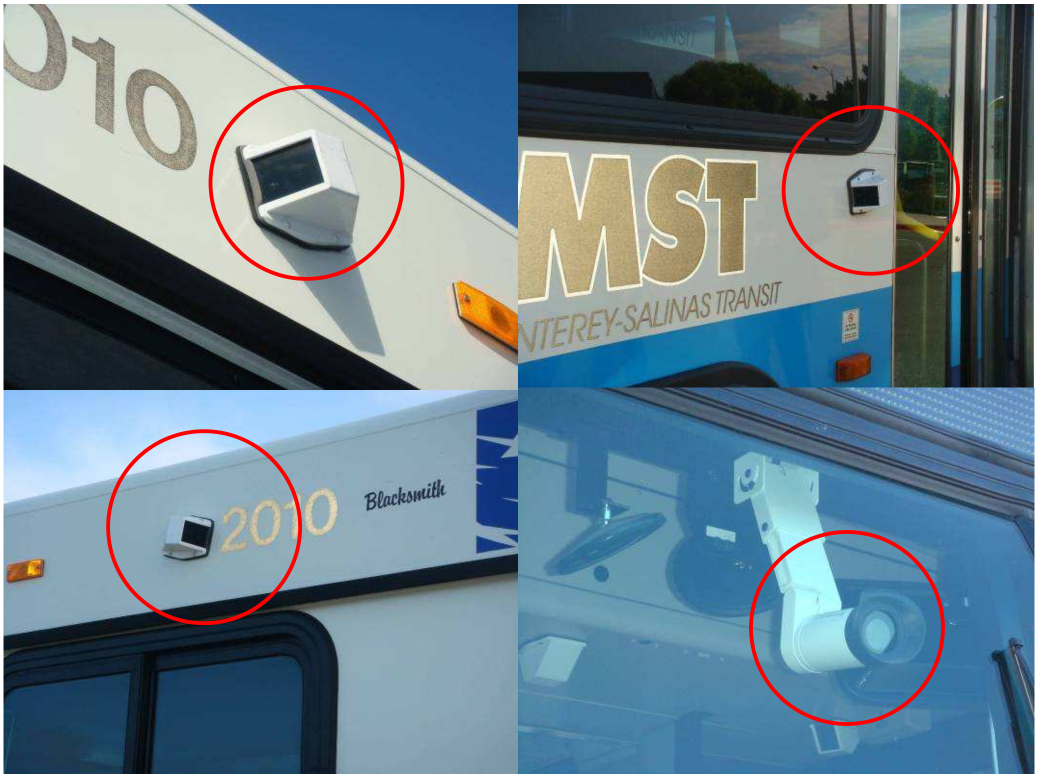

Figure 40. Exterior Camera Installations

Video is recorded on-board by digital video recorders (DVR). DVRs can store up to 72 hours of video, and the video is overwritten after 72 hours are recorded. These DVRs on all MST buses cumulatively capture up to 500 hours of video per day. MST downloads up to three DVRs a day for review. Central playback software is used to review the video. This capability assists MST in reviewing any accidents or incidents after the fact. These videos include both audio and video data from multiple cameras.

A panic button can be used by coach operators to tag incidents, after which the DVR software increases the speed of video recording. The videos are generally recorded at three frames per second (fps). On activation of the incident tagging, recording speed increases to 30 fps. This capability assists MST to capture the full-motion view of an incident or accident.

Generally, the on-board surveillance system has provided a safer transit system. Also, the surveillance system has helped MST reduce the number of false insurance claims from customers and defend against lawsuits. Accident investigations are conducted in-house, but outside consultants are involved when legal advice or assistance is required. MST has designated one staff member to perform in-house investigations. In summary, the surveillance system helps MST in:

- Resolving passenger disputes;
- Resolving complaints against drivers;
- Resolving passenger slip and falls claims;

- Verifying running red light complaints; and
- Verifying over-exaggerated complaints regarding operator assault.

CCTV video surveillance system has been installed at various physical facilities including transit centers (see Figure 41). The MST headquarters building does not yet have the surveillance system installed, but MST is pursuing a grant to install video cameras at this facility. MST believes that, as it grows, it will need to install cameras at more locations.

Figure 41. Facility Camera Installation (highlighted in circle) at Marina Transit Exchange

MST has also been planning to implement real-time video monitoring capability in which cameras will send live video feed to a central location on certain routes. However, it is uncertain whether or not MST will implement this system since its recurring cost is relatively high (e.g., $50 per vehicle per month). Also, the security staff thinks that a real-time video monitoring system is not required and the current system is sufficient to meet the agency's needs.

3.3.2 Findings

The security department reported during the Phase II interviews that implementation of the surveillance system has been very useful. Both employees and coach operators feel safer due to the presence of the video surveillance system. Also, coach operators believe that the surveillance system is for their protection and is not installed to "watch them." MST credits the employees' union for handling the implementation appropriately.

The major impact of the surveillance system has been on the process of handling incidents and accidents and resolution of financial claims by passengers, as described below.

3.3.2.1 Impact on the Number of Incidents/Thefts/Vandalism

When an accident or incident occurs, a road supervisor creates an incident form in the accident database of the MMS and attaches any relevant information (e.g., an image). The security department performs an investigation after receiving a claim related to an incident and attaches any further document (e.g., accident report, images, and the police report) to the initial report. The video surveillance system is not integrated with the ACS system and security investigators view the ACS control log to gather any additional information related to vehicle operations. The electronic filing of incident and accident data has made the retrieval of information much easier for MST employees. Previously, investigators had to comb through paper files for the pertinent information.

As stated above, after fall 2008, supervisors will be able to access the MMS and ACS systems from their vehicles through remote access on laptops. This capability will expedite the incident and accident investigation process and will also reduce supervisors' response times.

3.3.2.2 Impact on Financial Savings

The number and dollar amount of false insurance claims has been reduced since the video surveillance system was deployed. One of the reasons for this decrease is that passengers are aware that MST is using video surveillance and has evidence for incidents involving MST buses and physical facilities. In general, MST states that the video surveillance system has helped save the amount equivalent to 50 percent of the cost of the camera system as of FY 2007. Also, MST stated that the camera system has reduced its liability and insurance premiums since the video surveillance system was deployed.

Figure 42 shows the amount recovered by MST per the number of claims submitted by its customers in each fiscal year. This information is not available for fiscal years prior to 2005. However, the chart shows an increasing trend since the FY 2005 and supports MST's conclusion regarding the claim and insurance-related financial savings.

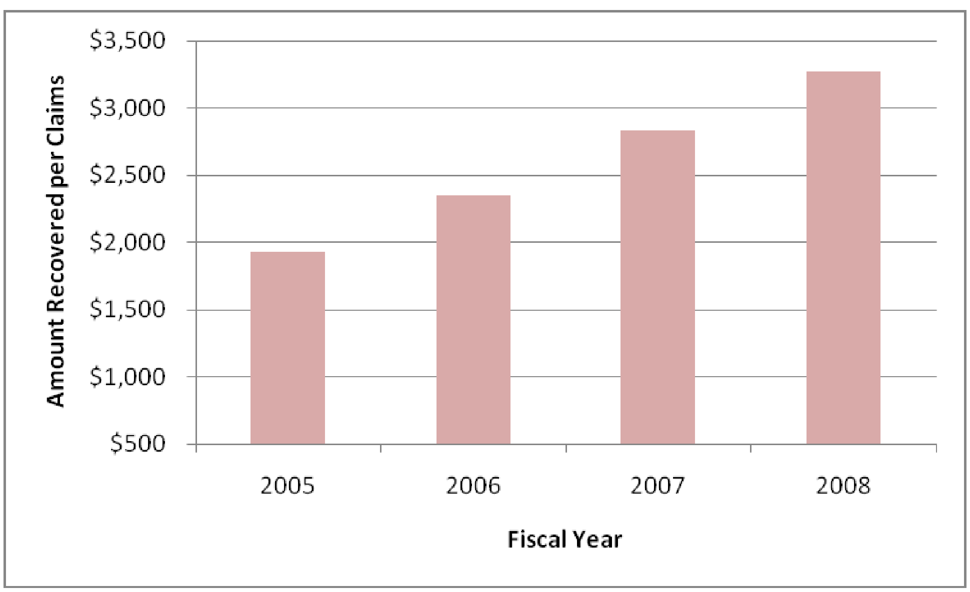

Figure 42. Amount Recovered per Claims

MST utilizes evidence from the video system to identify false passenger claims (e.g., slips and falls). MST reported that it recovered $70,000 in FY 2007, which it would have lost to customers making false claims in the absence of evidence. Before the installation of the video surveillance system, their recovery was between $800 and $1,800 per year. Also, MST was responsible for paying $3 million in settlements when it did not have video evidence to support or deny passenger claims.

Other impacts due to the video surveillance system are as follows:

- An insurance claim was made by a passenger against MST for $25,000 in July 2008. However, the final settlement was reduced to $2,500 when the party was made aware that MST had video evidence showing what actually happened.

- Coach operators are protected through the use of the video system when false complaints are received against them. In one instance, the video evidence helped MST to prove that the coach operator was not negligent as a passenger claimed.

- In July 2008, a particular vehicle was in the yard on a day that MST received a complaint from a passenger who claimed to be on this particular vehicle. The passenger claimed that he was standing because the bus was full, and ended up hitting his head when he fell down. Similarly, in a separate event, someone claimed that the bus had hit his bicycle even though the bus did not. MST was able to view the videos and prove that the complaints were false. In another incident, a coach operator saw an accident and called the Communications Center to notify them of the accident. 911 was subsequently contacted about the accident. MST received a call the next day from a person claiming that the MST bus was involved in the accident. But, the video evidence helped MST prove that that the claim was not accurate.

- One coach operator, whose actions were captured on video, was proven to be stealing. This operator was terminated. MST was aware that there was a discrepancy in money collection and passenger counting, and was able to investigate those discrepancies using the video monitoring system.

3.3.2.3 Other Impacts of the Surveillance System

MST has developed a good relationship with the local police department and works very closely with them by providing video information captured by the surveillance systems. MST has provided evidence in various criminal activities (e.g., bank robbery, shooting) to local police departments with the help of the surveillance system. Several examples are as follows:

- On Route 41, individuals were caught discharging a weapon and were later identified and apprehended by the police with the help of videos provided by MST.

- MST provided video footage of a bank robbery incident in Marina.

- The local police department in Sand City asked MST for help investigating a specific criminal activity. MST was able to provide the video evidence that showed an individual being beaten. The police were able to identify and apprehend everyone who was involved in the event the next morning.

- Video evidence provided by MST helped keep a Salinas police officer from being suspended. The officer was accused of being involved in an accident, but MST videos proved that the police officer was not involved.

- MST provides vehicles to the local police department for exercises as part of Special Weapons and Tactics (SWAT) training. Videos recorded by MST cameras assist the police in reviewing and critiquing officers' performance in these exercises. This assistance has further strengthened MST's relationship with local police departments.

MST recognizes that passengers realize the presence of the surveillance system and consequently misbehave or vandalize much less on-board MST vehicles or while waiting at MST transit centers. Also, placards on buses notify riders that they are being watched. This is perhaps one of the reasons why the number of rider incidents have decreased since the video system was installed.

Facility security cameras have assisted MST in catching vandals. For example, an individual was caught writing on a camera and was later identified and apprehended.

3.4 Impact on MST Reporting

MST recognizes that a large amount of data is being generated by the ITS systems installed at MST. They have limited resources with which to fully utilize all of the information. All of the deployed systems have reporting capabilities, but many of the canned reports are not very useful. For example, standard reports from the ACS currently (as of August 2008) do not meet the needs of the planning department. The planning staff has to use reports that were developed in-house using Microsoft Access. However, the ACS system provides a few monthly summary reports that are useful in presenting information to the MST Board. The finance and security departments stated that reports from the FAMIS and MMS systems do not meet their needs currently.

MST stated that the National Transit Database (NTD) reporting process has become easier with the presence of ridership data from the ACS. Revenue and boarding information reports are generated for NTD after combining farebox data with ridership information from the ACS. No information was available on the relative difference in the times necessary to produce NTD reports before and after the implementation of the technologies. However, there has been some anecdotal savings. For example, while collecting data for two trips at the same time, two separate people had to go out into the field before the technology implementation. Now one person goes into the field, and the other person counts boardings and alightings by reviewing the recorded on-board videos. Further, MST uses video recordings for verifying and correcting boarding or alighting data while doing triennial surveys.

Even though MST has various reports available to make better decisions from individual systems, the agency believes that a more sophisticated reporting system will be beneficial to all departments. A better reporting system will provide information across all MST systems (e.g., farebox, ACS, MMS and FAMIS) through just one single interface.

As reported in Phase II, MST had hired a consultant to review the information needs of each department and design reports using Microsoft Excel, Crystal Reports and other web-based tools. These new reports were expected to be designed during the fall of 2008. However, they were not yet ready at the time of

Phase III evaluation (as of June 2009) and no updated information is available on the impact of the usage of the archived ITS data and data from other systems (e.g., financial system) at MST.

3.5 Impact on Customer Service

As reported in Phase II of the evaluation, MST has developed a customer service database in-house using Microsoft Access. This database, which provides capabilities similar to that of a customized customer service system, allows customer service staff to categorize and track all comments and complaints at any time. Generally, MST resolves most of its complaints within one month. The Customer Service (CS) department assigns each complaint to the appropriate staff based on the category of the complaint via an e-mail. CS staff can either e-mail or send a fax to the customer when the complaint is resolved. Ironically, MST recognized that once it started responding to customer complaints in a timely fashion, it started receiving more complaints.

There are four ways for customers to provide their comments to MST: comments can be submitted on the website, submitted via email, reported via the phone, or reported in-person. Sometimes MST receives complaints in real-time (e.g., unavailability of on-board Internet access). Overall, the CS department receives a variety of comments, feedback, and complaints (e.g., vehicles not leaving on-time, late arrival of a bus, and incorrect on-board next stop announcements).

The CS department has four licenses available to access the ACS. Hence, CS staff can view the real-time location of a vehicle on the ACS to answer customer queries related to the location or arrival time of a vehicle. When the CS staff receives complaints related to an incident, representatives have the ability to playback (on the ACS) where the vehicle was and when in order to investigate the accident. Before the ACS, dispatchers were the only source of information to investigate a complaint. Also, now CS representatives are stationed at CS booths at MST transit centers with direct access to the ACS, meaning that they can provide the public with real-time information

The ACS and the complaints tracking function of the CS database provide the flexibility for MST to reassign duties among the CS staff as needed. Also, CS staff is spending less time answering customer phone calls due to the introduction of other modes of communication (e.g., e-mail and sending messages through the MST website).

Since street supervisors will eventually have access to the ACS remotely on laptops, they will be more proactive in monitoring vehicle performance. MST believes that this capability will help reduce the number of complaints made about on-time performance since this will be constantly monitored in the field as well as at the Communications Center.

MST is planning to include questions regarding technologies in upcoming customer surveys. For example, in the fall of 2007 customer survey, there was a question regarding customers' experience with the new on-board Wi-Fi internet access system. Similarly, questions regarding Google Transit, real-time information signs and online pass sales will be included in future surveys.

Figure 43 shows the layout of the customer service center recently built at the Marina Transit Exchange. The center is equipped with a workstation to access the ACS and other systems as needed. Also there is a workstation for CCTV monitoring from facility cameras.

 

Figure 43. Customer Service Center at Marina Transit Exchange

3.6 Impact on Finance

MST deployed a financial accounting and management system (FAMIS) from Microsoft in 2006. The system, called Microsoft Dynamic NAV (formerly Microsoft Navision), enables MST to manage its financial data (e.g., general ledger, cash management, and management of accounts payable and receivables). Before the FAMIS implementation, MST was using Fleetnet for general accounting. The FAMIS provides the capability to generate reports as needed. However, the current reporting capability will be enhanced in fall of 2008, as stated in Section 3.4

MST is planning to implement a proximity card-based login for coach operators, which eventually will be integrated with the attendance management (DDAM) and payroll systems. This integration will assist MST in automating the whole payroll process since attendance information will be fed directly into the payroll system.

MST was able to raise the pay-to-platform[12] ratio to more than 90 percent since the technology (primarily HASTUS and the ACS) implementation. Before this implementation, the pay-to-platform ratio was between 80 percent and 90 percent. Also, there has been a reduction in the number of deadhead (non-revenue) miles since the technology implementation.

Figure 44 shows that revenue has been steadily increasing since 2003 (these figures account for the fare increases that occurred during this timeframe as shown in Figure 9 above). The increase in revenue has been larger since 2005 as MST was able to make better use of the technologies after they stabilized. Also, MST made several operational changes since 2005 (implementing the recommendations from the COA studies).

[12] Pay-to-platform ratio refers to the ratio of the number of pay hours to the number of platform hours. The number of pay hours refers to the total number of hours a coach operator gets paid for including regular hours and overtime. The number of platform hours refers to the time spent by a transit vehicle in service between vehicle pull-in and pull-out.

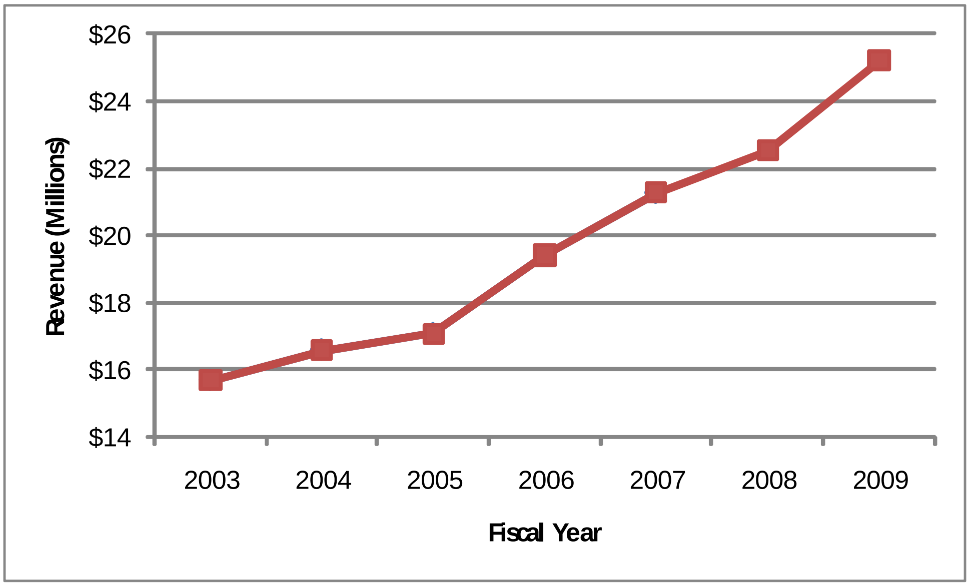

Figure 44. Annual Revenue

Figure 45 shows an increasing trend in revenue per passenger mile over the last 5 years. These statistics indicate MST's increase in revenue along with an increase in ridership since the implementation of technologies. Passenger-mile data for 2008 and 2009 could not be obtained from MST, so updated trend information is not available for revenue per passenger-mile.

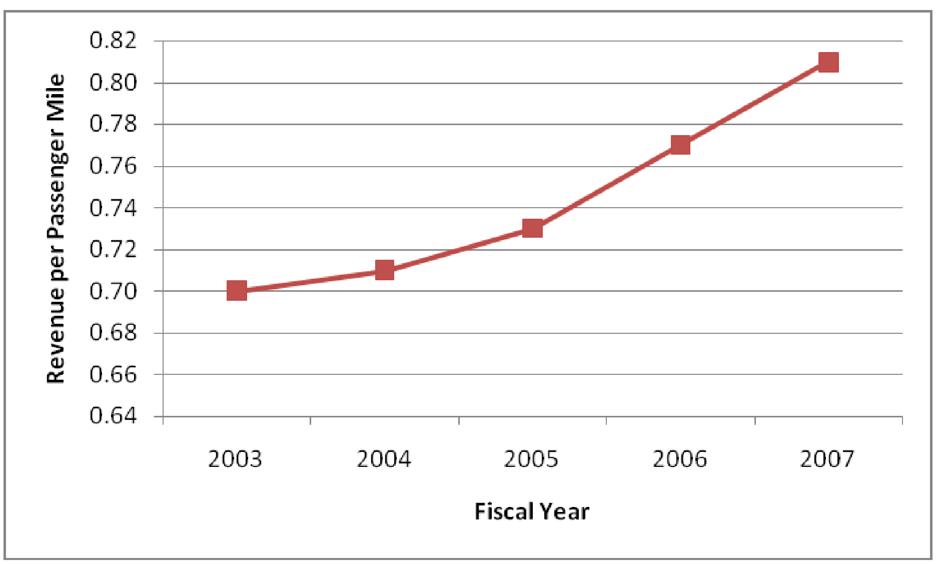

Figure 45. Annual Revenue per Passenger-Mile

3.7 Impact on Management and Administration

3.7.1 Improved Decision Making

The deployment of ITS technologies enables MST to make better decisions now that it has access to factual data from the field which is collected and archived by ITS technologies such as the ACS and video surveillance system. The MST staff is aware of the availability of archived ACS data and video recordings, so customer complaints can be verified before MST reacts to a situation.

Before the technology implementation, MST's primary source of information was mostly coach operators and field supervisors. The information was anecdotal in nature, and often could not be substantiated.

3.7.2 Organizational Improvements

MST managers believe that the implementation of the technologies has allowed them to function more efficiently by facilitating their daily processes. A few examples of these improvements are as follows:

- Runcutting using HASTUS helped MST management recognize that the agency needed a lower number of relief units. Also, buses are serving a larger number of passengers within the same service hours due to more efficient scheduling and runcutting using HASTUS.

- Videos have provided information that defend route and other operational changes. Additionally, on-board and facility cameras have reduced criminal activities that involve MST vehicles or physical facilities. For example, a front-facing camera on an MST bus captured a shooting incident and assisted the local police in identifying and apprehending the criminals. As stated earlier, MST's relationship with the local police departments has improved as MST provides video and other evidence as needed.

- The COA studies conducted for the Monterey Peninsula and Salinas areas used data from the ACS system. Hence, the data collection effort was significantly reduced and temporary staff was not required. Also, the data was more accurate and reliable than that previously collected manually. MST managers believe that they could not have done these studies in the timeframes that they did without the ACS data.

- The technology has helped to identify routes that are not cost effective and are candidates for contractor operation.

3.7.3 Increased Attention towards Future Technology Deployments

The success of technology deployment has facilitated the exploration and consideration of additional technologies for deployment. For example, after the success of the on-board Internet access program on commuter routes, MST is considering the creation of "web stations," which are stops that have wireless internet access. Further, online pass sales have increased since the introduction of on-board internet access.

As mentioned earlier, MST is considering the procurement of a smart card fare collection system, which will improve MST operations by reducing boarding times, facilitating revenue reconciliation, and increasing customer convenience.

Having been impressed with the acceptance of technology by the general public, the MST Board has adopted technology as a priority for the upcoming years to make the overall system and services more attractive to existing and potential riders.

3.7.4 Change in Resources

There have been some changes in resources since the technology implementation. First, an Information Technology (IT) director position was added and then a mechanic was reassigned as an ITS technician.

There have not been any reductions in operations staff, as additional staff was needed to monitor the ACS during regular service hours. Also, staff was needed to analyze the data being generated by the ACS in order to consider potential operational improvements.

3.7.5 Return on Investment

While there are no quantitative figures to provide an actual return on investment from the technologies, MST provided the following rough estimates:

- The implementation of HASTUS has resulted in a $1 million savings annually due to its ability to incorporate contractually required items, such as meal and rest breaks, for coach operators in daily schedules.

- MST managers believe that coach operator productivity has increased. Further, they feel that HASTUS runcutting has improved the pay-to-platform ratio.

- Video evidence from the surveillance system has helped MST reduce the number of false claims.

- The requirement for peak period vehicles has been reduced since the implementation of the ACS and HASTUS. As mentioned earlier, after retiring 17 buses, only 15 were needed as replacements.

- The implementation of maintenance software has improved inventory control and other functions such as warranty tracking.

- It is estimated that the implementation of the payroll system has resulted in up to $15,000 in savings per year.

- MST stopped using compressed natural gas (CNG) buses since the operating cost per hour for CNG buses was much higher than that for diesel buses. The average miles per gallon (mpg) for CNG was 1.4, while it was 5 mpg for diesel.

3.8 Impact on Customer Satisfaction

The Monterey-Salinas Transit (MST) Intercept Surveys were conducted to explore travel behavior and assess the perceptions of transit users at the Monterey Transit Plaza and Salinas Transit Center as they relate to the understandability and usefulness of the technology and sources of travel-related information. The following section describes the survey development and administration process followed by a discussion of the main findings of the survey.

The surveys were conducted to address the secondary hypothesis that the project will result in improved customer satisfaction. While an *increase* in customer satisfaction could not be directly measured (due to the absence of "before" data), this survey was developed to specifically to gain an understanding of MST rider's perceptions of the:

- On-board automated announcements (for bus stop information);
- Real-time traveler information in transit centers;
- Automated trip planning on Website;
- Bus schedule information sources;
- Reported use of future technologies for schedule information; and
- Overall satisfaction with the MST bus service.

The survey was designed to be easily completed in just a few minutes with a surveyor offering respondents the choice to have the survey read to them or to be self-administered. The survey was composed of multiple choice/check boxes and contained only 18 items, allowing for quick completion and minimizing the impact on commuters' time. The survey was also translated into (or administered in) Spanish, since in some areas MST provides transit services to persons who primarily speak Spanish.

On-site surveyors surveyed patrons who agreed to participate and met the following criteria:

- They were 16 years or older;
- They had not already completed a survey;
- They had seen the new signs (for Salinas Transit Center riders only); and
- They were boarding the bus at either the Monterey Transit Plaza or Salinas Transit Center.

A total of 805 surveys was completed; with 404 at the Monterey site and 401 at the Salinas site. This total exceeded the estimated sample size of 566 needed (the number who declined to participate was modest). The estimates for sample size were derived from the most recent passenger counts for the month of September. At the Monterey Transit Plaza, 26,566 passengers (or an average of 885 per day) boarded at the three (Pearl, Tyler, and Munras) boarding areas. At the Salinas Transit Center, 39,952 passengers (or about 1,331 per day) boarded at the eight gates. Using the average daily boarding rates at these locations it was determined a total of 566 surveys (268 at Monterey and 298 at Salinas) would be necessary to achieve a 95 percent confidence level (with a 5 percent confidence interval). This represented approximately 25 percent of the total daily boardings.

3.8.1 Survey Administration Process

Surveyors were identified by badges displaying the word "Surveyor" and bearing the MST logo. At each location, customers were approached by a surveyor, invited to participate, and made aware of participation incentives. Riders who declined to participate were thanked, and no further effort was made; however, the decline rate was modest. All participants were given the option of completing the survey in either Spanish or English. After completion of the survey, participants were offered three dollars in food vouchers at a local fast food restaurant for their participation.

Surveys were conducted mid-week (Tuesday and Wednesday) during peak travel periods. Morning surveys were administered between 7:00 a.m. and 11:00 a.m. at each location. Afternoon surveys were administered between 3:00 p.m. to 7:00 p.m. at the Monterey Transit Plaza. At the Salinas Transit Center, afternoon surveys were administered between 3:00 p.m. and 6:00 p.m. on Tuesday and between 2:00 p.m. and 6:00 p.m. on Wednesday (due to the absence of a security guard after 6:00 p.m.).

Surveyor training was conducted on Monday, September 14, 2009. Five bilingual surveyors and one field supervisor were stationed at the Salinas Transit Center during each survey period. Five surveyors and one field supervisor staffed the Monterey Transit Plaza as well, although only two morning surveyors and three afternoon surveyors were bilingual. The staffing service providing the surveyors at the Monterey Transit Plaza was not able to provide additional bilingual surveyors, resulting in the use of some English-only survey personnel.

The results presented in this section include comparisons between respondents in Monterey and Salinas. Generally, the results show a high level of agreement between Monterey Transit Plaza and Salinas Transit Center rider responses, especially in terms of their level of confidence in the bus arrival times.

As shown in Figure 46 the majority (90 percent) of riders were waiting for one of seven buses in Monterey. Almost two-thirds were waiting to travel on routes 9, 10, and 20. While in Salinas, shown in Figure 47, 98 percent of the riders were waiting for one of nine routes and the frequency was more evenly distributed among the routes.

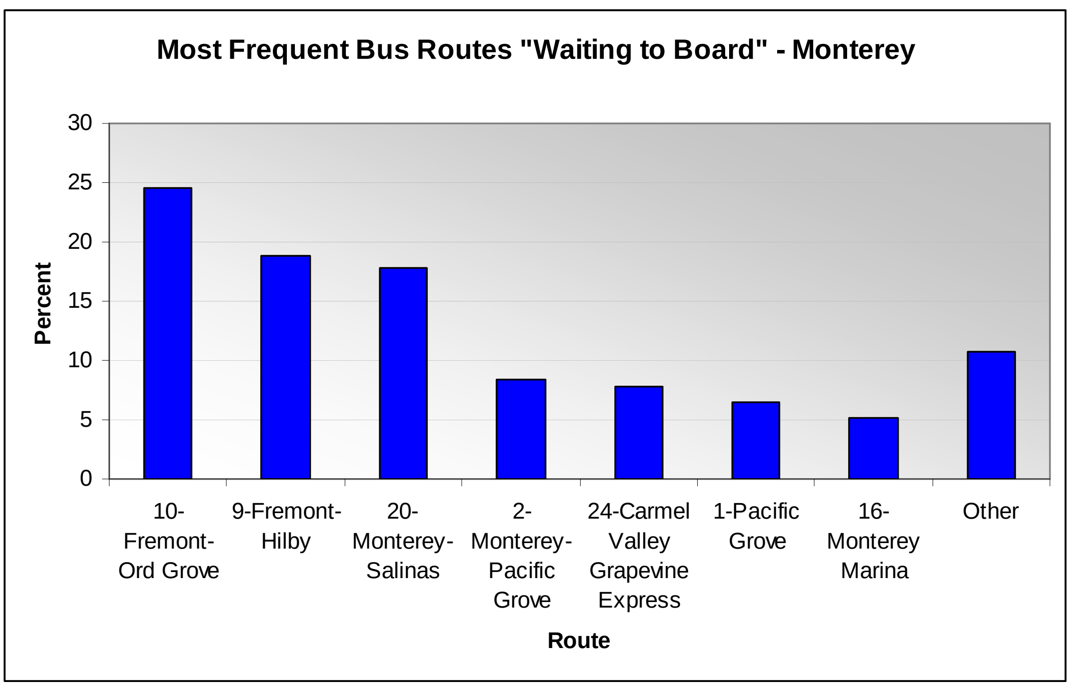

Figure 46. Most Frequently Reported Buses Respondents Were Waiting to Board – Monterey

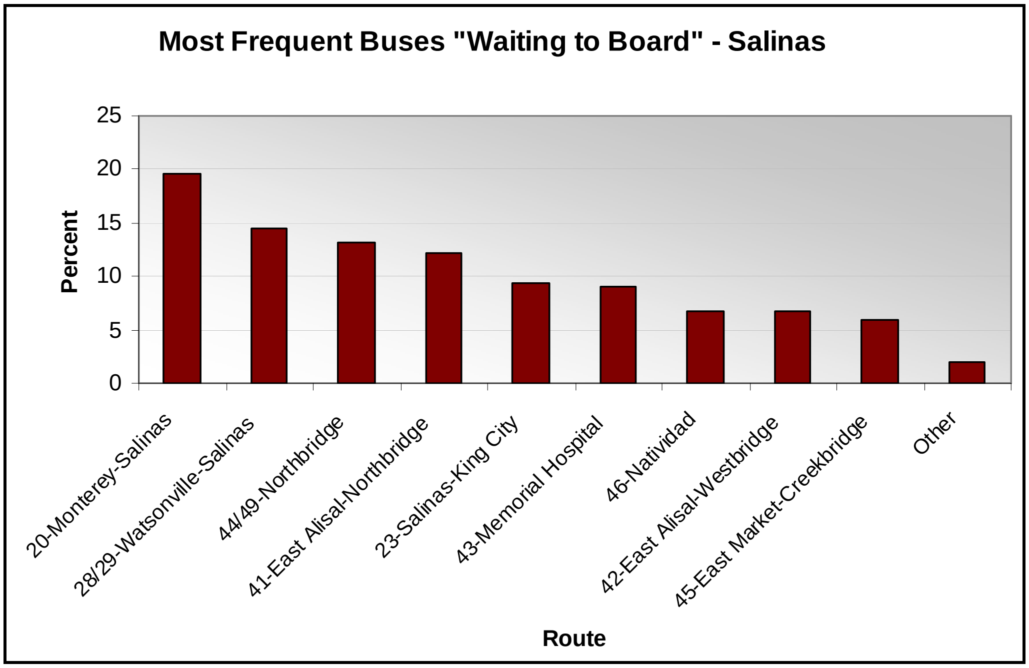

Figure 47. Most Frequently Reported Buses Respondents Were Waiting to Board – Salinas

3.8.2 Respondent Characteristics

3.8.2.1 Respondent Demographics

As shown in Figure 48, the majority of the transit users who responded to the survey were in the youngest age group (e.g., 16-25); this was consistent for both Monterey and Salinas respondents. Slightly higher proportions of the Salinas respondents were in the 26-35 and 35 to 45 age groups with approximately one-third of Salinas respondents in these age groups and one-fourth of the Monterey respondents. Approximately one-fourth of all respondents were aged 46 or older.

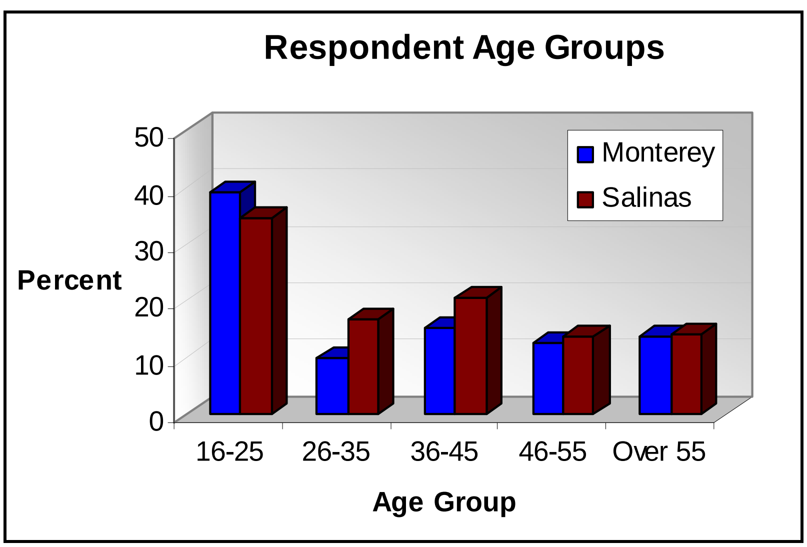

Figure 48. Respondent Age Group by Location

Distribution by gender is shown in Figure 49. As shown, for each location there was a slight majority of male respondents; however, the proportion of males and females was essentially identical for Monterey and Salinas respondents.

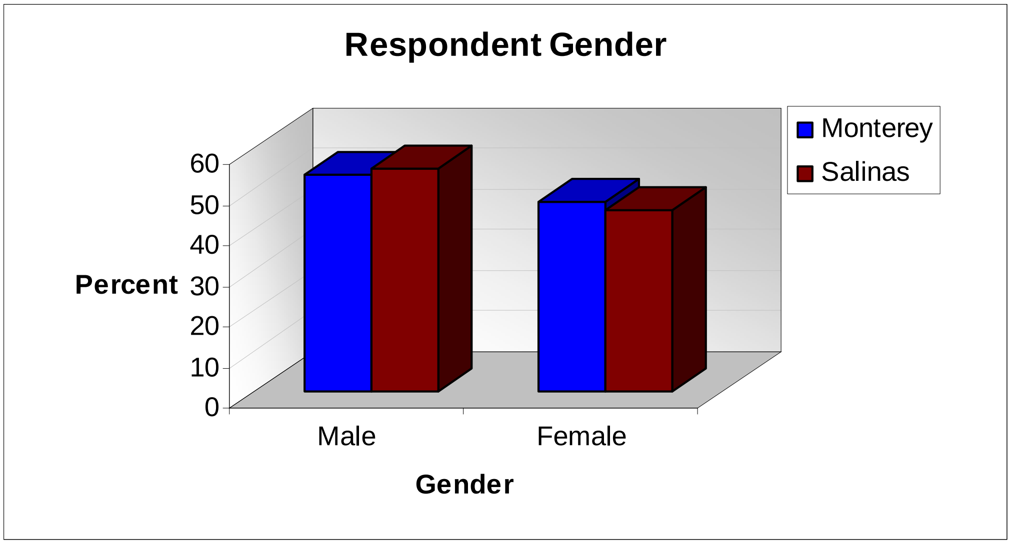

Figure 49. Respondent Gender by Location

When considering the primary language spoken at home (see Figure 50), a much higher proportion of the Salinas respondents reported Spanish as their primary language, compared to the Monterey respondents (44 percent and 29 percent, respectively). While a number also reported "Other," these were primarily reported by only one to three respondents and represented a broad range of languages including Filipino, Indian, Japanese, and Russian, among others.

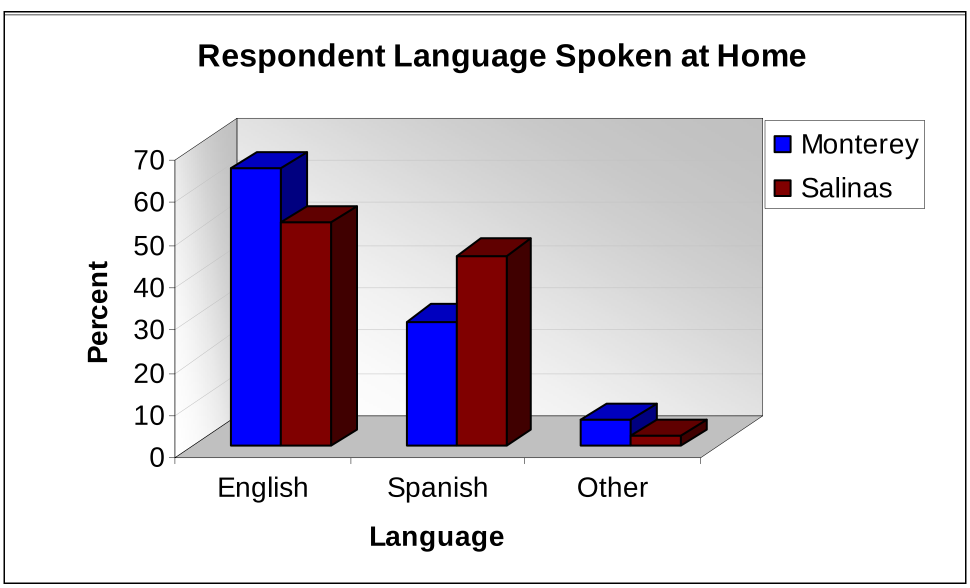

Figure 50. Primary Language Spoken by Location

3.8.2.2 Transit Use Characteristics

Figure 51 and Figure 52 summarize respondents' use of the buses and most frequent reasons for transit use. As shown in Figure 6, a much higher proportion (68 percent) of Monterey respondents reported riding the bus 5 or more days per week than their Salinas counterparts (50 percent). In fact, Salinas riders have a more varied pattern, with almost one-third riding the bus only 1 to 4 days per week and approximately one-fifth riding only a few times per month.

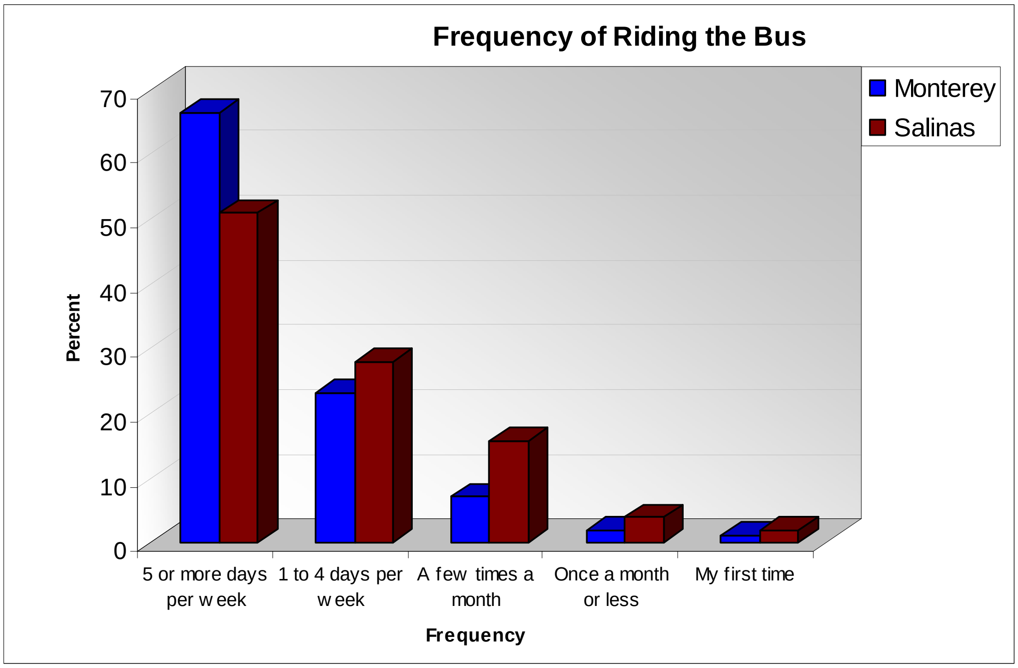

Figure 51. Bus Riding Frequency by Location

Riders' bus riding frequency could be related to their reported reasons for riding the bus (see Figure 52). Almost eight in ten of Monterey respondents reported they ride the bus to commute either to work or school, with "errands" and "other" reasons showing a much lower percentage. This might explain their more frequent and more regular bus usage. However, for Salinas respondents, their bus riding pattern appears to be less routine when considering all the queried reasons. Approximately 50 percent of Salinas respondents report they commute to work or school, but roughly one-third also report riding the bus to "run errands," a much higher proportion than Monterey respondents. This might also help explain the differences between the two respondent groups regarding frequency of use; the Salinas respondents' lower rate of bus riding could be due to the non-routine nature of their need to run errands, rather than regular commuting patterns. The reasons given as "other" (see Figure 53) also showed that Salinas respondents, more so than the Monterey riders, tended to use the bus for appointments (primarily medical), for visiting family and/or friends, and to "get around." It would appear that Salinas riders rely much more on the bus system than private vehicles for local travel.

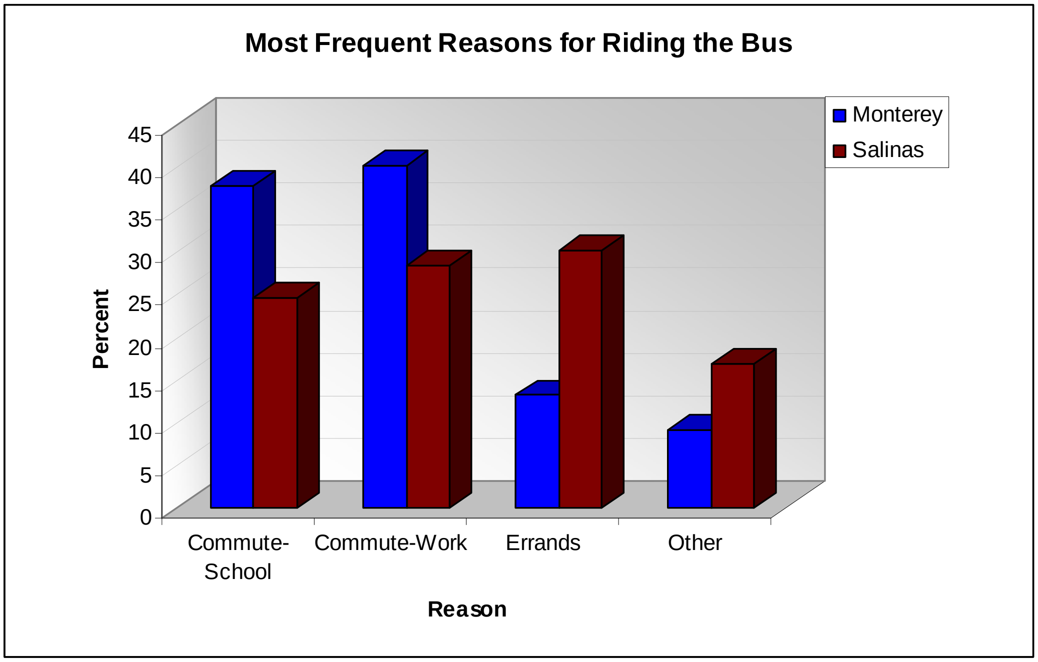

Figure 52. Reasons for Riding the Bus by Location

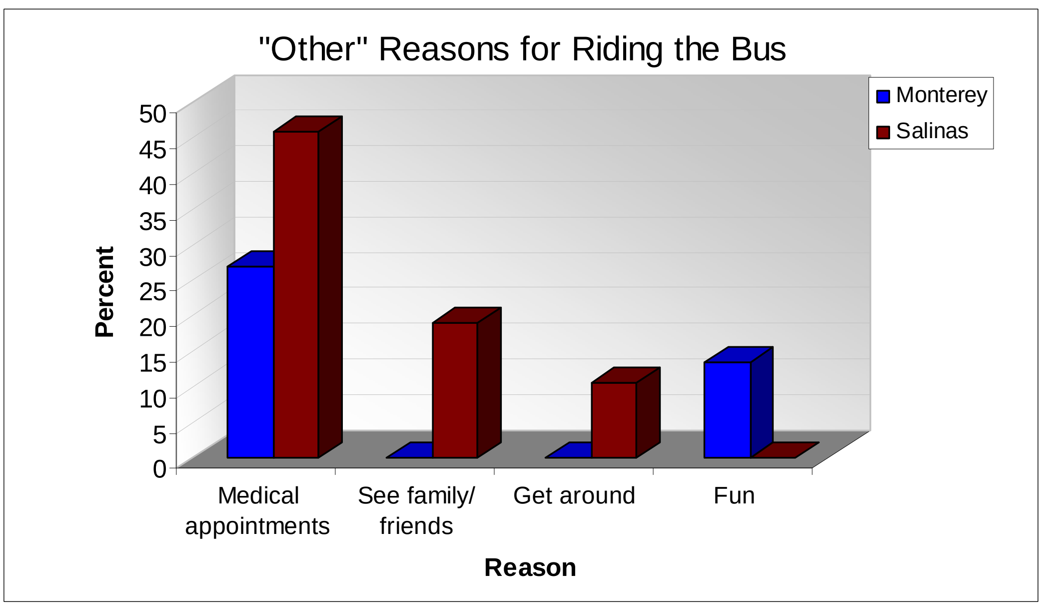

Figure 53. "Other" Reasons for Riding the Bus by Location

3.8.3 Survey Findings

3.8.3.1 Schedule Information Sources

As shown in Figure 54, there was a consistent pattern across all respondents regarding the sources used for schedule information. This consistency was also evident between the Monterey and Salinas respondents. By an overwhelming majority, respondents reported they used the Printed Schedule/Riders Guide (overall, 64 percent) when compared to the alternative choices: the MST website or calling Customer Service.

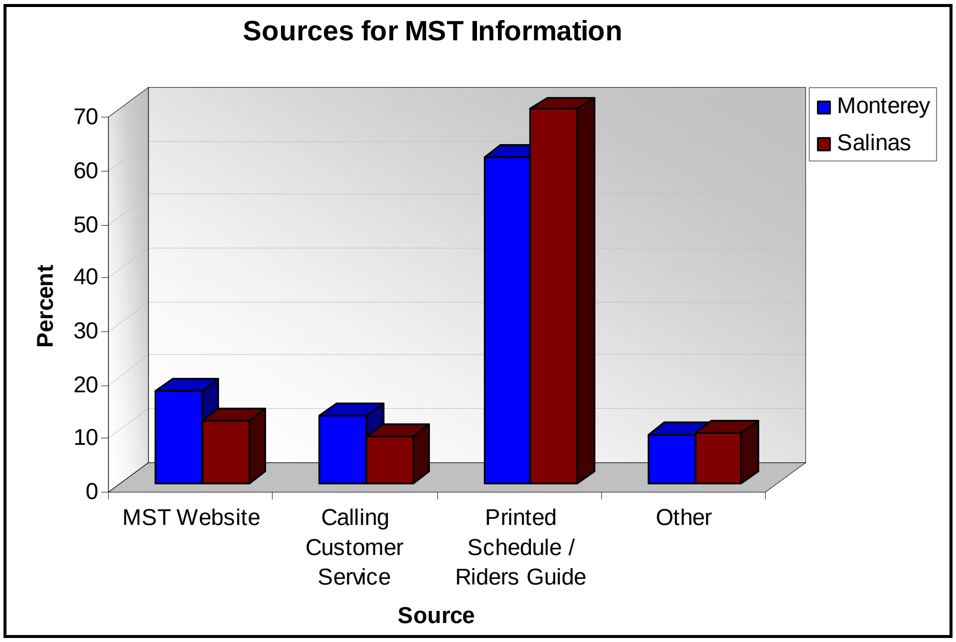

Figure 54. Sources Used to Obtain MST Schedule Information by Location

This pattern of responses could be seen as somewhat surprising, owing to the proportion of respondents who reported they had the internet available at their homes. As shown in Figure 55, almost two in three Monterey respondents and almost one in two Salinas respondents reported having internet access. It could be that bus riders who ride the same routes regularly (especially for the Monterey commuters), do not feel the need to check schedules based on their experience with the system and their specific route patterns. They may view using the internet as a source to check primarily for schedules on routes they normally do not ride.

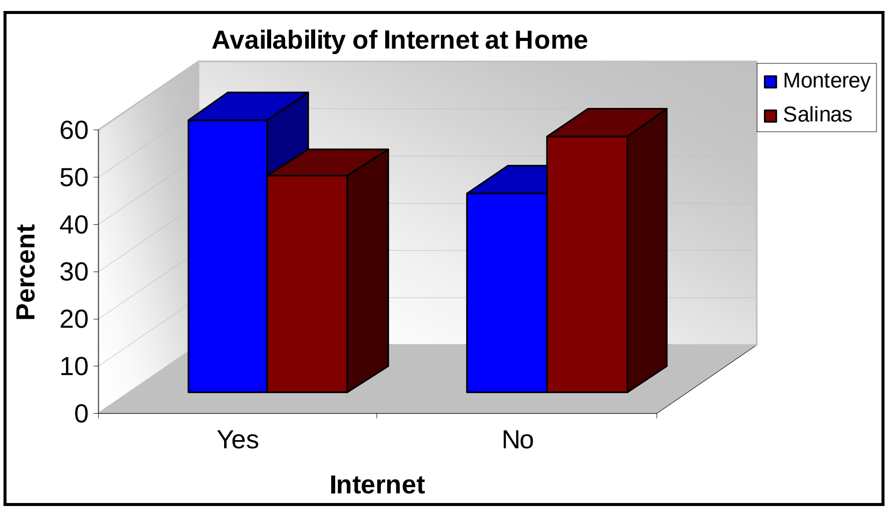

Figure 55. Availability of the Internet at Home

When considering internet availability by sources used (see Figure 56) this pattern is still evident. Even though approximately half of the respondents from each location indicate they have internet access at home, less than one-fifth of those with access report having visiting the MST website. It also seems apparent that those without internet access rely much more on the Printed Schedule/Riders Guide (almost 80 percent) than those with access (60 percent), although both groups' use of the printed material is very high.

As depicted in Figure 57, while visits to the MST website are reported at relatively low rates, it does appear that respondents in the younger age groups are more apt to use the MST website. Almost one-fifth of those in the 16-25 and 26-35 year old age groups reported accessing the site. This pattern is almost reversed for use of the Printed Schedule/Riders Guide, with the older age groups reporting use of this source (though, again, this source is the overwhelming source of schedule information).

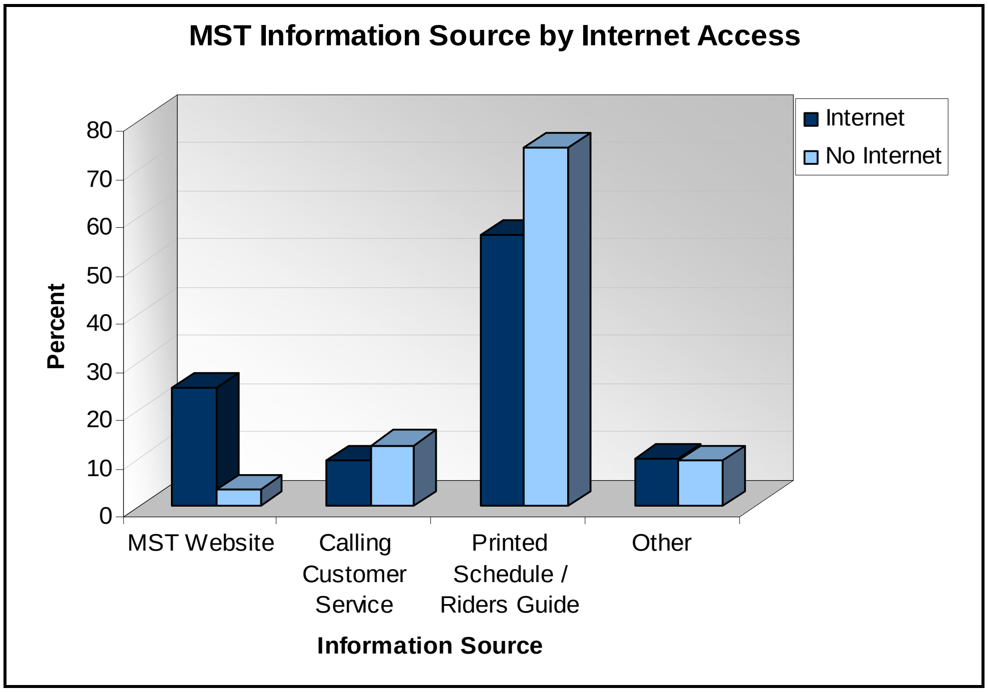

Figure 56. Schedule Information Sources by Internet Access

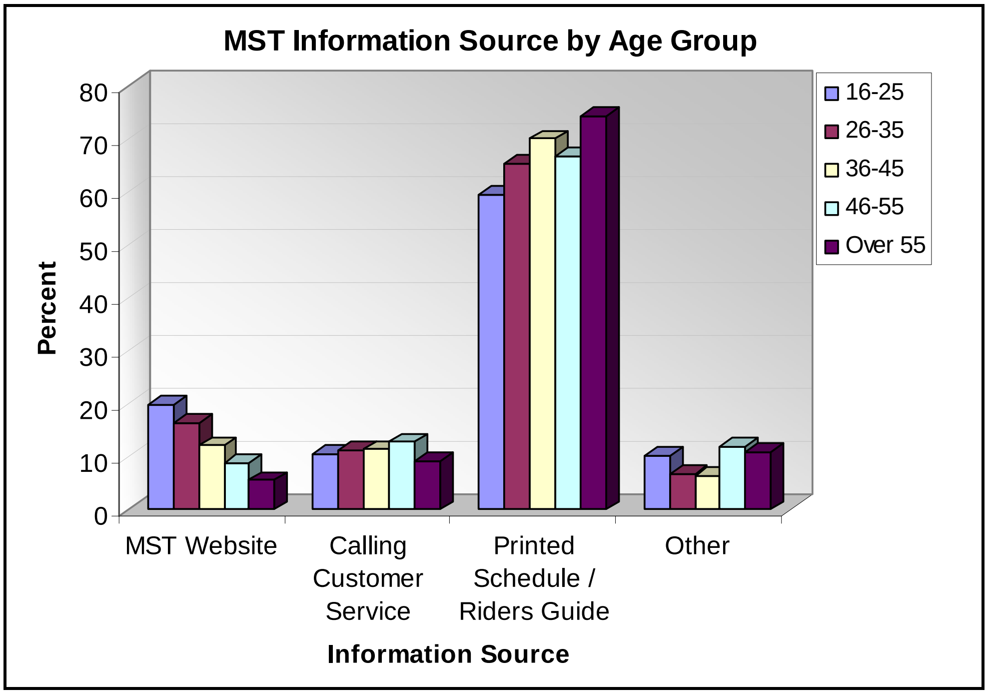

Figure 57. Schedule Information Sources by Age Group

Also, when considering information source by language, as shown in Figure 58, it appears that riders whose primary language is English report greater use of the MST website than Spanish speakers. Conversely, Spanish speaking riders show a higher proportion of use of the Printed Schedule/Riders Guide. The other sources, while reported by a much smaller proportion of riders, show no real difference by language.

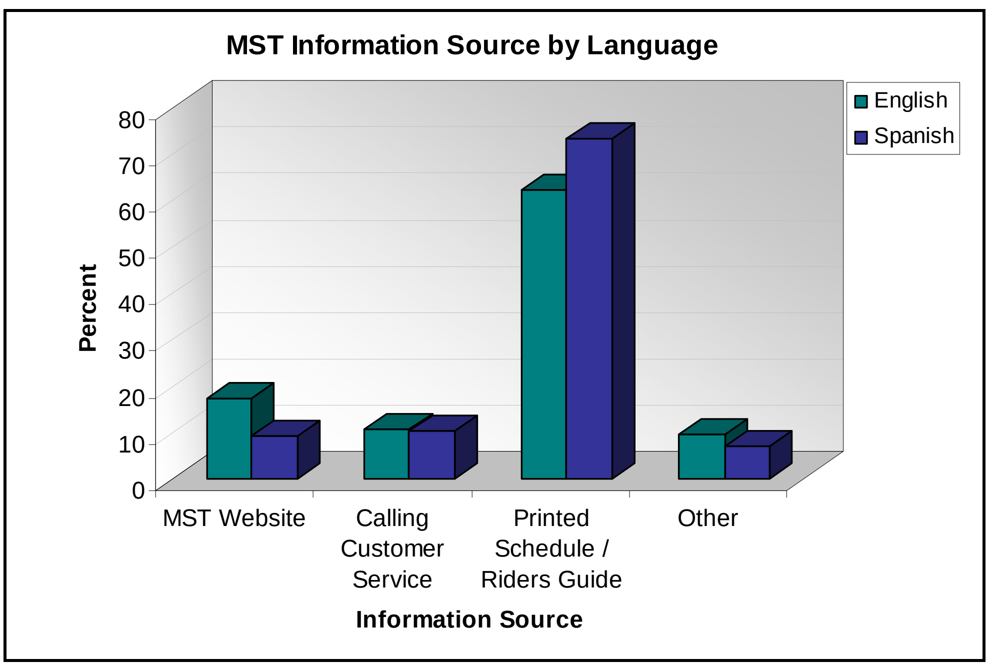

Figure 58. MST Information Source by Language

These results could be explained when examining internet access by the primary language reported spoken at home. As shown in Figure 59, the proportion of those who have internet access and those who do not is related to language. In fact, the proportions are essentially inverse; 60 percent of English speakers report having internet access, while essentially the same proportion of Spanish speakers report not having internet access at home.

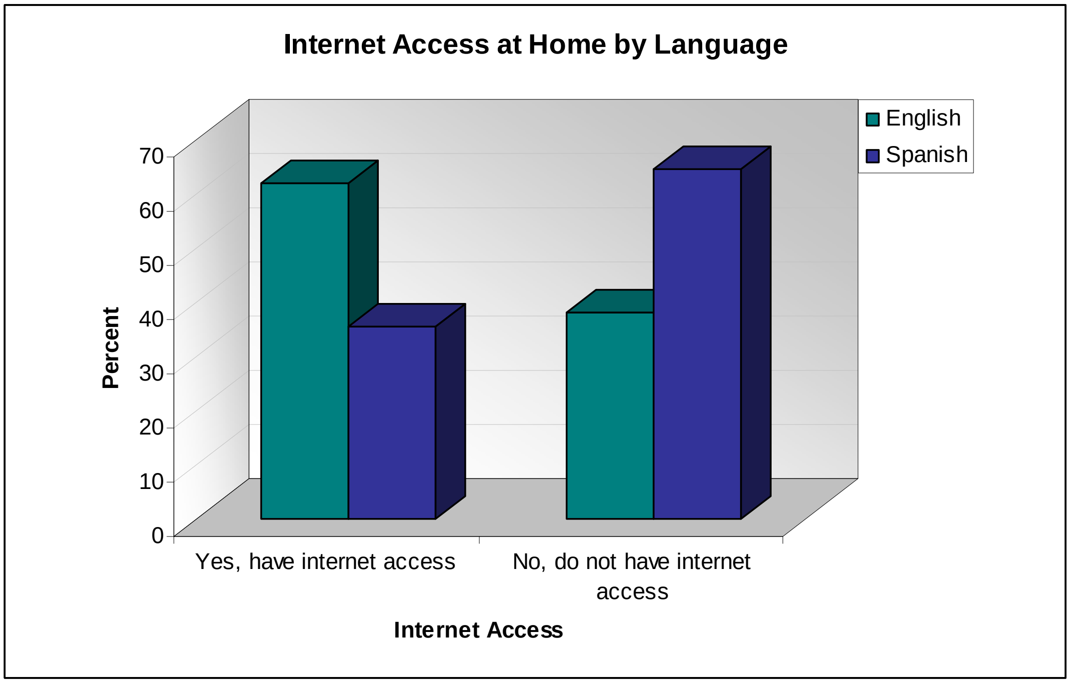

Figure 59. Internet Access by Primary Language Spoken at Home

These preferences (or non-preferences) for non-internet sources are also evident when considering respondents' use of the automated trip planning feature (see Figure 60). As seen, very few (14 percent) of the respondents used this feature; this included 12 percent of the Monterey respondents and 15 percent of the Salinas respondents. In fact, 28 percent of riders who used the automated trip planning feature regularly use the MST website as their information source; whereas 45 percent of those used this feature reported they use the printed materials as their primary information source.

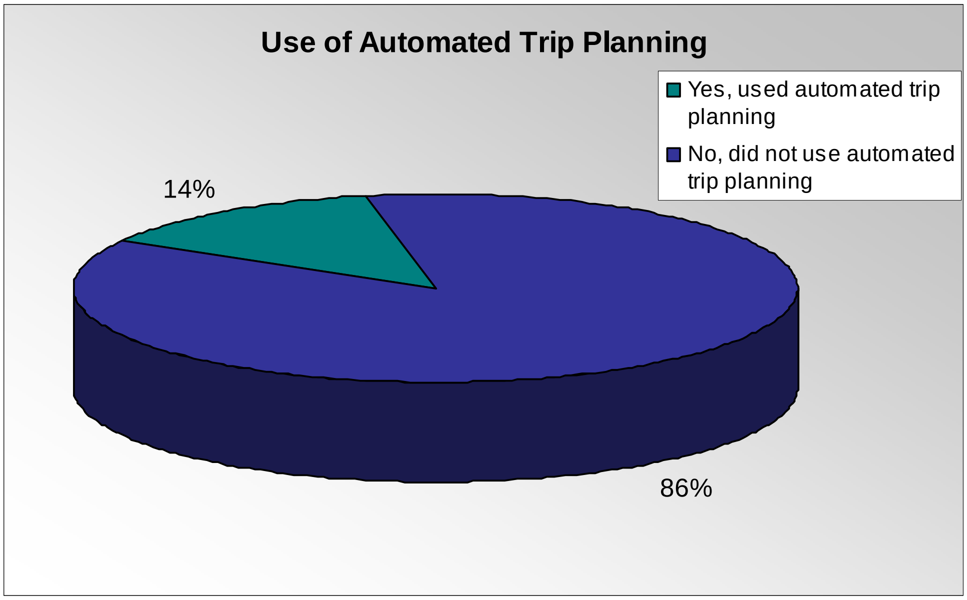

Figure 60. Respondents Use of the Automated Trip Planning Feature

3.8.3.2 Information Preferences

As shown in Figure 61, respondents at both locations overwhelmingly reported they would like to receive both arrival and departure times at the plaza/center. This finding is interesting since, at present, the Monterey Transit Plaza does not yet have the capability to present that information. However, at Salinas, where the electronic signs are in place, seven out of ten indicated they would like to see departure information in addition to the arrival information.

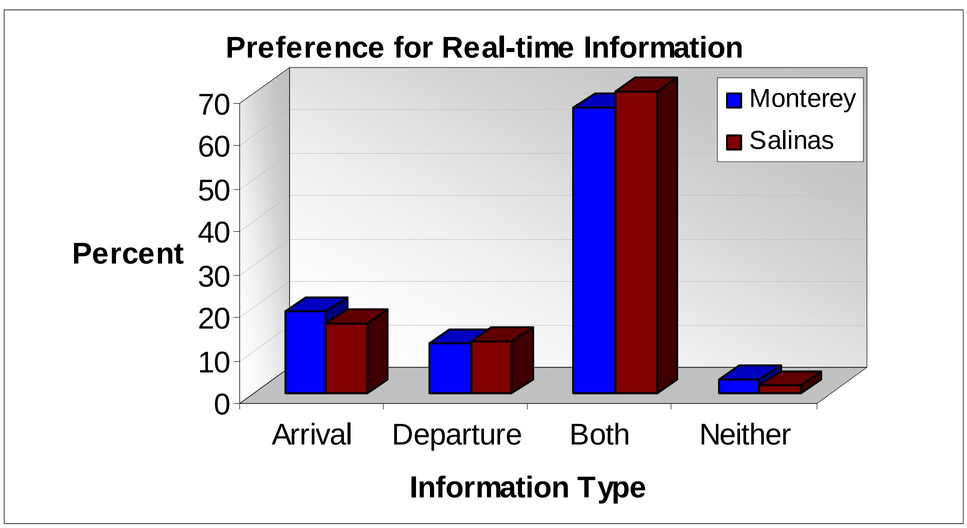

Figure 61. Preference for Arrival/Departure Information

Respondents from Salinas seemed to be very confident in the arrival times displayed on the electronic signs. As shown in Figure 62, approximately three-fourths of respondents reported they were "sure" or "very sure" of the arrival times. Less than 20 percent reported being "unsure" or "very unsure."

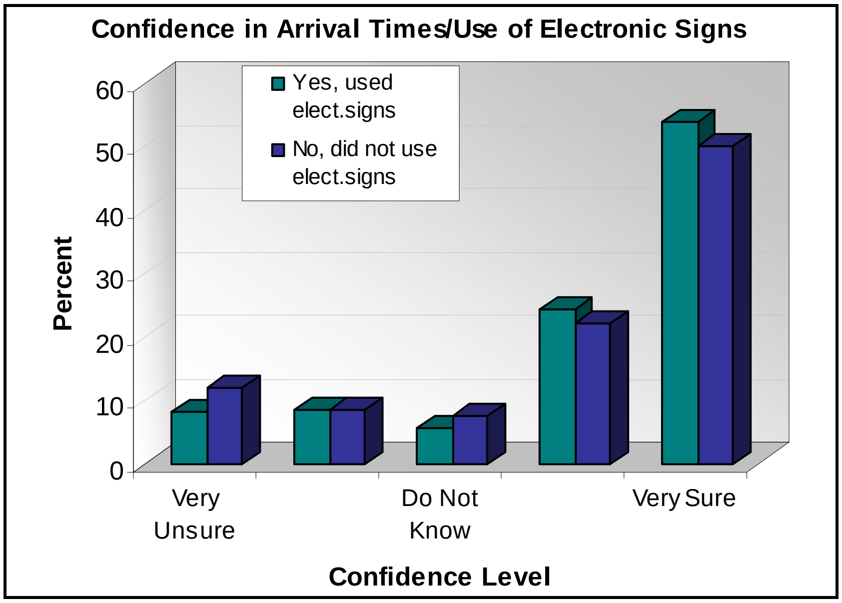

Figure 62. Confidence in Bus Arrival Times Using Electronic Signs (Salinas only)

As Figure 63 shows, use of the electronic signs is relatively stable by frequency of bus use. While it may have been expected that riders who rode the bus infrequently might use the signs more (based on their inexperience with the routes/schedules), it appears that almost two-thirds of riders use the signs across all levels of bus use. This is especially true for riders who use the bus 1 to 4 days per week and for those using the bus "for the first time."

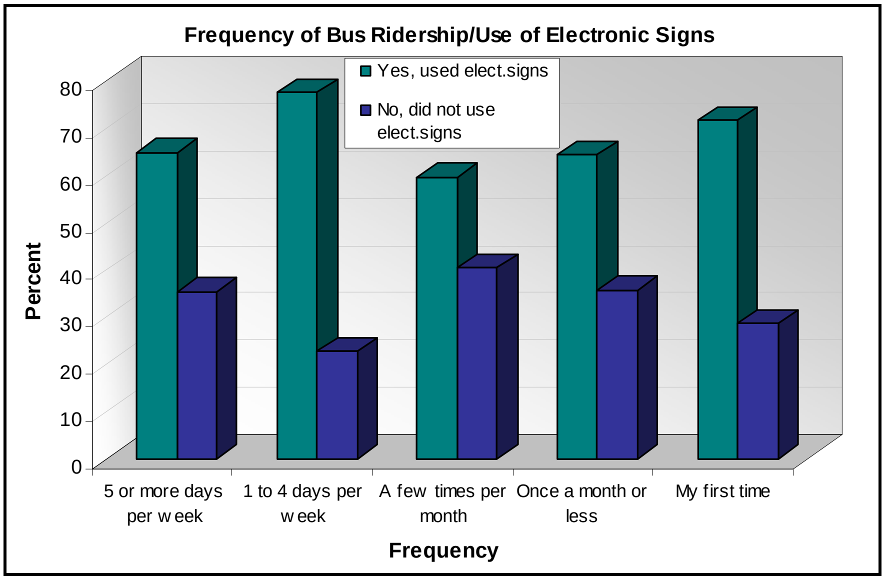

Figure 63. Use of Electronic Signs by Bus Use Frequency (Salinas only)

When considering riders' primary language, it appears that usage is very similar for riders who report speaking English or Spanish at home (see Figure 64). In fact, a slightly higher proportion of Spanish speaking riders use the electronic signs.

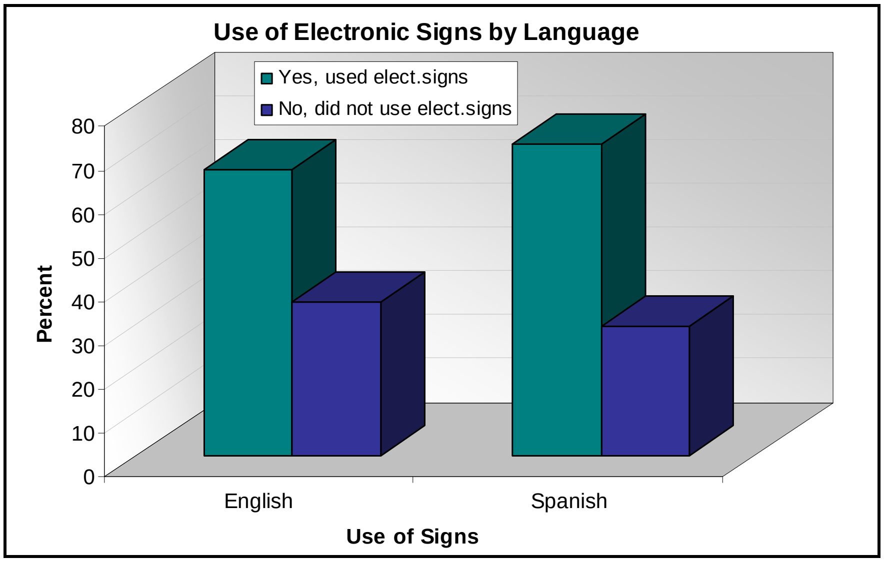

Figure 64. Use of Electronic Signs by Primary Language (Salinas only)

3.8.3.3 Confidence in Bus Arrival Times

When considering riders' ratings of the confidence they have in the arrival times, they responded very positively. As Figure 65 shows, almost 80 percent said they were "somewhat sure" or "very sure" of the arrival times. This level of confidence was consistent at both Monterey and Salinas, though the Salinas riders reported a slightly higher rating of "very sure." Analysis showed no difference in confidence by location (t = 0.67; p<.51).

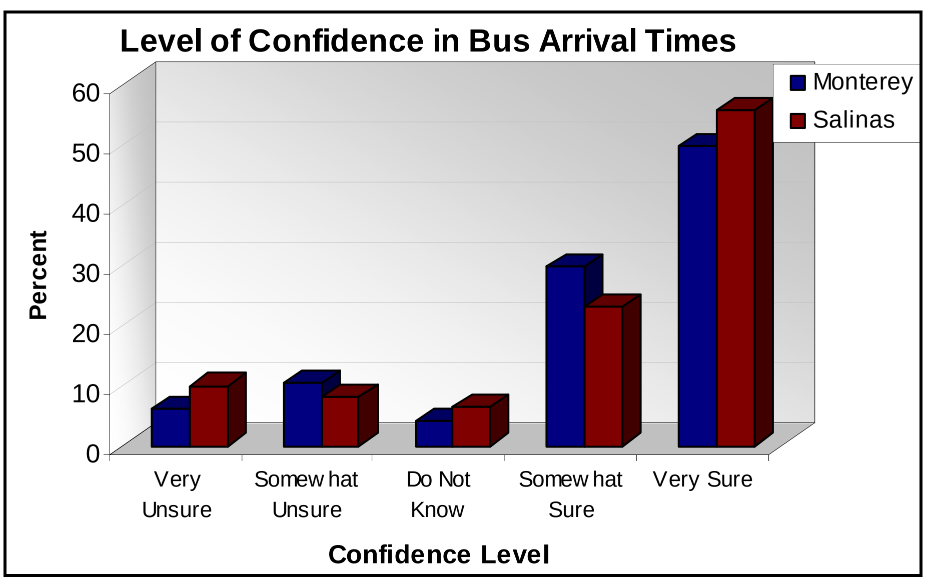

Figure 65. Confidence Level in Bus Arrival Times by Location

In addition, when examining riders' level of confidence, it appears that it is high regardless of how often they ride the bus and the reasons for riding the bus. Figure 66 shows riders' level of confidence based on their frequency of bus use. As shown, the level of confidence is consistent (and high; nearly 80 percent) whether they ride the bus "5 or more days per week" or "once a month or less." For first time riders, this proportion is somewhat less; approximately 75 percent reported they were "somewhat sure" and one-fourth reported being "very unsure." However, these riders represented less than two percent of the respondents.

Similarly, when examining the confidence in arrival times based on the reason for riding the bus (Figure 67), confidence also appears very high. Between 70 and 76 percent of riders report being "somewhat sure" or "very sure" of the arrival times. It does appear, however, that riders who commute to go to school, show slightly lower levels of confidence, with 15 percent reporting they were "somewhat unsure" of the arrival times.

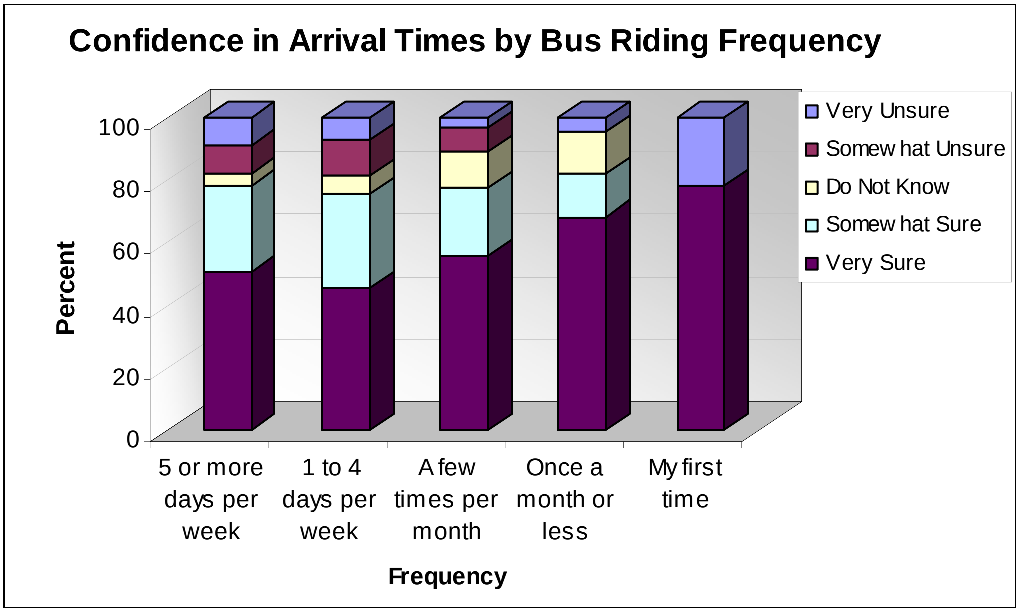

Figure 66. Confidence Level in Bus Arrival Times by Riding Frequency

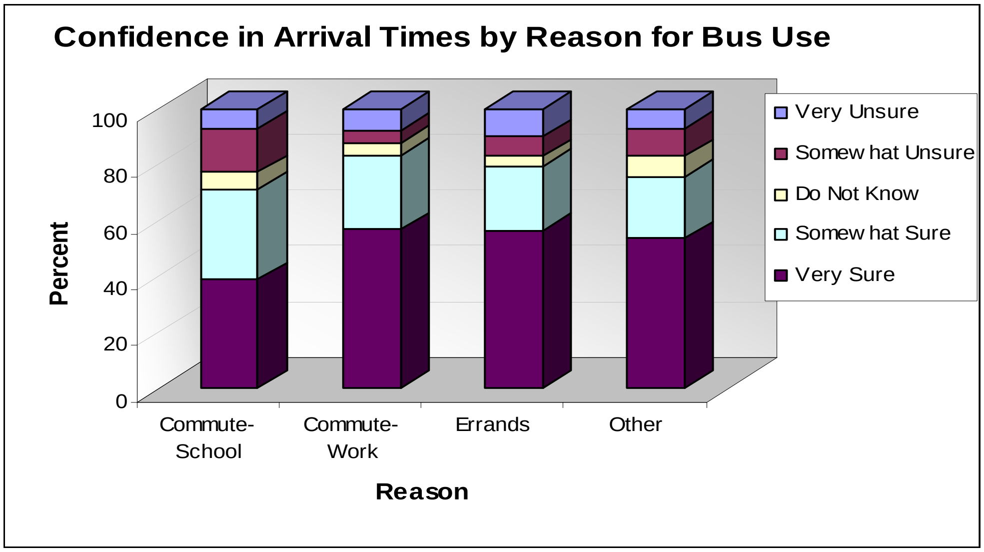

Figure 67. Confidence in Bus Arrival Times by Reason for Riding the Bus

Consistency of riders' confidence levels was also obtained when considering the sources of schedule information they used (Figure 68). As the figure illustrates, few riders were unsure of arrival times – the overwhelming majority reported they were "somewhat sure" or "very sure." Responses of "very sure" were consistently near or slightly above 40 percent those who reported "somewhat sure" also showed high degrees of consistency, though riders who used the MST Website reported slightly higher levels of being "somewhat sure."

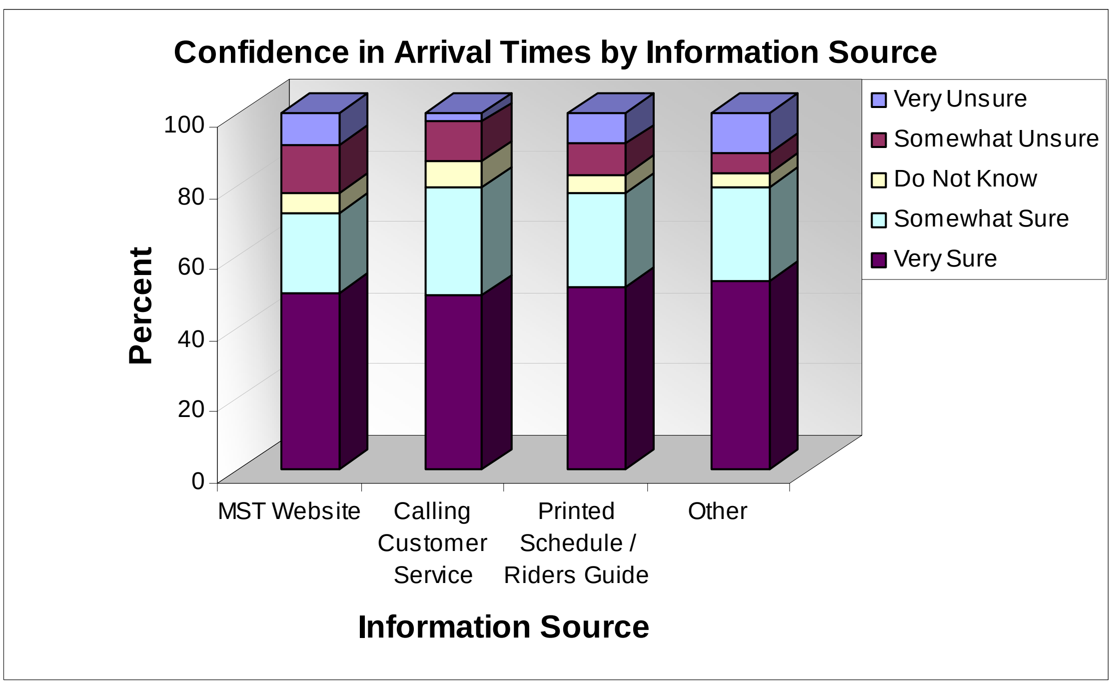

Figure 68. Confidence in Bus Arrival Times by Schedule Information Source

Finally, when considering only Salinas riders, comparisons of confidence level by use of the electronic signs showed essentially no difference, as depicted in Figure 69. The proportion of riders who reported being "somewhat sure" and "very sure" was essentially identical for those who used the electronic signs and those who did not. Further analysis showed the difference in confidence level was not significant (t = 1.12; p < .24).

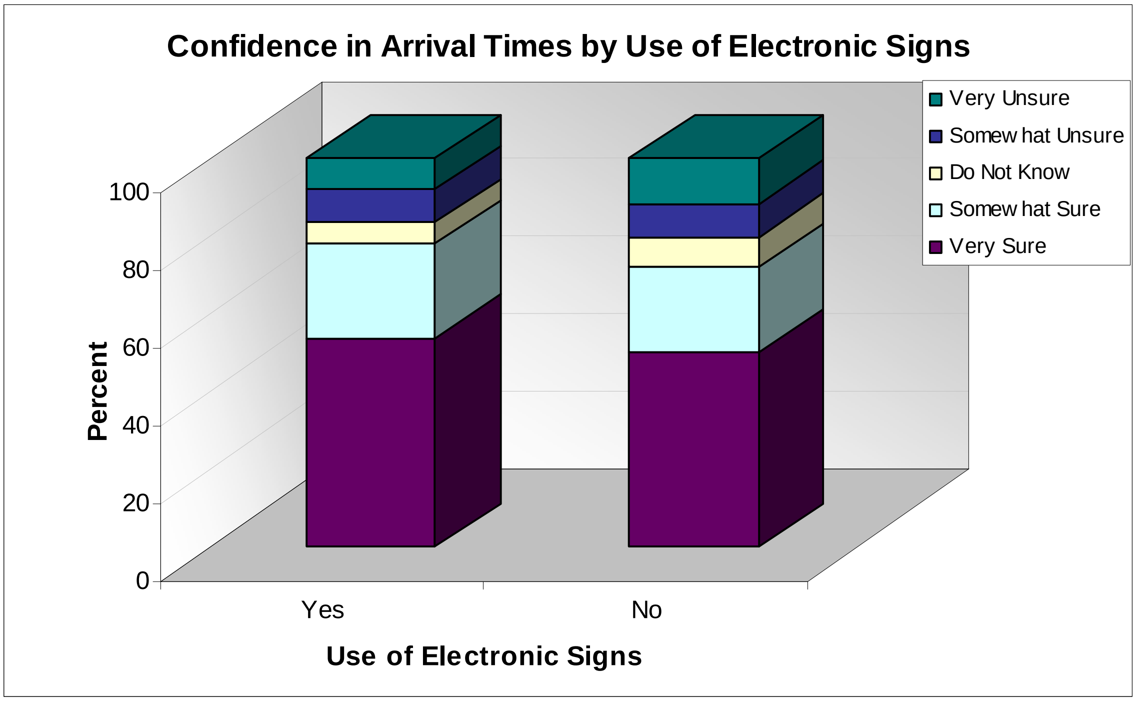

Figure 69. Confidence in Bus Arrival Times by Use of Electronic Signs (Salinas only)

3.8.3.4 Overall Satisfaction with MST

When considering riders' overall satisfaction with the MST, riders from both Monterey and Salinas report high levels of satisfaction across many attributes of the MST (see Figure 70). Approximately 70 percent of riders from both Monterey and Salinas report they are "satisfied" or "very satisfied" with the system's on-time performance, ease of making transfers, frequency of service, hours of service, and number of routes served. Furthermore, only between 10 and 13 percent report being "unsatisfied" or "very unsatisfied" with these aspects of the system.

When considering the most frequently traveled routes in Salinas (see Figure 71) riders' average ratings across all the aspects are very high, hovering near a value of 4.[13] Of the 11 routes examined, the ratings of 9 routes are either equal to or greater than 4.

[13] The scale used for this item included the following values: 1=Very Unsatisfied, 2=Unsatisfied, 3=Neutral, 4=Satisfied, and 5=Very Satisfied.

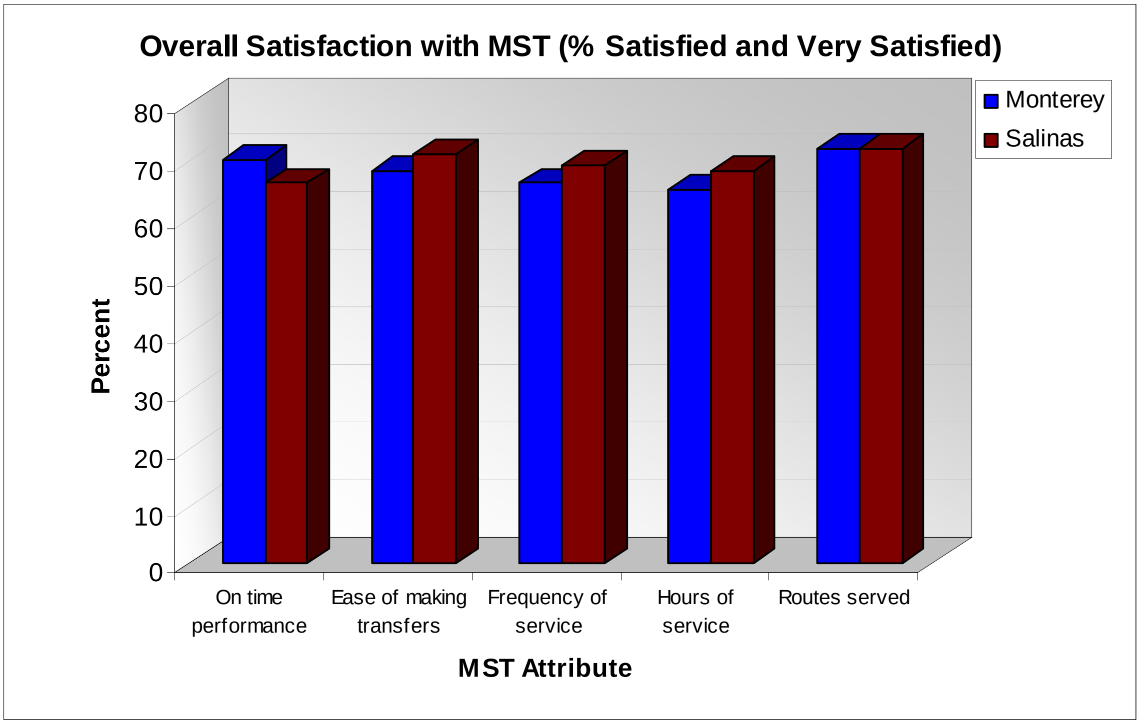

Figure 70. Overall Satisfaction with MST Attributes

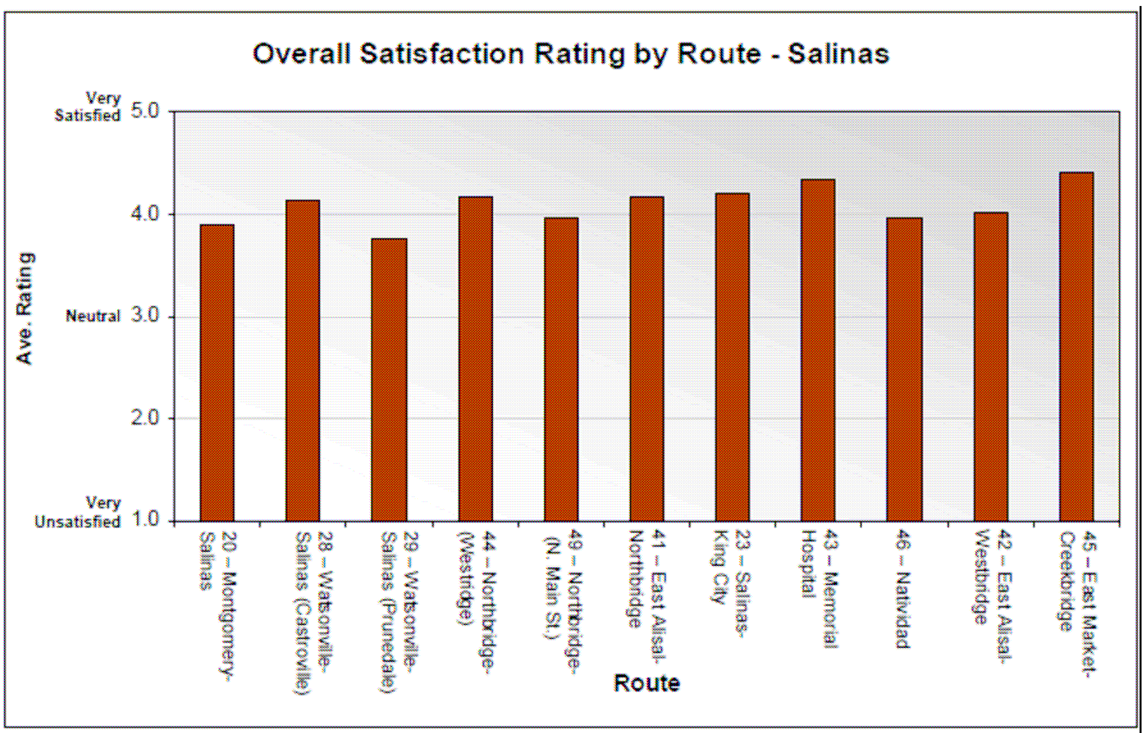

Figure 71. Overall MST Satisfaction Ratings by Route - Salinas

Similar findings were obtained for the most frequently ridden routes in Monterey (see Figure 72). All overall mean ratings were near 4 (using the same scale) and for the seven routes included, five were equal to or greater than 4.

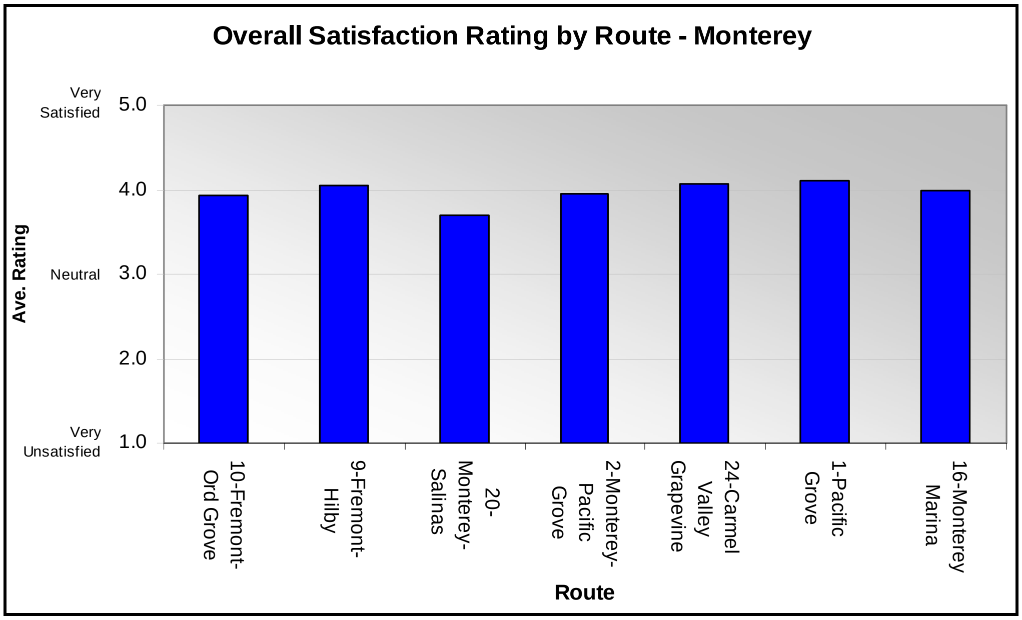

Figure 72. Overall MST Satisfaction Ratings by Route - Monterey

Similarly, as shown in Figure 73, when queried about various attributes of the automated stop announcement, riders reported high levels of agreement that the announcement was loud enough, helped them find their stops, and gave them enough time to get ready before the stop. These results were consistent across both locations and the levels of agreement were consistently in the 70 to 75 percent range.

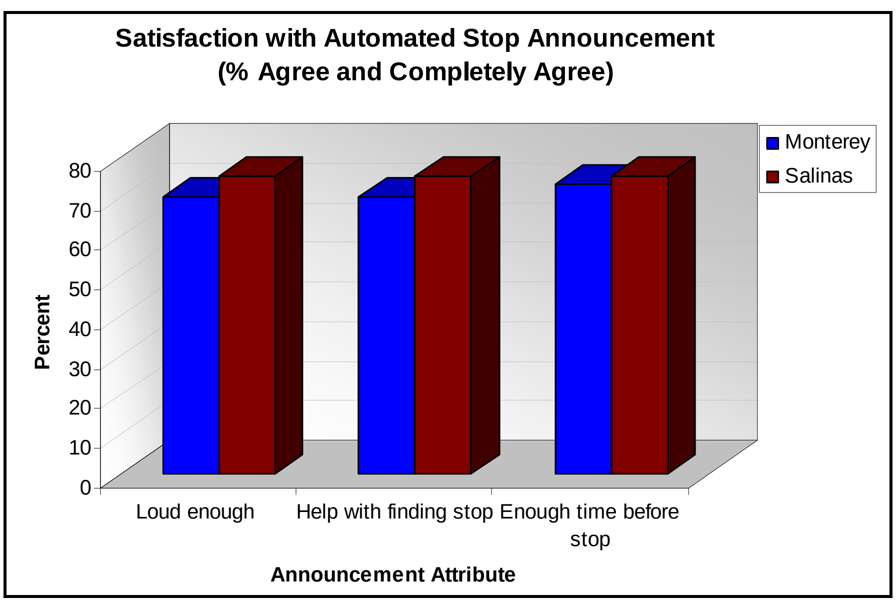

Figure 73. Riders' Agreement with Automated Stop Announcement Attributes

Finally, the Salinas riders were asked to rate the performance of the electronic signs. As shown in Figure 74, again, agreement with the attributes of the signs was high, with approximately three-fourths responding that they "somewhat agree" or "completely agree."

This rating was consistent for the signs' usefulness, accuracy, ease of understanding, and displaying the bus status information.

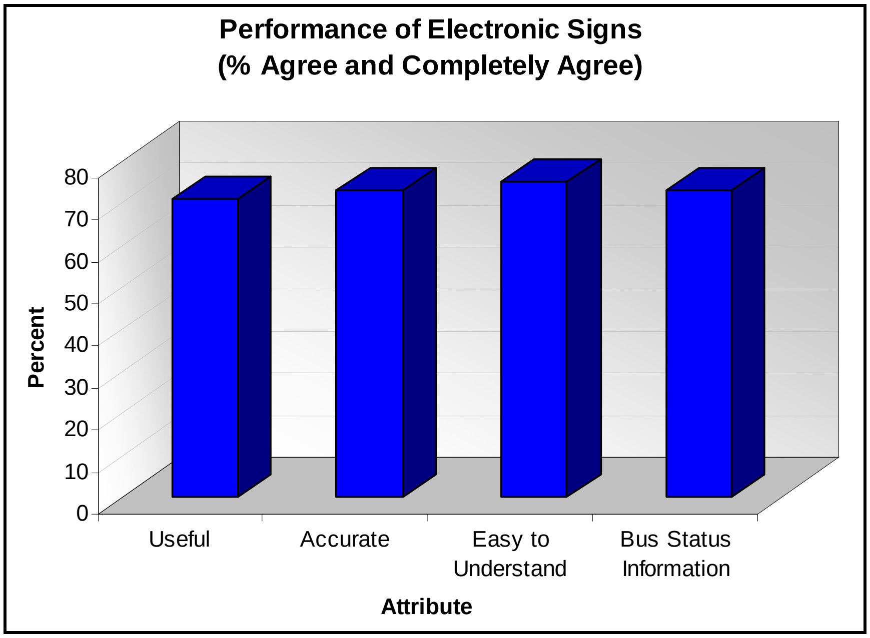

Figure 74. Riders' Agreement with Attributes of Electronic Signs (Salinas only)

3.8.3.5 Future Use of Technology

When asked if they would use real time bus information if offered, riders in Monterey and Salinas overwhelmingly said they would use the information, with almost two-thirds responding favorably (see Figure 75). This finding is consistent with riders' previous responses concerning their reported use of electronic signs in Salinas and the Monterey riders' indicating they would use electronic signs. That a majority of riders have confidence in the system information currently available might reflect that riders would like as much information as possible to plan their trips. However, reflecting their current use and reliance on paper schedules, slightly over one-third of riders indicated they would not use real time bus information if offered.

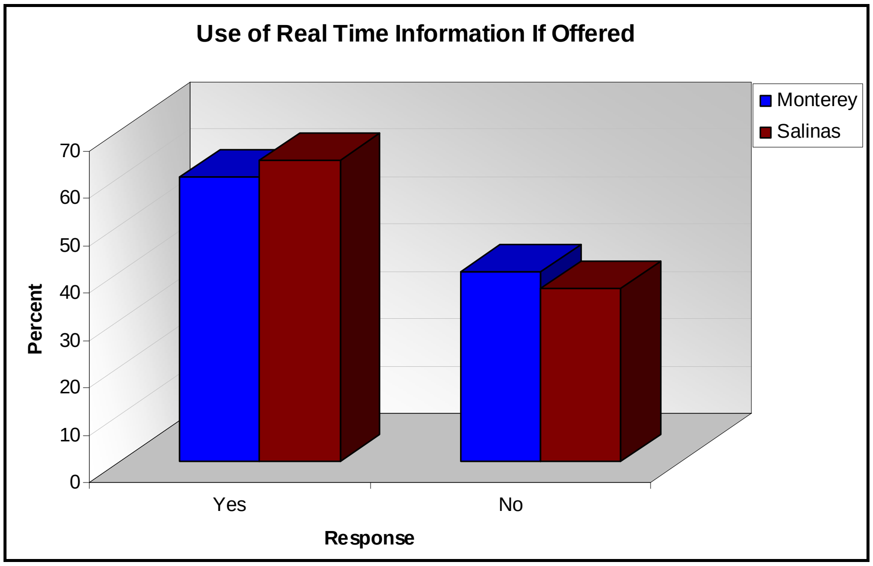

Figure 75. Use of Real Time Bus Information by Location

Finally, when queried how they would like to get transit information, by technology type (see Figure 76), most riders, especially in Monterey, indicated they would prefer electronic signs at the bus stops. Riders were asked to "check all that apply" for this item and as seen in the figure below, approximately one-fourth of Monterey riders and one-third of Salinas riders would use the internet on a mobile device and the internet in general. This is somewhat surprising due to the current low proportion of riders who currently use the internet for bus information. A slightly lower proportion also indicated they would use electronic signs within the information booths. Monterey riders were relatively consistent in their preferences for technologies besides electronic signs at bus stops, in fact indicating they would also use smart cards for fare payment. The proportion of Monterey riders willing to use this last technology was more than double the riders in Salinas. Perhaps these patterns are reflective of Salinas riders' experience with the electronic signs and their comfort (and possible reliance) on the information from the signs.

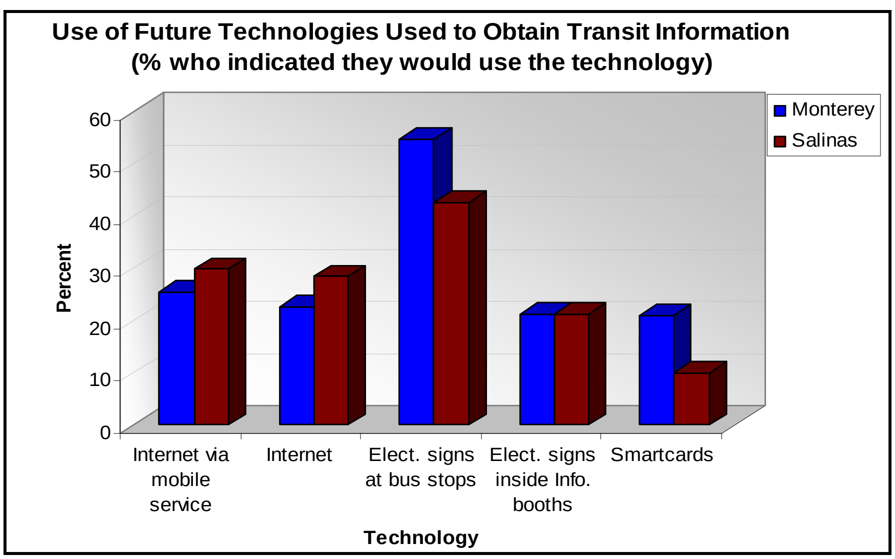

Figure 76. Use of Future Technologies to Access Transit Information/Services

3.8.4 Summary of Key Findings

The survey was conducted to gain insights into:

- Overall satisfaction with the MST bus service;
- On-time performance;
- On-board automated announcements [for bus stop information];
- Real-time traveler information in transit centers;
- Automated trip planning on Website;
- Bus schedule information sources; and
- Reported use of future technologies for schedule information.

Overall satisfaction with MST was highly rated by a majority of riders at both locations, with riders at both locations providing ratings that averaged a score of 4 out of a possible 5. On-time performance perceptions of MST service by riders at both locations overwhelmingly showed that they were "somewhat sure" or "very sure" of bus arrival times – this was true in Salinas where riders had access to information using the electronic signs as well as Monterey where the electronic signs were not available. This high level of satisfaction was also found for riders across all levels of bus use frequency, types of scheduling information used, and their reasons for using the bus.

When considering the characteristics of those riders who responded they were "very sure," the data suggest that riders at both locations were "satisfied" or "very satisfied" in terms of the system's on-time performance, frequency of service, hours of service, and routes served. They were, however, somewhat less satisfied with the ease of making transfers. When considering the Salinas riders who reported high levels of confidence in the arrival times, they tended to:

- Be male
- Have used the electronic signs;
- Ride the bus 5 or more days per week; and
- Less likely to have used the Printed Schedules.

Monterey riders who were "very sure" tended to:

- More frequently be in the 26-35 year old age group and
- More likely to use the MST website for information.

Findings for the automated stop announcement also showed that riders were also very positive in their views; 7 out of 10 (from both locations) reported they "agree" or "completely agree" that the announcements were loud enough, helped them find their stop, and gave them enough time to get ready before the stop.

The real-time information displayed on the electronic signs at Salinas was found to be useful, accurate, easy to understand, and kept riders informed about the status of their buses for almost three-fourths of Salinas riders using the electronic signs. In addition, when queried about the type of information they would like to see displayed, respondents at both locations overwhelmingly reported they would like to receive both arrival and departure times at the plaza/center.

Use of the automated trip planning feature on the MST Website was only reported by 14 percent of the respondents, perhaps due to the low proportion of respondents who used the MST website as a source for bus schedule information.

In fact, when reviewing the bus schedule information sources used, results showed that riders from both locations overwhelmingly reported using the Printed Schedule/Riders Guide over the other sources (over 60 percent). Monterey riders show slightly higher rates of MST website use, though even those with internet access rely on the printed information.

In terms of future technologies, two-thirds of respondents at both locations indicated they would use real-time information if it were offered. In addition, approximately one-fourth said they would use the internet via a mobile device or at home, a higher proportion than report using it now. Most respondents reported they would prefer to get information at electronic signs at the bus stops and another one-fourth would like to see information on electronic signs inside the information booths. Finally, few respondents (especially in Salinas) reported they would use Smartcards.

3.8.5 Conclusions

In general, a majority of riders reported they were satisfied with the overall bus service and on-time performance of MST. Riders were also very positive in their views of the automated stop announcement as 7 out of 10 (from both locations) reported they “agree” or “completely agree” that the announcements are loud enough, help them find their stop, and give them enough time to get ready before the stop. While use of the real-time information was reported by a vast majority of Salinas riders and was found to be useful, accurate, easy to understand, and kept riders informed about the status of their buses, there was a preference at both locations for both arrival and departure information to be displayed. Interestingly, while internet access at home was available for approximately half of the riders, the automated trip planning feature was found to be used by only fourteen percent of respondents and almost three-fourths indicated they used the Printed Schedule/Riders Guide as their source of schedule information. Interestingly, when queried about use of other technologies in the future, one-fourth said they would access the internet (either using a computer or a mobile device). Consequently, although a majority of riders appear to be satisfied with many aspects of the MST bus service, it appears that many of the riders are not yet making use of the benefits of (or have access to) the most recent MST technological advances such as real-time travel information and automated trip planning.

4 Implementation Experience

MST learned significant lessons from the implementation of the ACS, which has contributed to improving overall operations at the agency. MST had to be persistent with the vendor until the system became stable in 2005, almost 4 years after the start of implementation.

In general, process management during previous technology deployments was a challenge for MST. During the initial ACS implementation phase, MST had to interact with several different project managers from the vendor, which made process management challenging. Also, MST recognizes that this is an ongoing challenge for MST with current implementations and will be taken into account during any future deployments.

MST's experience with the implementation of various technologies is as follows:

- The HASTUS implementation was relatively straightforward and was completed within a year. The timekeeping (DDAM) module of HASTUS was added subsequent to the initial HASTUS deployment and has been live for 1 year (as of August 2008).

- The FAMIS implementation started in 2006 and is not completed yet. Several modules, such as grants tracking, have not been implemented so far. MST believes that FAMIS is not functioning as expected since certain business rules are not set up correctly in the system. Also, MST cannot access some of the information stored in FAMIS (e.g., tables in the database).

- The MMS has been operating for 3 years (as of August 2008). MST has not faced any major issues with implementing or operating this system. They encountered relatively minor issues with the hardware that is used in the FuelFocus component at the beginning of the implementation, but that has been resolved.

- The video surveillance system implementation was relatively straightforward, and its operation has been as expected for both on-board and facility systems. As stated in Section 0, security cameras were installed on buses and inside facilities in several phases.

- MST evaluated several alternatives for an automated trip planning system before selecting Google Transit. Google Transit went live in November 2008. The use of Google Transit was evaluated in Phase III by analyzing the results of the customer intercept survey.

5 Lessons Learned

5.1 Overall

MST learned several lessons regarding deployment process management, vendor management and the significance of adopting a flexible approach while overseeing numerous simultaneous project implementations over the last 7 years. Some of these lessons learned are summarized below.

5.1.1 Process Management

Agencies should "own" the project by having one (or more) project champions and should not solely rely on vendors to conduct the implementation successfully. Agencies should have commitment from management at the highest possible level (e.g., at General Manager level). For example, at MST, both the current General Manager/Chief Executive Officer and his predecessor were actively involved in the ITS Augmentation Project and provided full support and commitment to the deployment of each system within the Project.

Agencies also should appoint a Project Manager that can devote full time to the project.

5.1.2 Staffing

Agencies should be willing to increase the number of staff as needed. For example, MST needed an additional full-time staff member to monitor revenue service throughout the service day using the ACS system. Another example is that MST had to increase the number of shifts in its Communications Center in order to monitor the ACS system adequately.

MST believes that it is critical to recruit "right" staff members for the project implementation and later for operations and maintenance of each system. The recruited staff should have the right talent, interest and should be receptive to new ideas. MST has increased its staff since the technology implementation, but recognizes that it probably needs even more staff. For example, MST added an IT Director position, an IT hardware/software management position, and an ITS technician position. But the agency believes that it also needs a person for performing GIS analysis in the planning area.

MST recognizes that finding the right person to "get the job done" can be a challenge. On the vendor side, MST's experiences suggest that the vendor's project manager should understand the project thoroughly and have a competent project team to support him/her. For example, MST experienced many issues with the configuration of the ACS, and it took considerable time for the project team to figure out the best solution. These issues were the reason, in part, for the late implementation of the system.

5.1.3 Flexibility

Agencies should be flexible in their expectations regarding the benefits that they can achieve from a technology. MST recognizes that sometimes it is a challenge to meet the original expectations due to several issues (e.g., technical failures, operational restrictions, and issues with institutional agreements). Further, agencies should be open to negotiating with vendors to obtain something else in exchange of the technology or component that cannot be delivered (and was identified in the original project scope). For example, MST was able to get additional licenses and spare parts in exchange for the functions that were promised by the vendor and not delivered as part of ACS.

Agencies should maintain a good personal relationship with vendors while, at the same time, being persistent about their expectations. This “good customer” attitude often leads to success for both the vendor and the agency.

5.1.4 Innovation

MST’s experience is that innovative and perhaps unconventional systems can save a significant amount of money. For example, MST decided not to implement a traditional automated passenger counting (APC) system, since it was skeptical about the reliability of APC systems in the market. Also, the agency thought it was not cost-effective to install a fully-functional APC system, so it decided to implement an interface for the coach operator to enter the number of boardings at each stop. MST developed this approach internally and was able to use the money that they saved on another project. This innovative solution has provided MST with highly accurate passenger counts.

5.1.5 Implementation Management

MST thinks that an adequate amount of time should be allowed for implementing a technology and should not be rushed.

Further, agencies should ensure that they have the right tools to operate and maintain the system. For example, MST is not able to upload the current route structure into the GIS interface of the ACS system. As a result, the mapping function displays an old route layer, with the current route traces not matching the old route traces. The ACS vendor provided a map interchange program as part of the ACS, but it was never able to provide an accurate display with current route traces.

MST believes that ITS vendors should also analyze how the system would interact with other existing systems while implementing their technologies. This issue of interaction and integration with legacy systems can cause problems in the implementation process. The vendors and agency should also save mission-critical data before any software upgrade. At MST, the ACS vendor did a software upgrade in 2005, which resulted in a significant loss of data. MST was not able to restore that information.

Finally, agencies should be aware of the operations and maintenance (O&M) requirements for each system. This often gets overlooked when the focus of a project is on initial implementation. The recurring costs for operations and maintenance can be a significant financial burden on an agency.

5.1.6 Forward Thinking Approach

MST believes that agencies should be forward thinking. Once a system implementation is complete, they should start thinking about what could be done in the future. The exploration of new technologies should be critical to an agency’s strategic plan as technologies change rapidly and the current systems may become obsolete 5 years from the original implementation. For example, MST management will start exploring a new CAD/AVL system that is based on newer technologies. The ACS system has been deployed at MST for only 6 years, but it is based on much older technology.

The following sections describe lessons learned by specific departments based on their experience with deployed systems.

5.2 Planning and Operations

5.2.1 Data Utilization

MST believes that anecdotal information obtained from field supervisors and the operational data logged by the ACS system should be combined together to obtain a complete picture about an event or incident. Prior to the implementation of the ACS, the source of the majority of information was anecdotal. Now, data from the ACS system combined with information from field supervisors and coach operators can be used to make fact-based decisions.

Along with the database information, the ACS system generates control logs that provide information on the chronological sequence of operational events throughout each day. Even though the control log provides information about missed and cancelled trips, these events are not currently logged in the database under separate data columns. Currently, MST staff needs to search the control log using keyword searches (e.g., missed trip) to find the occurrence of these specific events.

5.2.2 Training

MST had some issues with the timing of the training of dispatchers on the ACS system. Training was conducted while the vendor was still trying to resolve problems with the system. Since the system was still in the state of flux, not only was the dispatchers' trust in the system lost, but additional training was needed once the problems were resolved. MST has learned that training should be conducted once the system is fully setup and working reliably.

Agency staff should be provided ample time to learn the system. MST believes that vendors should have direct users of the system more involved in the implementation process, and that agency staff should understand both the front-end (e.g., graphical user interface) and back-end (e.g., database) aspects of the system in order to have comprehensive knowledge of the system.

5.2.3 Implementation Management

Agencies should be patient during the implementation process since it often takes some time for systems to stabilize. MST had a number of "unknowns" at the beginning of the ACS installation. Most of its route surveys were incorrect and needed to be re-done. The survey errors resulted in a loss of data at the beginning of the implementation since the arrival zones were smaller than they should have been. MST adjusted timepoint boundaries (or arrival zones) before 2005 in part to fix the problem.

5.3 Maintenance

MST learned that it needs to make many more inquiries of vendors before contracting with them. In addition, after the implementation, MST learned that it has to be more pro-active and cannot just rely on vendors to maintain a stable operation. For example, one of the selling points of the ACS system for MST was the remote access capability for field supervisors. However, the vendor did not really have that module developed and operational yet. This lack of capability led MST to implement two shifts since there was only one workstation that could be used for monitoring by dispatchers; field supervisors did not have access.

MST has become more cautious while evaluating vendor products, but is willing to embrace a technology if it is satisfying a specific need. The agency thinks that it helped to do some research before buying specific systems, including conducting one or more site-visits to locations where the vendor's product(s) was operational.

5.4 Information Technology

5.4.1 Training

MST did not have any challenges with training per se, but found that getting people to use the system in the manner that it was intended was a big challenge. Further, as mentioned earlier, the timing of training was critical. For example, for the ACS, MST has a "train the trainer" program, but the system was not available for their use after the training. So they lost whatever they had learned during the training since they could not apply what they had learned on a regular basis.

5.4.2 Culture of Change

The "change culture" is very important for implementing technology in an organization. Many staff members are very familiar with the way an older system works, and may not be amenable to accepting new systems. For example, since MST personnel are used to earlier maintenance and financial management systems, it is challenging for them to work with the user interfaces of new systems.

However, the deployment of other ITS systems such as ACS, HASTUS, and DDAM were accepted well in the organization. The primary reason for this was that their implementation resulted in a decrease in the volume of manual effort required by MST employees to perform their functions.

5.4.3 Standardization

MST believes that database and technology platforms should be standardized across agency systems. Hence, they are building other systems around the ACS. The standard platform for all technologies is Microsoft Windows, and SQL Server is used for all databases except for MMS, which uses an Oracle database.

5.5 Safety and Security

5.5.1 Procurement Process

MST believes that agency staff should visit other sites that have already installed systems similar to those that they are considering for deployment. If on-site visits are not possible, agencies can participate in the American Public Transportation Association (APTA) EXPO, in which many of the technology vendors display and can demonstrate their technology. In this forum, agencies can speak with vendor representatives directly and possibly get a "feel" for the systems that they are considering.

Agencies should ensure that they specify the functional requirements and the number of units of hardware and software according to their specific needs. Also, they should be persistent with the vendor to ensure that the system they are purchasing is what was specified. This means that a rigorous implementation management approach should be used (e.g., conducting design reviews, overseeing vendor installations, conducting testing according to the specifications, etc.). The vendor alone should not be relied upon to ensure a successful implementation.

If at all possible, agencies should order system components when they identify a need. Initially, MST did not deploy exterior cameras that would have provided specific views for security monitoring. The agency believes that the lack of these specific cameras cost MST $3 million; if they had had video from those specific views, a costly lawsuit may have been dismissed.

MST's experience with exterior cameras suggests that such footage is especially beneficial in the event of accidents or incidents.

5.5.2 Technology Upgrade

MST recognizes the importance of keeping its systems up to date as much as possible. MST had to upgrade its DVRs twice when the old DVR technologies became obsolete. Also, MST's experience suggests that agencies should ensure the consistency of various system platforms (e.g., DOS or Windows).

6 Conclusions

The evaluation of the ITS deployment at MST has resulted in the identification of key factors about MST's experience related to the procurement, implementation, management, and utilization of ITS technologies. Also, the evaluation identified the impacts of the technology on various departments at MST. Further, the customer satisfaction survey conducted in Phase III of the evaluation helped measure the customer perception of the impacts of the technology deployment at MST.

The following paragraphs provide a summary of the evaluation findings with respect to both key and secondary hypotheses. The results of testing the hypotheses revealed that they were either supported or inconclusive. For example, a few of these hypotheses (e.g., related to the improvement of on-time performance, and increase in ridership) were not supported by the data. The contribution of related technologies was not obvious due to involvement of external factors (e.g., service change, and operational improvements). Further, given that it takes considerable time for technologies, such as those deployed at MST, to stabilize, to become integral to agency operations and management, and to be accepted by staff, all hypotheses were re-examined in Phase III. However, as discussed below, in many cases, the conclusions were not markedly different from those that were determined in Phase II. Also, some hypotheses did not require retesting in Phase III since quantitative or anecdotal evidence obtained in Phase II had already provided sound conclusions.

The key hypotheses for this evaluation are as follows:

- Hypothesis: The project will result in a reduction in operations and planning costs and improved service planning. In Phase II, the Evaluation Team found increases in annual revenue and annual revenue per passenger-mile from the time of the technology implementation. However, it was not obvious that the improvements have been due to technology. Also, quantitative estimates of the benefits to MST departments were not available for most technologies. MST did provide some basic estimates of savings from technologies, such as from the deployment of the scheduling software and fuel management systems highlighted in Section 3.7.5 of this report.

  Also, as part of the staff interviews conducted in Phase II, MST provided anecdotal evidence of the benefits perceived to result from ITS implementations (as of August 2008), which provides the basis for the assertion that technology contributed to service planning and operations improvements. MST reported improvements in service planning due to the accuracy and reliability of the archived ACS data used in recent comprehensive operational analysis (COA) studies. Also, MST has been able to reduce the cost of data collection by reducing the manual effort required by COA studies (e.g., recruitment of temporary staff). Among other benefits, MST uses archived data from the ACS for analysis with the help of other tools such as ArcView, Microsoft Excel, and Microsoft Access for planning needs (e.g., using passenger count data for determining stop and shelter needs and identifying appropriate shelter locations).

  This hypothesis was not revisited in Phase III since anecdotal evidence obtained in Phase II led to the conclusion that new technologies played a significant role in improving MST service. MST staff considers these improvements to be a result of changes made in the service based on recommendations resulting from ACS data analyses.

- Hypothesis: The project will result in improved on-time performance of MST operation. The intent of this hypothesis was to determine if there were improvements in schedule adherence due to the availability of real-time vehicle information for dispatchers and supervisors. Also, the Team wanted to evaluate the impact of MST's ability to adjust schedules by utilizing the archived ACS data. However, ***this hypothesis could not be supported with the results obtained from the quantitative data analysis***. The results were inconclusive in Phase II because MST had made several changes in planning and operations during the time period selected for analysis. Therefore, this hypothesis was re-examined in Phase III of the evaluation.

  In Phase III, the Team analyzed a larger amount of AVL data (daily schedule adherence data from March 2005 through June 2009) but, similar to Phase II, the analysis results did not suggest any consistent trends for schedule adherence (e.g., consistent improvement after AVL deployment). It should be noted that, in most cases, vehicles were found to be on-time per MST standards (less than 5 minutes late). Also, the variability across the evaluation timeframe was well within 2 minutes. However, as concluded in Phase II, it cannot be confirmed that the use of the ACS system alone had an impact on MST's on-time performance. Various changes in the system implemented by MST during the evaluation timeframe (see Figure 9 for a series of changes) could have contributed to the trends as well.

  Even though the hypothesis cannot be supported with the results from the quantitative analysis, MST staff input obtained during Phase II interviews provided an understanding of the positive impacts of ACS. MST staff believes (see their detailed input in Section 3.1.2.2.3) that on-time performance has improved since the technology implementation and technology have contributed directly or indirectly to this improvement (e.g., by providing data for COA analysis and subsequent service restructuring).

- Hypothesis: The project will result in an increase in the reliability of services. In Phase II, we concluded that the reliability of MST service should be measured by performing a qualitative assessment of customers' perception of on-time performance. Based on the customer survey, it can be concluded that at least 70 percent of the riders who were surveyed in Monterey and Salinas are "satisfied" or "very satisfied" with the on-time performance of MST service. Also, a similar percentage of riders are "satisfied" or "very satisfied" with the ease of making transfers. These statistics indicate that a significant number of MST riders find MST service reliable.

- Hypothesis: The project will enhance system productivity. This hypothesis is supported by several statistics that serve as indicators of productivity improvements (e.g., revenue per passenger-miles and passenger-miles). These statistics were calculated in Phase II of the evaluation. However, these statistics are inconclusive since it is not clear from the productivity indicator data whether the improvements are due to technology implementation or other changes in the organization.

  This hypothesis was revisited by examining productivity data for fiscal years 2008 and 2009. A trend indicating some improvement in productivity was based on several of the statistics (e.g., revenue and revenue-hours), but in most cases, the statistics (e.g., boarding/revenue-hour) showed inconsistencies when compared to the trends observed in Phase II. These inconsistencies were mostly due to a decrease in MST ridership in fiscal years 2008 and 2009. Thus, the results of the quantitative data analyses were inconclusive.

However, as reported in Phase II, based on staff interviews, MST staff believes that the technology has assisted in increasing MST's productivity by allowing the agency to carry more passengers during the same service hours with improved scheduling. MST also pointed out during staff interviews that a productivity increase may not be an absolute indicator of service improvements since a decrease in productivity sometimes benefits the organization by helping it provide on-time service. For example, reducing the number of passengers on overcrowded buses can reduce dwell times at stops, and subsequently improve the schedule adherence of those buses.

- Hypothesis: The project will result in an improvement in maintenance scheduling and planning. This hypothesis is supported by the information provided by the maintenance department during on-site interviews conducted as part of Phase II of the evaluation. MST staff believes that the MMS has enabled the agency to track daily maintenance activities such as inventory control, maintenance-workflow management, and fuel management. Other systems such as the ACS and the video surveillance system assist MST by enabling staff to review on-board system performance logs and to monitor the quality of maintenance work (through reviews of recorded videos), respectively.

  As reported in Phase II, the Team also wanted to evaluate the capabilities and impact of the remote diagnostics system implemented as part of the ACS. However, MST discontinued the remote diagnostics feature after initial use since the diagnostics were completely unreliable. MST was receiving an overwhelming number of false alarm messages which led them to ignore the remote diagnostics.

  We did not revisit this hypothesis in Phase III since anecdotal evidence obtained from Phase II interviews were sufficient to conclude that there are positive impacts of the deployment of MMS and ACS on managing maintenance activities at MST.

The secondary hypotheses for this evaluation include the following:

- Hypothesis: The project will result in improved customer satisfaction: Customer intercept surveys were conducted at the Monterey Transit Plaza and Salinas Transit Center locations in mid-September 2009. The overall satisfaction with MST was found to be very high with riders at both locations — they provided ratings that averaged a score of 4 out of a possible 5. Also, this overall average was reflected in riders' perceptions of MST's on-time performance, the ease of making transfers, the frequency of service, the hours of service, and the number of routes served. In fact, almost three-fourths of the survey respondents said that they were "satisfied" or "very satisfied" with each of the system attributes discussed above.

  Further, riders were very positive in their views of the AVA system, with 7 out of 10 (from both locations) reporting that they "agree" or "completely agree" that the announcements are loud enough, help them find their stop, and give them enough time to get ready before the stop. Salinas riders were positive in their views of the electronic signs. Again, almost three-fourths of surveyed riders reported that they "agreed" or "completely agreed" that the signs were useful, accurate, easy to understand, and conveyed the correct bus status information.

  However, although a majority of riders appear to be satisfied with many aspects of the MST bus service, it appears that many of the riders are not yet making use of the benefits of (or have access to) the most recent MST technological advances such as real-time travel information and automated trip planning.

Thus, it can be concluded, based on the results of the intercept surveys, that the technology implementation has resulted in improved customer satisfaction.

- Hypothesis: The project will result in an increase in ridership. The data provided by MST shows an increasing trend in ridership since 2003. However, this information does not support the hypothesis as it is not clear if the ridership increases have been due to just technology implementations.

  This hypothesis was revisited during Phase III by analyzing customer satisfaction obtained from intercept surveys. As discussed above, a large number of MST riders are satisfied with the service.

- Hypothesis: The project will result in an improvement in driver and passenger security. The Evaluation Team obtained several anecdotal references that support this hypothesis through MST staff interviews conducted in Phase II. The general perception at MST is that security systems have helped them create a safer environment for MST riders and coach operators. MST has posted placards on-board vehicles that inform riders that they are under video surveillance.

  The local police consider MST buses as "mobile surveillance units." MST's ability to provide video evidence of criminal activities that involve MST buses with the help of on-board cameras has helped them improve their relationship with the local police.

  The on-board security cameras assist MST in primarily capturing evidence of any criminal activity. Additionally, these cameras have continually assisted MST in reducing the number of insurance claims submitted by passengers (e.g., related to slip and falls). Also, the video evidence assists MST in protecting its drivers from being victims of false customer complaints.

  Since the Phase II results discussed above provided evidence regarding the impact of surveillance systems on driver and passenger security, this hypothesis was not revisited in Phase III.

- Hypothesis: The project will result in a reduction in the travel times of specific routes where TSP is deployed. This hypothesis was not tested in Phase III since MST has not yet implemented TSP.

- Hypothesis: The project will help reduce response time for incidents and emergency management. The hypothesis can be supported by information provided by operations and maintenance staff from interviews conducted during Phase II. However, the Team did not receive any quantitative estimates of improvements in response time.

  It was reported in Phase II that the availability of the ACS assists MST staff to track vehicle locations in real-time and enables them to send a supervisor to the accident site immediately. Also, MST drivers can select a specific text message from the list of pre-loaded messages on mobile data terminals (MDTs) and send it to the dispatcher to notify operations that there has been an incident; in this way, the driver can avoid making a voice call, if necessary. Text messaging capability has helped MST reduce the voice radio traffic by 60 percent. Also, starting fall 2008, MST supervisor will be able to connect remotely to the ACS to obtain any additional information that is needed while responding to an incident.

The ACS enables MST to provide and monitor evacuation services in the event of natural disasters, such as the wildfires that struck during summer 2008. During the recent wildfire event in Big Sur, MST was able to develop and manage task forces using MST vehicles through the use of the ACS.

Also, the number of incidents has been reduced in recent years, subsequently contributing to reduced insurance premiums.

Since anecdotal and quantitative evidence obtained in Phase II provided sufficient information to conclude that there are improvements in incident response time, this hypothesis was not re-examined in Phase III.

- Hypothesis: The project will result in a reduction in vehicle hours. The intent of this hypothesis was to test whether the technology has assisted MST in reducing the number of revenue hours since 2003. Since annual revenue-hour statistics do not show a consistent increasing or decreasing trend, this hypothesis could not be supported. The number of revenue-hours decreased between 2003 and 2005, but an increasing trend can be seen since 2005. This inconsistency could be due to operational changes (e.g., addition of more trips to a route) implemented by MST throughout the evaluation timeframe.

  This hypothesis was not re-examined in Phase III since the trend of revenue vehicle-hours alone does not provide a reasonable indication of the impacts of technology on overall MST operations. Trends in revenue vehicle-hours need to be examined in conjunction with the number of passengers carried by those vehicles.

  A reduction in deadhead-miles or deadhead-hours may be a reasonable indicator of improvements in transit operations, but the Evaluation Team did not have access to the data required to measure the non-revenue miles or hours experienced by MST vehicles.

- Hypothesis: The project will reduce the number of customer complaints. This hypothesis was not tested completely in Phase II since MST did not have a record of the number of customer complaints for the “before” and “after” cases. However, it was indicated by MST during the Phase II interviews that the reduction in the number of complaints should not be an absolute indicator of improved customer service. MST staff has noticed that the number of complaints have increased since MST developed an efficient process to track and respond to a customer complaint. It is evident that customers like to provide more comments and feedback only when they are assured of receiving a response.

  This hypothesis was not revisited in Phase III since no additional data could be obtained to make additional conclusions.

- Hypothesis: The project will result in improved facility security. This hypothesis is supported by the facts and anecdotal references obtained during on-site interviews as part of Phase II of the evaluation. The physical facilities are equipped with cameras and the closed circuit television (CCTV) technology that enables the real-time video monitoring of facilities by the safety and security group. MST staff believes that the video monitoring capability has assisted the agency in reducing vandalism activities and creating a more secure environment for MST riders waiting at transit centers.

  Also, MST has implemented controlled access to its facilities. The access is restricted to MST staff with a valid proximity card-based identification. This implementation is assisting MST in securing its physical facilities (headquarters and the transit centers) by restricting entrance to only authorized employees.

- Hypothesis: The project will establish a comprehensive reporting system. This hypothesis cannot be supported with the available information as the reporting process could not be evaluated "before" and "after" the technology.

  However, MST staff believes that current reporting needs to be improved. The standard reports provided by various deployed systems (e.g., ACS, MMS, FAMIS) do not necessarily provide the information needed by MST employees. MST had hired an outside consultant to conduct a needs assessment for reporting. However, it was reported by MST during the Phase III onsite visit that the project could not be completed. Thus, this hypothesis is not supported with currently available information.

- Hypothesis: The project will result in reduced cases of false financial claims. Through the staff interviews conducted in Phase II, MST provided several anecdotal references (see Section 3.3.2.2) that serve as evidence of financial savings due to the implementation and use of technologies, primarily the video surveillance system. The video playback component of the ACS also assists MST in responding to customer complaints related to late arrivals or departures.

  The on-board cameras have helped MST save money on various false complaints and accidental damage claims from passengers. MST reported that it recovered $70,000 during fiscal year 2007. However, before the installation of the video surveillance system, cost recovery was only in the order of $800- $1800. Also, MST had to pay $3 million in settlements due to lack of sufficient evidence, which could have been mitigated with the help of an additional exterior camera on the bus.

Since the findings from Phase II were sufficient to support this hypothesis, it was not re-examined in Phase III.

Figure 77 highlights the overall benefits found during this evaluation. Even though the Evaluation Team was not able to derive conclusions regarding the direct impact of technology for specific expected changes (e.g., increased ridership, improved on-time performance), anecdotal information obtained from MST staff has provided significant evidence to show that, so far, the technology has made significant improvements in operations and planning. Also, survey findings reveal a high satisfaction among MST riders which can be partially attributed to changes in the system based on recent studies (which used ACS data for analyses), or new customer-centric technology implementations (e.g., AVA or real-time information signs). Generally, technologies have played a significant role in improving the efficiency of all departments as reported by the MST management. Improved efficiency has helped MST achieve cost savings as well. It is expected that even more benefits will be realized as these technologies are increasingly relied upon to perform specific operational and management functions.

Summary of Overall Benefits

Improved decision-making based on facts/information available from ACS and other systems

Organizational Improvements:

- Availability of archived ACS data for analysis by service planning department
- Improved scheduling with scheduling and operations software
- Video evidence of boardings and alightings helped defend operational changes (e.g., discontinuation of a route)
- ACS and other technologies helped identify routes that are not cost-effective

Current benefits have generated management support for future technology deployments (e.g., MST Board of Directors adopted technology as a priority).

Return on Investment:

- $1 million/year savings from scheduling and operations software by incorporating meal and rest breaks (per new contract rules) and improved pay-to-platform ratio
- Efficient resource usage - purchased only 15 buses as replacement for 17 buses
- Improved inventory control and warranty tracking from MMS using CCTV monitoring
- Reduction in false insurance claims with video evidence$15,000/year savings from new payroll system

Figure 77. Summary of Overall Benefits

The ITS technologies implemented have primarily assisted MST operations by enabling real-time vehicle tracking and quick response to incidents and emergency situations. Also, HASTUS and the ACS, along with other tools, have helped MST improve its planning, which has subsequently helped the agency to run better operations (e.g., improved on-time performance resulting from route changes and schedule adjustments). The impact of the video surveillance system is also significant because it has created a safer rider environment and has enabled MST to defend itself against lawsuit claims and to reduce insurance-related costs. The maintenance department has experienced benefits through the MMS as it assists MST in improving the workflow process and quality control.

Figure 78 highlights the overall lessons learned identified during this evaluation. The technology implementations provided an opportunity for MST to learn several lessons that will help the agency in future procurements. As MST plans to replace some of its systems (e.g., the ACS) with upgraded and better technologies, agency officials believe that the prior deployment experience gives it enough confidence to procure from and negotiate with vendors and manage the implementation of new technologies.

Summary of Lessons Learned

- Need good process management during procurement and implementation
- Should be willing to increase staff
- Should be flexible in embracing benefits of technology
- Should consider timely technology upgrade
- Should factor both ITS data and anecdotal information in decision-making
- Need good training plan for successful technology implementation
- Need “culture of change” for successful technology implementation
- Need technology standardization across agency

Figure 78. Summary of Lessons Learned

Appendix A: Hypotheses

Table 5. Key Hypotheses

Hypothesis Number	Hypothesis	MOE	Data Source	Proposed Analysis Method
1	The project will result in a reduction in operations and planning costs and improved service planning.	• Time needed to complete COA studies • Cost of COA studies • Changes to routes/services as a result of COA studies • Changes in costs to operate modified routes/services	MST staff interviews	Before and after analysis of characteristics of comprehensive operational analysis (COA) studies.
2	The project will result in improved on-time performance of MST operation	Early/late statistics	MST archived data	Before and after analysis of schedule adherence data
3	The project will result in an increase in the reliability of services	• On-time performance of whole fixed route system • On time performance by route • On-time performance by trip • On-time performance by operator • On-time performance during peak hour operation • On-time performance during off-peak hour operation	MST archived data	Analyze change in on-time performance due to the ITS Augmentation project

Hypothesis Number	Hypothesis	MOE	Data Source	Proposed Analysis Method
4	The project will enhance system productivity	• Number of passengers • Platform hours* • Transit vehicle miles • Boardings/hour • Passenger miles per employee or revenue dollar • Cost of operation and maintenance • Cost per passenger mile • System revenue	MST archived data	Before and after analysis of data
5	The project will result in an improvement in maintenance scheduling and planning	• Staff perceptions of the use of remote diagnostics • Number of false remote diagnostic messages • Number of total remote diagnostic messages	MST archived data regarding remote diagnostics MST staff interviews	Qualitative assessment regarding the use of remote diagnostics
* Platform hours refer to the time spent by a transit vehicle (in this case a bus) in service between vehicle pull-in and pull-out.				

Table 6. Secondary Hypotheses

Hypothesis Number	Hypothesis	MOE	Data Need	Proposed Analysis Method
6	The project will result in improved customer satisfaction	Customer perception of the following technology elements has to be measured: • On-board automated announcements • Real-time traveler information in transit centers • Automated trip planning on website • Translink fare payment system • Changes in travel times due to changes in routes and service frequencies (headways) • Changes in wait times at stops • Change in time spent talking to customer service	Customer satisfaction survey data Surveys completed for COA studies	Qualitative analysis of customer survey data
7	The project will result in an increase in ridership	• Ridership per route • Overall system ridership • Ridership by stop • Peak ridership • Off-peak ridership	MST archived data	Before and after analysis of ridership
8	The project will result in an improvement in driver/ passenger security	• Number of on-board incidents • Number of on-board incidents where perpetrator identified • Number of transit center incidents • Number of transit center incidents where perpetrator identified	MST archived data from digital cameras MST staff interviews	Before and after analysis of the data. Qualitative analysis needed

Hypothesis Number	Hypothesis	MOE	Data Need	Proposed Analysis Method
9	The project will result in a reduction in the travel times of specific routes where TSP is deployed	• Travel time per route • Change in average vehicle speeds	MST staff Interviews MST archived data	Before and after TSP deployment analysis of travel times and vehicle speeds
10	The project will help reduce response time for incidents and emergency management	• Change in response time for incidents	Staff interviews	Before and after analysis of MST incident data
11	The project will result in a reduction in vehicle hours	• Non-revenue vehicle hours • Non-revenue vehicle miles • Revenue vehicle hours • Revenue vehicle miles	MST archived data	Before and after analysis of vehicle hours and miles
12	The project will reduce the number of customer complaints	• Change in number of complaints	MST archived data	Before and after analysis of complaint data
13	The project will result in improved facility security	• Number of registered cases of theft • Number of registered cases of theft with trespassers identified	MST archived data from digital cameras MST staff interviews	Before and after analysis of the data; Qualitative analysis needed
14	The project will establish a comprehensive reporting system.	• Change in time taken in generating daily, monthly and periodic operational reports • Change in time taken in generating annual NTD reports	MST staff interviews	Analysis of staff interviews; Before and after analysis of data

Hypothesis Number	Hypothesis	MOE	Data Need	Proposed Analysis Method
		• Number and types of reports generated		
15	The project will result in reduced cases of false financial claims	• Financial claim statistics	MST staff interviews	Analysis of financial claims before and after the surveillance system deployment

Appendix B: Missing Data by Schedule Period

The legend for Table 7 and Table 8 is as follows:

(pink)	more than 80% data missing	(amber)	41%- 60% data missing
(orange)	61% -80% data missing	(light yellow)	21%- 40% data missing

A lot of cells are empty in Table 7 since several routes were not operational in the Phase III evaluation timeframe. Also, cells that contain values and are not highlighted in any color represent schedule periods in which less than 20% of the data was missing.

Table 7. Missing Data by Schedule Period from 2005 to 2006, for All MST Bus Routes

Bus Route	Nov 25 2004- Apr 28 2005	Apr 29 2005- May 27 2005	May 28 2005- Jul 07 2005	Jul 30 2005- Aug 18 2005	Aug 19 2005- Oct 28 2005	Oct 29 2005- Nov 23 2005	Nov 24 2005- Jan 27 2006	Jan 28 2006- May 26 2006	May 27 2006- Sep 29 2006	Sep 30 2006- Nov 22 2006	Nov 23 2006- Nov 23 2006	Nov 24 2006- Dec 01 2006	Dec 02 2006- Dec 24 2006	Dec 25 2006- Dec 25 2006	Dec 26 2006- Dec 31 2006
1	3%	1%	7%	5%	9%	13%	10%	6%	7%	4%	0%	4%	1%	0%	4%
2	8%	4%	5%	15%	18%	21%	17%	20%	9%	8%		4%	6%		8%
4	4%	5%	7%	5%	23%	9%	5%	5%	7%	4%		11%	4%		3%
5	6%	8%	12%	9%	23%	11%	7%	7%	9%	5%	5%	13%	5%	35%	3%
9	3%	3%	1%	2%	10%	6%	7%	2%	6%	2%	23%	5%	2%	0%	2%
10	4%	3%	1%	2%	10%	6%	8%	2%	7%	2%	27%	5%	2%	0%	1%
11								11%	17%	18%	25%	22%	14%	0%	4%
12		7%	5%	12%	16%	23%	16%								
16	42%	30%	22%	21%	27%	32%	29%	40%	58%	58%		57%	57%		56%
17	42%	48%	44%	43%	46%	47%	45%	68%	69%	69%		70%	69%		69%
20	9%	6%	8%	10%	17%	10%	10%	17%	19%	17%	18%	16%	16%	15%	14%
21	53%	38%	34%	41%	48%	52%	42%	25%	29%	60%		49%	41%		40%
22			40%	81%	95%				49%						
23	17%	25%	27%	72%	73%	76%	76%	82%	49%	64%		68%	67%		68%
24	16%	14%	27%	61%	59%	82%	59%	15%	61%	56%		58%	55%		49%
25	59%	63%	75%												
26	77%	77%	71%												
27	9%	7%	7%	52%	50%	70%	62%	41%	25%	17%		17%	17%		13%
28	19%	17%	18%	22%	41%	29%	21%	37%	24%	21%		21%	17%		18%
29	10%	9%	9%	29%	48%	49%	43%	32%	8%	6%		6%	3%		2%
37		0%			30%										
38		29%			25%										
39		38%			25%										
41	10%	4%	6%	9%	15%	12%	9%	15%	19%	20%	4%	13%	10%	5%	15%
42	6%	2%	3%	5%	13%	9%	7%	10%	12%	16%		7%	8%		16%
43	21%	19%	20%	4%	31%	35%	21%	60%	61%	5%		5%	4%		0%
44	15%	13%	15%	13%	41%	25%	21%	86%	80%	80%		82%	16%		30%
45	1%	1%	2%	8%	19%	12%	5%	7%	10%	11%		10%	16%		15%
46	20%	19%	22%	19%	44%	25%	20%	30%	35%	28%		37%	41%		68%
48								37%	9%	5%		4%	5%		6%
49						14%	12%	79%	75%	76%		75%	19%		35%
50	4%	96%	5%	6%	84%		45%		28%						
51			100%	35%	79%										
53	24%	15%	18%	46%	16%	14%	15%	25%	31%	25%		19%	23%		22%
54								52%	21%	11%		1%	19%		15%
55										90%	41%	39%	38%	41%	51%

Table 8. Missing Data by Schedule Period from 2007 to 2009, for All MST Bus Routes

Bus Route	Jan 01 2007-Jan 01 2007	Jan 02 2007-Jan 26 2007	Jan 27 2007-May 25 2007	May 26 2007-Jun 29 2007	Jun 30 2007-Aug 31 2007	Sep 01 2007-Oct 04 2007	Oct 05 2007-Nov 22 2007	Nov 23 2007-Jan 25 2008	Jan 26 2008-May 23 2008	May 24 2008-Jul 04 2008	Jul 05 2008-Aug 29 2008	Aug 30 2008-May 22 2009	May 23 2009-Jul 03 2009
1	1%	4%	10%	4%	6%	8%	10%	20%	22%	9%	11%	19%	20%
2		9%	22%	7%	7%	9%	8%	9%	10%	9%	10%	26%	22%
4		4%	54%	44%	46%	40%	43%	55%	30%	32%	31%	32%	35%
5	11%	2%	41%	10%	13%	48%	43%	41%	15%	7%	8%	5%	5%
6			16%	18%	8%	8%	3%	11%	4%	2%	4%	3%	0%
7					17%	38%	37%	33%	42%	46%	48%	51%	44%
9	0%	6%	3%	15%	7%	3%	2%	1%	0%	1%	2%	6%	9%
10	2%	6%	3%	12%	5%	3%	3%	1%	0%	1%	2%	2%	1%
11	0%	11%	24%	23%	23%	29%	29%	25%	8%	5%	6%	3%	2%
12												58%	98%
16		60%	39%	40%	37%	43%	28%	12%	15%	21%	23%	19%	11%
17		72%											
20	15%	31%	28%	28%	7%	6%	2%	1%	1%	1%	4%	7%	1%
21		46%	27%	31%	48%	46%	42%	41%	38%	34%	35%	32%	27%
22			36%	20%	10%	4%	14%	18%	25%	27%	31%	34%	22%
23		68%	68%	64%	63%	67%	66%	67%	22%	12%	14%	16%	8%
24		44%	48%	35%	33%	24%	24%	32%	36%	31%	21%	23%	23%
27		30%	38%	35%	35%	31%	10%	3%	7%	4%	12%	8%	5%
28		21%	19%	18%	34%	31%	21%	18%	27%	17%	7%	6%	6%
29		5%	3%	2%	7%	8%	4%	3%	7%	7%	2%	2%	1%
41	4%	13%	9%	20%	6%	6%	6%	5%	7%	5%	9%	7%	5%
42		9%	5%	17%	2%	2%	2%	1%	3%	1%	3%	21%	1%
43		3%	3%	3%	5%	2%	4%	2%	1%	1%	2%	4%	2%
44		30%	30%	39%	40%	29%	19%	16%	15%	29%	29%	30%	15%
45		23%	20%	22%	18%	23%	26%	26%	22%	25%	4%	3%	2%
46		39%	37%	4%	18%	21%	23%	20%	18%	19%	2%	3%	1%
48		8%	4%	1%	3%	3%	1%	11%	9%	3%	6%	4%	1%
49		36%	31%	30%	16%	32%	7%	3%	4%	5%	4%	6%	4%
50				4%	4%					7%	3%		3%
51												55%	
53		23%	25%	22%	20%	59%	43%	28%					
54		16%											
55	31%	38%	35%	26%	23%	19%	13%	26%	27%	14%	24%	38%	43%
56						55%	53%	47%	50%	41%	43%	69%	74%

Appendix C: Data Analysis Results

Average Earliness by Route and Day of Week

Table 9 . Average Earliness in Minutes per Early Trip for the Inbound Direction on Weekdays

Schedule Period (End Date)	Route 1	Route 9	Route 10	Route 41	Route 42
4/28/2005	-1.65	-1.80	-1.64	-2.67	-2.55
5/27/2005	-1.69	-1.82	-1.39	-2.65	-2.59
7/7/2005	-1.91	-1.82	-1.50	-2.60	-2.60
8/18/2005	-1.75	-1.87	-1.53	-2.80	-2.60
10/28/2005	-1.75	-1.70	-1.44	-2.66	-2.57
11/23/2005	-1.88	-1.68	-1.45	-2.77	-2.66
1/27/2006	-2.10	-2.02	-1.74	-3.08	-2.97
5/26/2006	-1.91	-1.94	-1.59	-1.89	-2.05
9/29/2006	-1.96	-1.98	-1.66	-1.92	-1.91
11/22/2006	-1.88	-1.88	-1.78	-1.91	-1.81
12/1/2006	-1.70	-2.02	-1.84	-2.17	-2.18
12/24/2006	-1.80	-2.05	-1.92	-2.06	-2.07
1/26/2007	-1.80	-2.11	-1.74	-2.10	-2.21
5/25/2007	-2.51	-1.70	-1.50	-1.87	-2.00
6/29/2007	-2.40	-2.21	-1.95	-1.71	-1.72
8/31/2007	-2.42	-1.81	-1.60	-2.67	-2.64
10/4/2007	-2.38	-1.58	-1.50	-2.66	-2.54
11/22/2007	-2.51	-1.66	-1.52	-2.69	-2.65
1/25/2008	-2.54	-1.86	-1.58	-2.88	-2.99
5/23/2008	-2.40	-1.64	-1.39	-2.88	-2.82
7/4/2008	-2.37	-1.80	-1.61	-2.61	-2.78
8/29/2008	-2.30	-1.59	-1.49	-2.68	-2.66
5/22/2009	-2.36	-1.54	-1.46	-1.15	-1.73
7/3/2009	-2.27	-1.58	-1.57	-2.21	-2.10

Table 10: Average Earliness in Minutes per Early Trip for the Outbound Direction on Weekdays

Schedule Period (End Date)	Route 1	Route 9	Route 10	Route 41	Route 42
4/28/2005	-1.31	-2.14	-1.31	-2.46	-2.20
5/27/2005	-1.39	-2.32	-1.08	-2.21	-2.17
7/7/2005	-1.37	-2.40	-1.21	-2.11	-2.14
8/18/2005	-1.30	-2.21	-1.12	-2.21	-2.15
10/28/2005	-1.32	-2.25	-1.18	-2.02	-2.19
11/23/2005	-1.47	-2.28	-1.07	-2.04	-2.25
1/27/2006	-1.49	-2.49	-1.23	-2.19	-2.38
5/26/2006	-1.41	-2.33	-1.24	-2.04	-2.25
9/29/2006	-1.36	-2.25	-1.30	-1.90	-2.17
11/22/2006	-1.46	-2.19	-1.10	-1.86	-2.23
12/1/2006	-1.43	-2.42	-1.19	-1.94	-2.25
12/24/2006	-1.45	-2.34	-1.10	-2.19	-2.41
1/26/2007	-1.37	-2.62	-1.11	-2.21	-2.38
5/25/2007	-1.34	-2.37	-1.28	-2.08	-2.27
6/29/2007	-1.13	-2.81	-1.46	-2.13	-2.45
8/31/2007	-1.01	-2.56	-1.36	-1.92	-2.28
10/4/2007	-0.93	-2.30	-1.23	-1.94	-2.24
11/22/2007	-1.13	-2.21	-1.23	-1.98	-2.17
1/25/2008	-1.19	-2.43	-1.21	-2.13	-2.36
5/23/2008	-1.05	-2.34	-1.15	-2.06	-2.19
7/4/2008	-1.08	-2.48	-1.24	-1.93	-1.96
8/29/2008	-0.99	-2.41	-1.23	-1.94	-1.87
5/22/2009	-1.11	-2.68	-1.85	-2.37	-2.77
7/3/2009	-1.28	-2.39	-1.23	-2.36	-2.78

Table 11: Average Earliness in Minutes per Early Trip for the Inbound Direction on Sundays

Schedule Period (End Date)	Route 1	Route 9	Route 10	Route 41	Route 42
4/28/2005	-1.68	-2.17	-2.11	-2.09	
5/27/2005	-1.28	-2.28	-2.02	-1.72	
7/7/2005	-1.58	-2.05	-1.91	-1.98	
8/18/2005	-1.51	-2.54	-1.98	-1.47	
10/28/2005	-1.55	-1.93	-1.86	-1.96	
11/23/2005	-1.54	-2.25	-1.59	-2.20	-3.48
1/27/2006	-1.85	-2.25	-1.76	-2.69	-4.36
5/26/2006	-1.68	-1.99	-1.67	-2.04	-4.35
9/29/2006	-1.66	-1.90	-1.64	-1.78	-3.19
11/22/2006	-2.14	-2.01	-1.68	-1.63	-3.16
12/1/2006	-2.15	-2.13	-1.95	-2.25	-4.43
12/24/2006	-1.86	-2.13	-1.71	-2.09	-3.64
1/26/2007	-1.67	-1.94	-1.95	-1.99	-4.49
5/25/2007	-2.60	-3.73	-3.22	-1.73	-3.49
6/29/2007	-2.54	-3.74	-3.70	-1.30	-1.89
8/31/2007	-2.30	-3.64	-3.27	-1.88	-2.74
10/4/2007	-2.56	-3.92	-3.42	-1.77	-2.64
11/22/2007	-2.67	-4.71	-3.69	-2.18	-3.27
1/25/2008	-2.46	-4.32	-3.43	-2.38	-3.90
5/23/2008	-2.46	-3.89	-3.23	-2.59	-3.58
7/4/2008	-2.48	-3.87	-3.47	-2.14	-2.86
8/29/2008	-2.64	-3.41	-2.97	-1.90	-3.33
5/22/2009	-2.58	-4.48	-3.35	-1.64	-3.52
7/3/2009	-2.73	-4.66	-3.08	-1.61	-3.08

Table 12: Average Earliness in Minutes per Early Trip for the Outbound Direction on Sundays

Schedule Period (End Date)	Route 1	Route 9	Route 10	Route 41	Route 42
4/28/2005	-1.27	-2.10	-2.08	-1.81	
5/27/2005	-1.28	-2.76	-1.26	-1.41	
7/7/2005	-1.27	-2.94	-1.46	-1.66	
8/18/2005	-1.15	-3.33	-1.56	-1.64	
10/28/2005	-1.16	-2.62	-1.58	-1.63	
11/23/2005	-1.16	-2.28	-1.39	-1.56	-3.59
1/27/2006	-1.05	-2.58	-1.74	-1.96	-4.10
5/26/2006	-1.26	-2.70	-1.53	-1.81	-3.60
9/29/2006	-1.39	-2.57	-1.25	-1.66	-3.26
11/22/2006	-1.37	-2.49	-1.43	-1.68	-3.07
12/1/2006	-1.05	-2.35	-1.54	-1.73	-3.13
12/24/2006	-1.38	-2.33	-1.55	-1.87	-3.95
1/26/2007	-1.25	-2.86	-1.38	-1.91	-3.67
5/25/2007	-1.51	-3.37	-1.75	-1.84	-3.42
6/29/2007	-0.88	-3.76	-1.86	-1.76	-3.59
8/31/2007	-1.07	-3.68	-1.60	-1.57	-2.75
10/4/2007	-0.89	-4.08	-1.79	-1.57	-3.00
11/22/2007	-1.17	-3.46	-1.71	-1.48	-2.71
1/25/2008	-1.23	-3.51	-1.78	-1.82	-3.40
5/23/2008	-1.12	-3.63	-1.73	-1.77	-3.57
7/4/2008	-1.04	-4.11	-1.79	-1.37	-1.89
8/29/2008	-1.04	-3.78	-1.69	-1.37	-1.95
5/22/2009	-1.17	-3.82	-1.99	-2.20	-2.54
7/3/2009	-1.07	-3.39	-1.71	-1.64	-3.03

Average Earliness by Route and Time-of-Day

Table 13: Average Earliness in Minutes per Early Trip for the Inbound Direction during Weekday Peak Period

Schedule Period (End Date)	Route 1	Route 9	Route 10	Route 41	Route 42
4/28/2005	-1.72	-1.99	-1.70	-3.06	-2.90
5/27/2005	-1.75	-2.04	-1.38	-2.80	-2.90
7/7/2005	-1.79	-2.07	-1.51	-2.85	-2.89
8/18/2005	-1.77	-1.96	-1.62	-2.84	-2.86
10/28/2005	-1.71	-1.99	-1.48	-2.67	-2.88
11/23/2005	-1.73	-1.95	-1.41	-2.83	-2.99
1/27/2006	-1.88	-2.33	-1.66	-3.18	-3.47
5/26/2006	-1.87	-2.22	-1.62	-2.27	-2.65
9/29/2006	-1.90	-2.20	-1.72	-2.15	-2.36
11/22/2006	-1.88	-1.95	-1.73	-2.12	-2.26
12/1/2006	-1.79	-2.28	-1.98	-2.52	-2.88
12/24/2006	-1.92	-2.20	-1.87	-2.39	-2.82
1/26/2007	-1.87	-2.31	-1.70	-2.47	-2.78
5/25/2007	-2.13	-2.45	-1.86	-2.26	-2.63
6/29/2007	-2.05	-2.66	-2.25	-2.06	-2.32
8/31/2007	-1.98	-2.33	-1.97	-2.66	-2.95
10/4/2007	-1.89	-2.15	-1.84	-2.63	-2.87
11/22/2007	-2.08	-2.31	-1.89	-2.58	-3.00
1/25/2008	-2.11	-2.51	-1.94	-2.86	-3.35
5/23/2008	-2.02	-2.24	-1.83	-2.83	-3.09
7/4/2008	-2.00	-2.46	-2.13	-2.68	-2.91
8/29/2008	-1.94	-2.29	-1.94	-2.71	-2.76
5/22/2009	-1.92	-2.57	-2.08	-1.95	-2.50
7/3/2009	-1.98	-2.54	-1.88	-2.49	-2.71

Table 14: Average Earliness in Minutes per Early Trip for the Outbound Direction during Weekday Peak Period

Schedule Period (End Date)	Route 1	Route 9	Route 10	Route 41	Route 42
4/28/2005	-1.66	-2.13	-1.78	-2.99	-2.79
5/27/2005	-1.69	-2.30	-1.39	-2.75	-2.78
7/7/2005	-1.62	-2.45	-1.50	-2.75	-2.78
8/18/2005	-1.69	-2.12	-1.51	-2.69	-2.57
10/28/2005	-1.64	-2.21	-1.49	-2.55	-2.75
11/23/2005	-1.69	-2.26	-1.49	-2.68	-2.85
1/27/2006	-1.71	-2.44	-1.56	-2.96	-3.23
5/26/2006	-1.78	-2.39	-1.61	-2.27	-2.67
9/29/2006	-1.75	-2.33	-1.69	-2.14	-2.42
11/22/2006	-1.81	-2.17	-1.63	-2.10	-2.37
12/1/2006	-1.79	-2.52	-1.77	-2.38	-2.74
12/24/2006	-1.85	-2.42	-1.69	-2.41	-2.96
1/26/2007	-1.79	-2.62	-1.65	-2.50	-2.84
5/25/2007	-1.81	-2.76	-1.89	-2.27	-2.70
6/29/2007	-1.69	-3.06	-2.22	-2.17	-2.38
8/31/2007	-1.55	-2.85	-2.03	-2.52	-2.81
10/4/2007	-1.49	-2.72	-1.81	-2.51	-2.76
11/22/2007	-1.71	-2.67	-1.86	-2.50	-2.86
1/25/2008	-1.75	-2.79	-1.84	-2.70	-3.10
5/23/2008	-1.65	-2.66	-1.82	-2.69	-2.92
7/4/2008	-1.63	-2.81	-1.98	-2.55	-2.74
8/29/2008	-1.54	-2.77	-1.82	-2.55	-2.67
5/22/2009	-1.55	-3.03	-2.11	-2.23	-2.86
7/3/2009	-1.67	-3.05	-1.81	-2.59	-2.83

Average Lateness by Route and Day of Week

Table 15: Average Lateness in Minutes per Late Trip for the Inbound Direction on Weekdays

Schedule Period (End Date)	Route 1	Route 9	Route 10	Route 41	Route 42
4/28/2005	2.11	2.33	2.12	2.44	2.66
5/27/2005	2.07	2.42	2.14	2.37	2.67
7/7/2005	2.27	2.40	2.09	2.34	2.59
8/18/2005	2.08	2.58	2.23	2.36	2.67
10/28/2005	1.87	2.50	2.02	2.39	2.63
11/23/2005	2.22	2.50	2.19	2.07	2.55
1/27/2006	1.81	2.37	1.80	1.85	2.03
5/26/2006	1.96	2.30	1.94	3.86	3.79
9/29/2006	2.16	2.56	2.13	3.92	3.91
11/22/2006	1.87	2.71	2.09	3.81	3.83
12/1/2006	2.04	2.55	1.98	3.85	3.67
12/24/2006	1.88	2.62	2.07	3.61	3.61
1/26/2007	1.96	2.48	2.02	3.39	3.49
5/25/2007	2.24	2.46	1.92	3.56	3.64
6/29/2007	2.37	2.05	1.82	3.19	3.72
8/31/2007	2.46	2.38	1.95	2.17	2.29
10/4/2007	2.02	2.70	2.20	2.32	2.47
11/22/2007	1.89	2.45	2.16	2.25	2.27
1/25/2008	1.81	2.30	1.91	1.93	2.11
5/23/2008	2.18	2.33	1.94	2.06	2.34
7/4/2008	2.20	2.44	2.07	2.40	2.57
8/29/2008	2.43	2.64	2.35	2.41	2.69
5/22/2009	2.53	2.36	1.92	3.68	4.36
7/3/2009	2.32	2.26	1.66	2.57	2.21

Table 16: Average Lateness in Minutes per Late Trip for the Outbound Direction on Weekdays

Schedule Period (End Date)	Route 1	Route 9	Route 10	Route 41	Route 42
4/28/2005	1.77	2.56	2.54	2.62	2.53
5/27/2005	1.78	2.35	2.78	2.61	2.60
7/7/2005	1.94	2.36	2.78	2.63	2.46
8/18/2005	1.99	2.14	2.99	2.56	2.37
10/28/2005	1.82	2.23	2.84	2.64	2.32
11/23/2005	1.94	2.27	2.84	2.39	2.32
1/27/2006	1.73	1.96	2.42	2.02	1.89
5/26/2006	1.88	2.29	2.74	2.71	2.26
9/29/2006	1.97	2.42	2.93	3.17	2.65
11/22/2006	2.01	2.25	2.80	3.17	2.60
12/1/2006	2.16	1.98	2.56	2.87	2.54
12/24/2006	1.95	2.07	2.70	2.62	2.42
1/26/2007	2.01	2.11	2.71	2.48	2.29
5/25/2007	2.14	2.26	2.71	2.59	2.29
6/29/2007	2.51	2.39	2.62	2.84	2.56
8/31/2007	2.74	2.58	2.87	2.72	2.03
10/4/2007	2.24	2.75	3.02	2.83	2.35
11/22/2007	2.10	2.55	2.53	2.65	2.23
1/25/2008	1.97	2.20	2.57	2.23	2.02
5/23/2008	2.25	2.42	2.72	2.44	1.99
7/4/2008	2.23	2.46	2.82	2.83	2.23
8/29/2008	2.58	2.75	3.04	2.68	2.44
5/22/2009	2.27	3.00	2.66	2.80	2.54
7/3/2009	2.16	3.14	2.23	2.73	2.43

Table 17: Average Lateness in Minutes per Late Trip for the Inbound Direction on Sundays

Schedule Period (End Date)	Route 1	Route 9	Route 10	Route 41	Route 42
4/28/2005	1.05	1.52	2.13	2.75	
5/27/2005	0.79	1.81	2.06	3.58	
7/7/2005	1.39	1.98	2.08	3.38	
8/18/2005	1.52	2.32	1.58	3.77	
10/28/2005	1.67	2.31	1.83	3.32	
11/23/2005	1.94	2.14	2.10	2.53	3.26
1/27/2006	1.42	1.81	2.02	1.56	3.09
5/26/2006	1.75	1.86	2.02	2.50	3.69
9/29/2006	2.38	2.21	2.36	3.76	3.83
11/22/2006	2.08	2.08	2.20	3.45	3.89
12/1/2006	0.86	1.73	1.66	2.66	3.53
12/24/2006	1.95	2.01	2.62	2.44	3.29
1/26/2007	1.93	2.18	1.81	2.45	3.26
5/25/2007	1.98	2.31	1.89	2.59	4.13
6/29/2007	1.83	2.18	1.48	2.90	4.26
8/31/2007	1.70	2.18	1.90	2.79	4.49
10/4/2007	1.94	2.31	1.80	3.30	4.19
11/22/2007	1.88	1.93	1.53	2.67	4.05
1/25/2008	1.49	2.16	1.60	1.88	3.47
5/23/2008	1.57	2.52	1.76	2.44	3.94
7/4/2008	1.50	1.81	1.63	2.25	3.83
8/29/2008	1.68	2.42	2.11	2.92	4.08
5/22/2009	1.64	2.02	1.60	2.77	3.55
7/3/2009	1.98	2.49	2.02	2.36	2.78

Table 18: Average Lateness in Minutes per Late Trip for the Outbound Direction on Sundays

Schedule Period (End Date)	Route 1	Route 9	Route 10	Route 41	Route 42
4/28/2005	1.34	1.93	1.68	2.69	
5/27/2005	1.03	2.05	1.93	3.23	
7/7/2005	1.02	2.00	2.29	3.16	
8/18/2005	1.29	1.45	1.75	3.51	
10/28/2005	1.41	2.02	2.17	2.80	
11/23/2005	1.64	1.98	1.93	2.20	2.29
1/27/2006	1.36	1.84	2.10	1.72	1.83
5/26/2006	1.70	1.64	2.14	2.33	2.42
9/29/2006	1.89	1.84	2.27	3.16	3.40
11/22/2006	1.63	1.96	1.87	3.18	3.28
12/1/2006	1.00	1.56	1.53	1.79	2.58
12/24/2006	1.86	1.83	1.81	2.33	2.05
1/26/2007	1.59	1.90	2.05	2.31	2.11
5/25/2007	1.98	1.90	1.70	2.38	2.82
6/29/2007	2.21	1.70	1.55	2.65	3.48
8/31/2007	1.93	1.77	1.86	2.71	3.55
10/4/2007	2.15	2.09	1.58	3.09	3.29
11/22/2007	2.17	1.69	1.58	2.47	2.76
1/25/2008	1.71	1.95	1.76	1.95	1.91
5/23/2008	1.97	1.96	1.78	2.29	2.80
7/4/2008	1.82	1.98	1.54	2.56	3.81
8/29/2008	2.21	2.50	2.12	2.87	3.70
5/22/2009	1.65	1.77	1.73	2.57	2.85
7/3/2009	1.97	2.25	2.16	2.70	3.32

Average Lateness by Route and Time-of-Day

Table 19: Average Lateness in Minutes per Late Trip for the Inbound Direction during Weekday Peak Period

Schedule Period (End Date)	Route 1	Route 9	Route 10	Route 41	Route 42
4/28/2005	1.62	2.54	2.57	2.45	2.54
5/27/2005	1.58	2.51	2.69	2.56	2.79
7/7/2005	1.61	2.46	2.51	2.47	2.53
8/18/2005	2.06	2.86	2.99	2.43	2.40
10/28/2005	1.64	2.72	2.65	2.64	2.50
11/23/2005	1.84	2.70	3.03	2.03	2.36
1/27/2006	1.59	2.36	2.43	1.84	1.78
5/26/2006	1.77	2.49	2.53	3.19	3.02
9/29/2006	1.94	2.69	2.76	3.67	3.49
11/22/2006	1.77	2.80	2.64	3.37	3.33
12/1/2006	1.88	2.51	2.42	3.25	2.87
12/24/2006	1.97	2.49	2.52	3.11	3.02
1/26/2007	1.91	2.52	2.49	2.93	2.82
5/25/2007	2.27	2.59	2.47	3.00	3.04
6/29/2007	2.38	2.41	2.34	3.08	3.28
8/31/2007	2.69	2.73	2.73	2.56	2.22
10/4/2007	2.24	2.91	2.75	2.89	2.64
11/22/2007	1.96	2.53	2.51	2.63	2.31
1/25/2008	1.77	2.44	2.33	2.15	1.91
5/23/2008	2.17	2.63	2.53	2.24	2.19
7/4/2008	2.22	2.55	2.58	2.51	2.37
8/29/2008	2.60	2.87	3.05	2.58	2.52
5/22/2009	2.63	2.74	2.49	3.14	3.64
7/3/2009	2.47	2.65	2.06	2.50	2.16

Table 20: Average Lateness in Minutes per Late Trip for the Outbound Direction during weekday Peak Period

Schedule Period (End Date)	Route 1	Route 9	Route 10	Route 41	Route 42
4/28/2005	1.66	2.61	2.30	2.34	2.54
5/27/2005	1.62	2.50	2.49	2.47	2.80
7/7/2005	1.61	2.38	2.31	2.36	2.64
8/18/2005	2.02	2.80	2.69	2.30	2.53
10/28/2005	1.69	2.61	2.52	2.54	2.62
11/23/2005	1.78	2.69	2.78	1.94	2.56
1/27/2006	1.61	2.29	2.32	1.76	2.02
5/26/2006	1.86	2.41	2.44	2.69	2.55
9/29/2006	2.01	2.59	2.60	3.16	3.03
11/22/2006	1.84	2.64	2.52	2.98	2.97
12/1/2006	1.90	2.44	2.34	2.65	2.70
12/24/2006	1.99	2.46	2.45	2.55	2.66
1/26/2007	1.99	2.48	2.38	2.41	2.49
5/25/2007	2.21	2.50	2.40	2.64	2.69
6/29/2007	2.48	2.38	2.33	2.85	2.97
8/31/2007	2.84	2.70	2.60	2.57	2.39
10/4/2007	2.37	2.87	2.58	2.86	2.80
11/22/2007	2.07	2.50	2.38	2.61	2.58
1/25/2008	1.86	2.39	2.29	2.19	2.18
5/23/2008	2.23	2.60	2.48	2.23	2.34
7/4/2008	2.25	2.54	2.46	2.48	2.51
8/29/2008	2.67	2.92	2.86	2.51	2.66
5/22/2009	2.67	2.86	2.41	2.89	3.02
7/3/2009	2.50	2.75	1.99	2.53	2.43

Average Earliness at Timepoint Level for Individual Routes

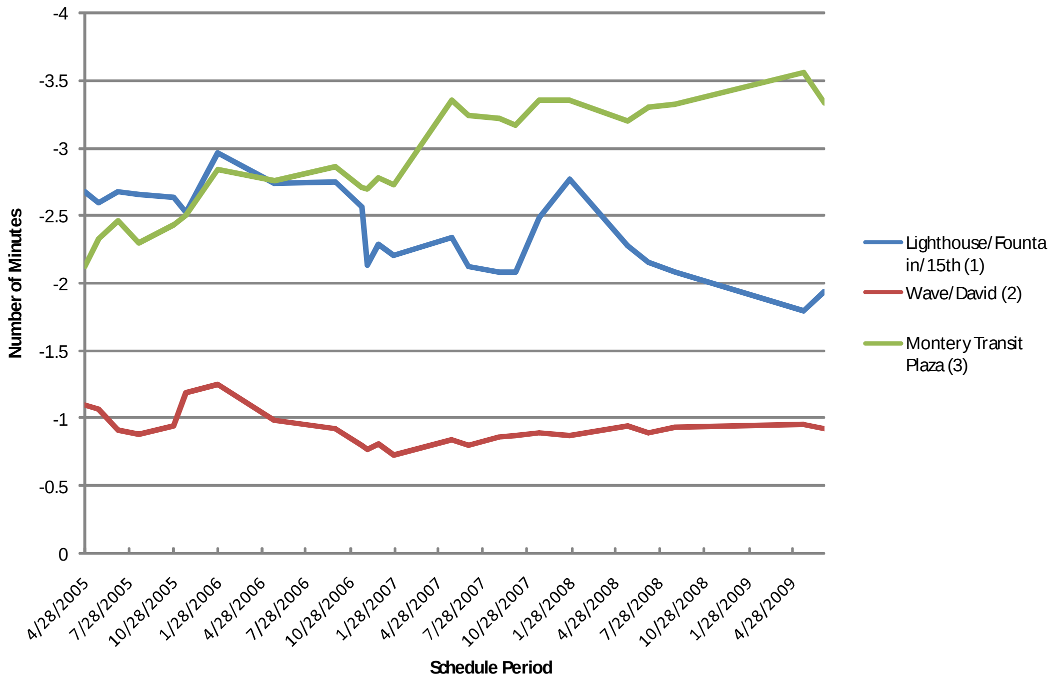

Figure 79: Average Earliness at Route 1 Timepoints in the Inbound Direction

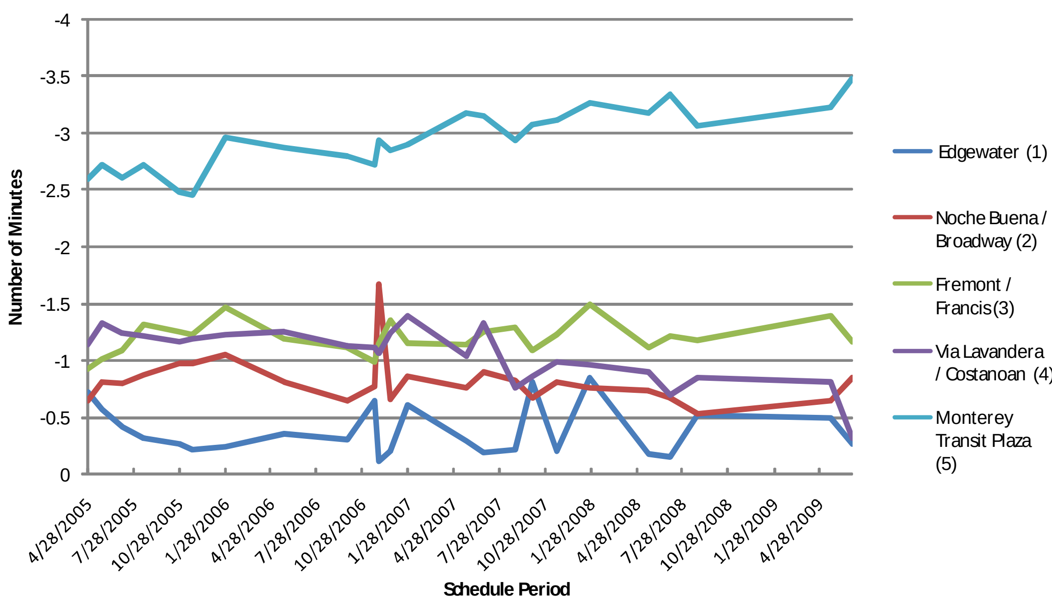

Figure 80: Average Earliness at Route 9 Timepoints in the Inbound Direction

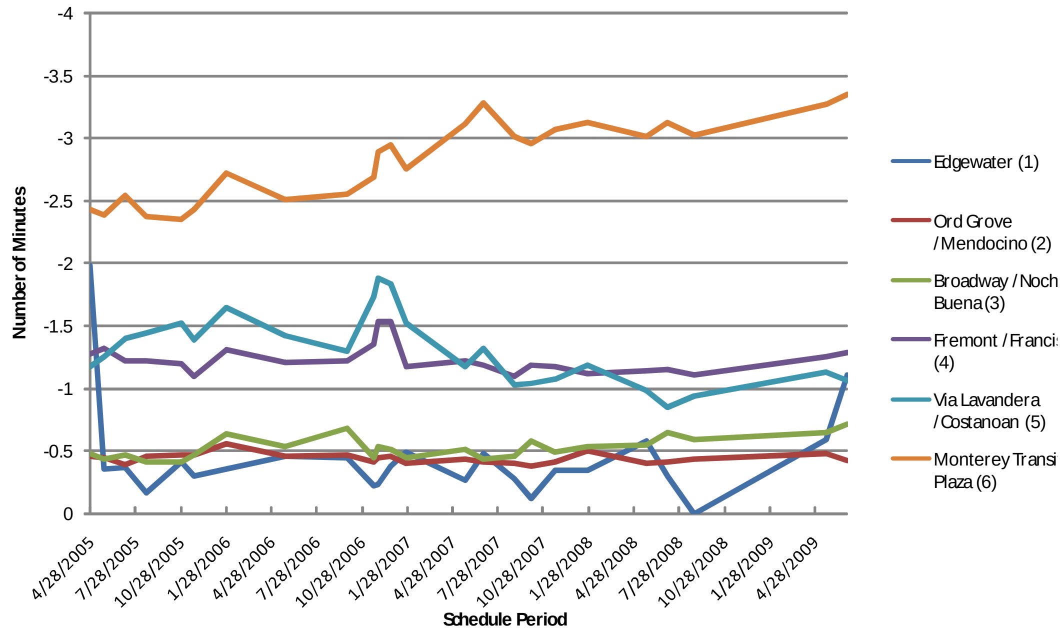

Figure 81: Average Earliness at Route 10 Timepoints in the Inbound Direction

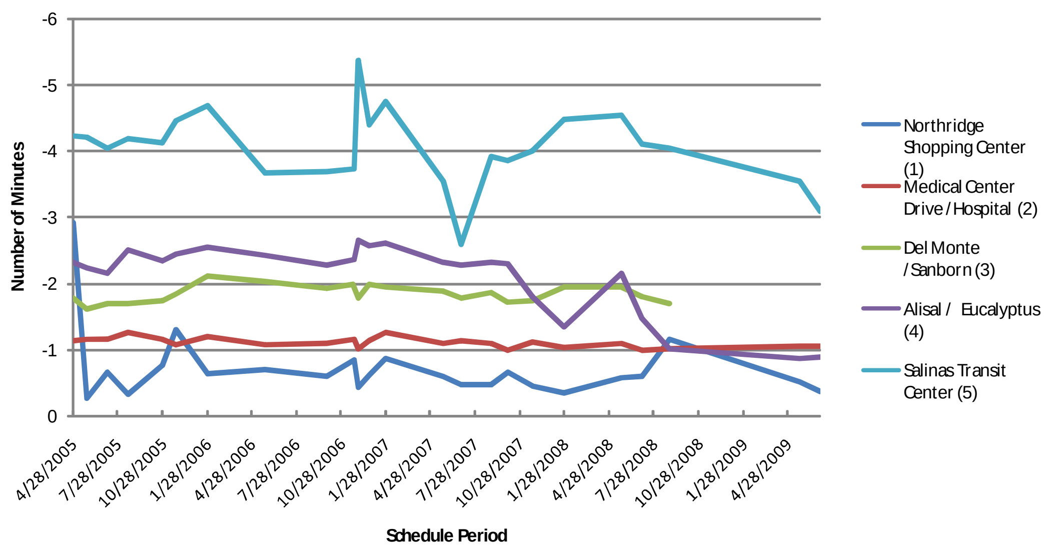

Figure 82: Average Earliness at Route 41 Timepoints in the Inbound Direction

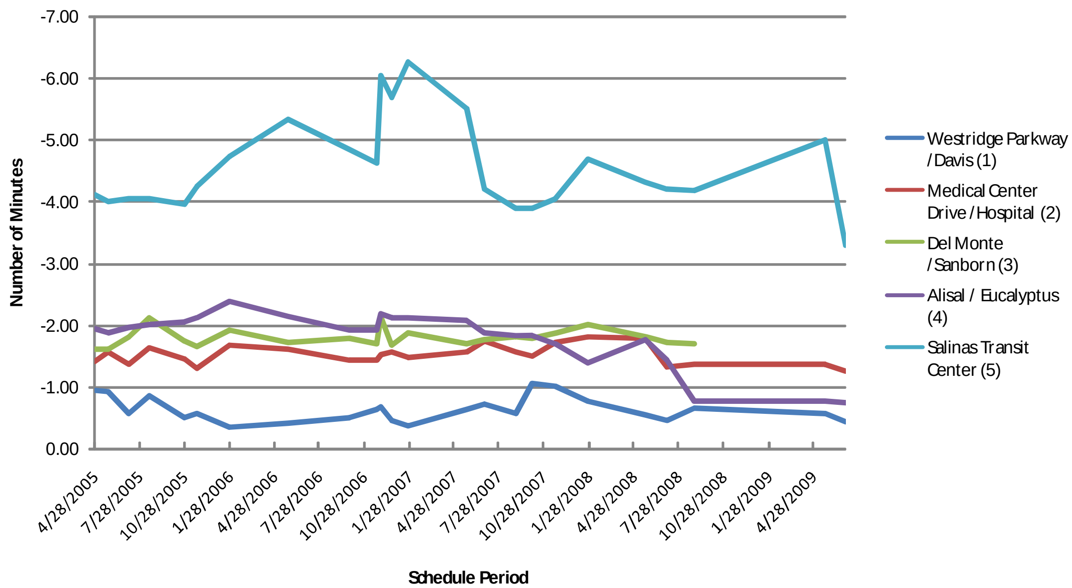

Figure 83: Average Earliness at Route 42 Timepoints in the Outbound Direction

Average Lateness at Timepoint Level for Individual Routes

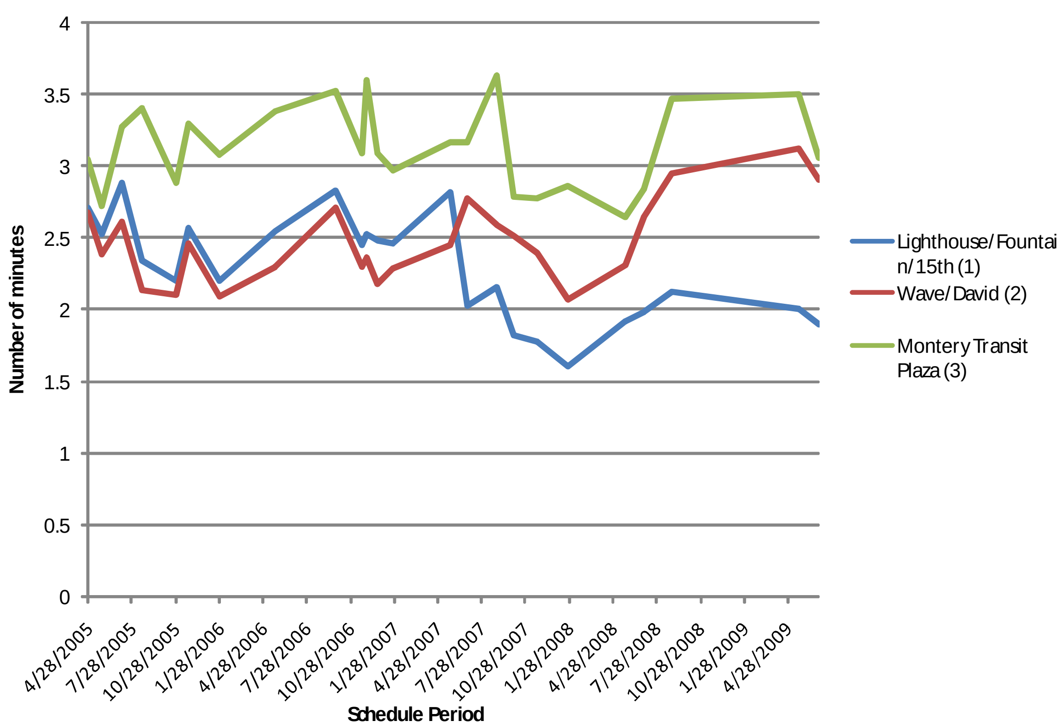

Figure 84: Average Lateness at Route 1 Timepoints in the Inbound Direction

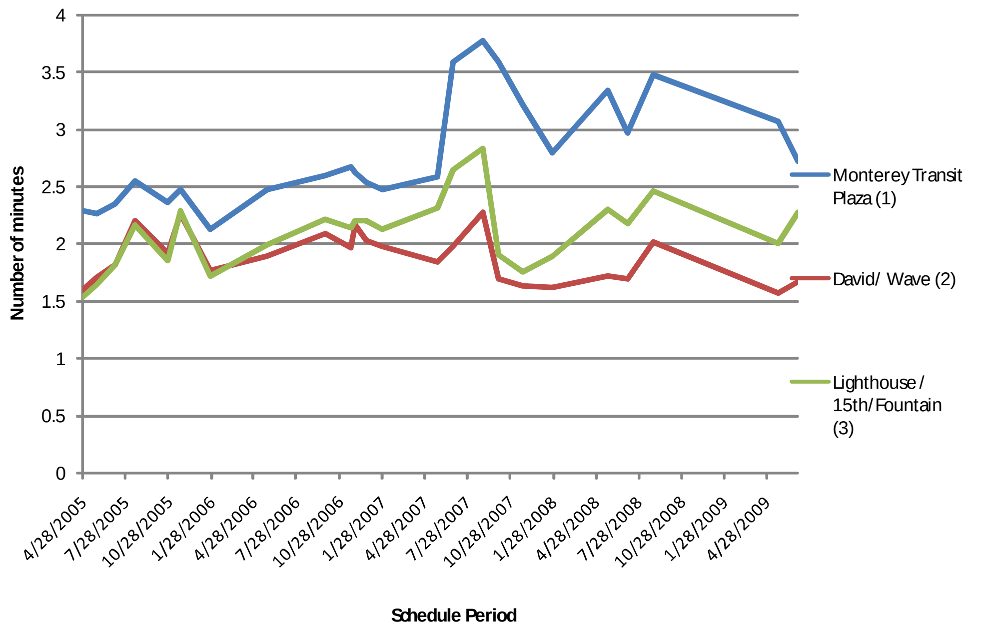

Figure 85: Average Lateness at Route 1 Timepoints in the Outbound Direction

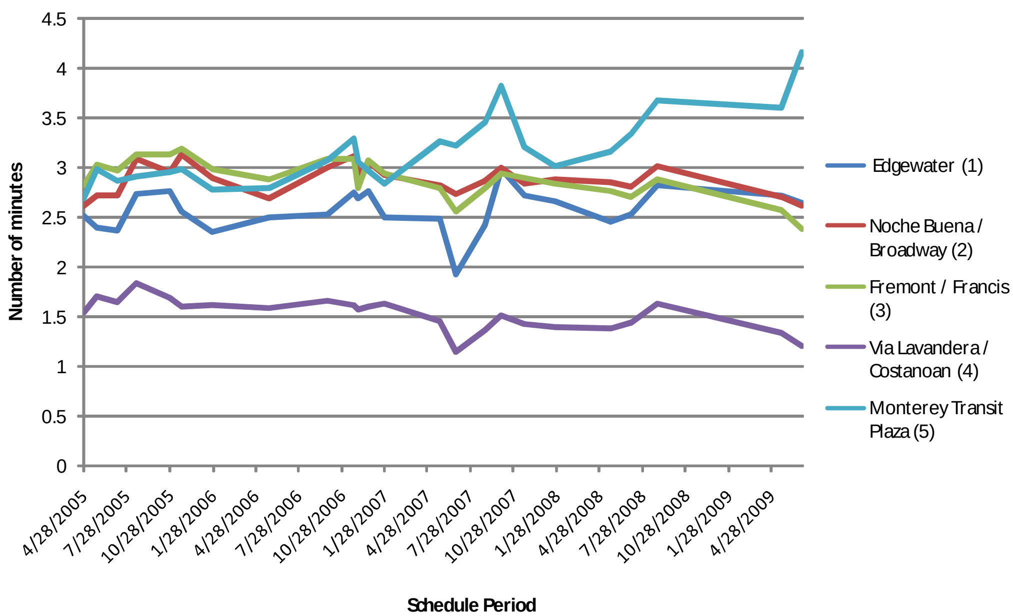

Figure 86: Average Lateness at Route 9 Timepoints in the Inbound Direction

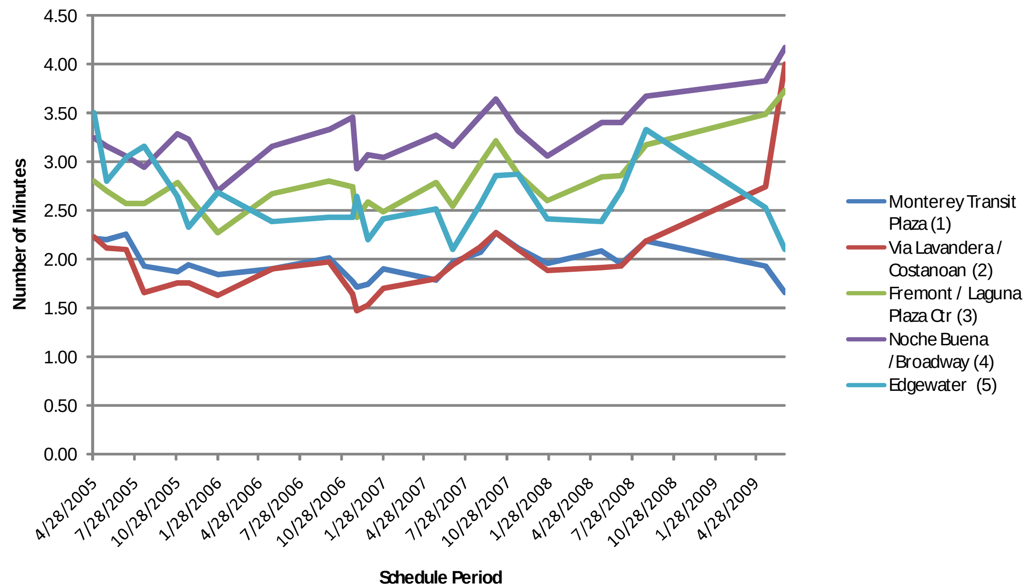

Figure 87: Average Lateness at Route 9 Timepoints in the Outbound Direction

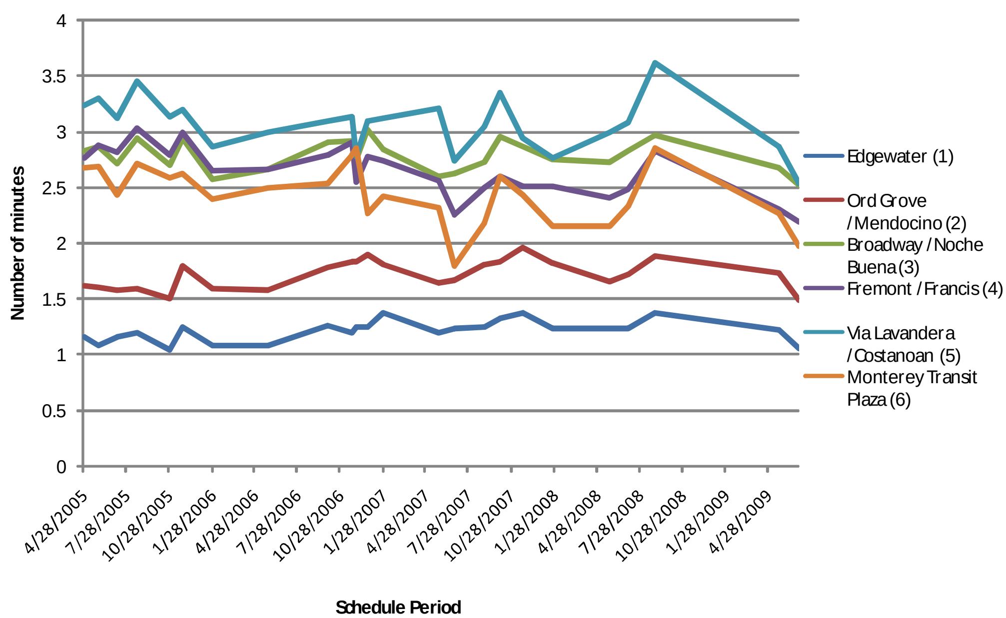

Figure 88: Average Lateness at Route 10 Timepoints in the Inbound Direction

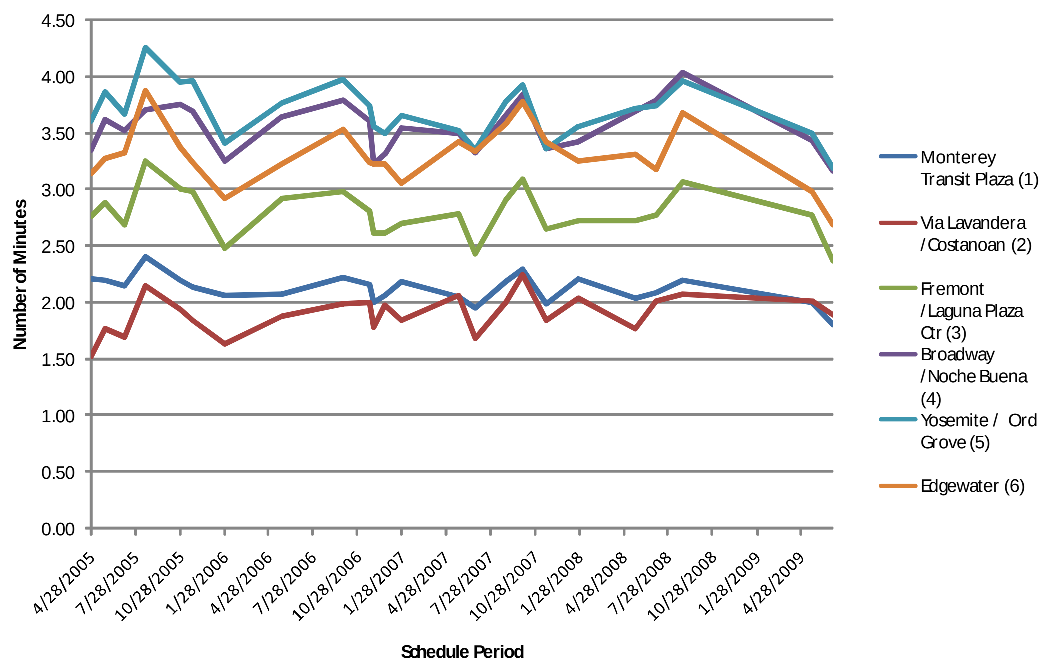

Figure 89: Average Lateness at route 10 Timepoints in the Outbound Direction

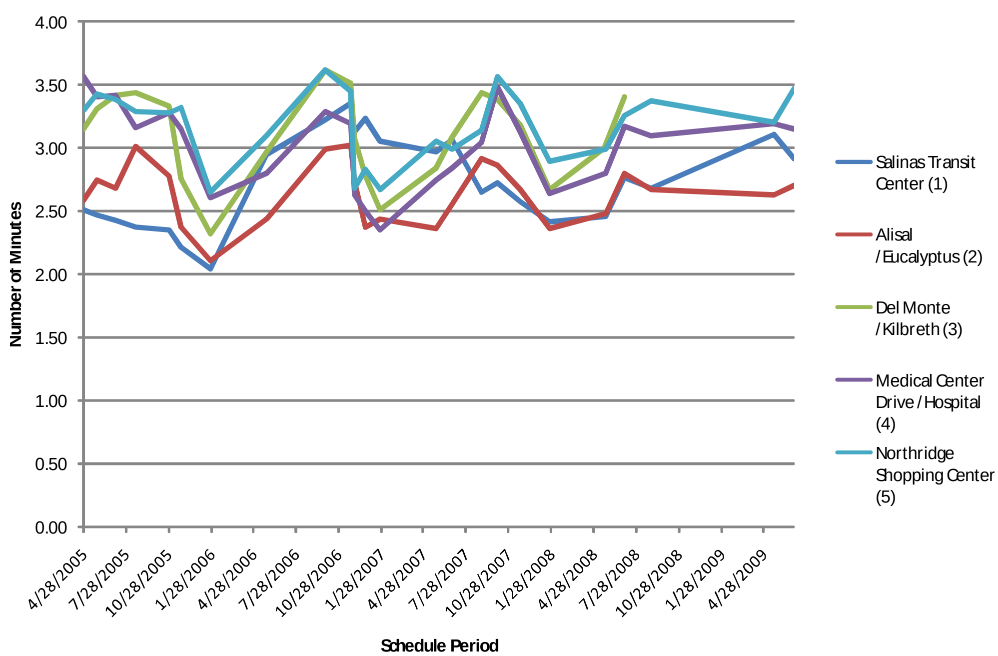

Figure 90: Average Lateness at Route 41 Timepoints in the Outbound Direction

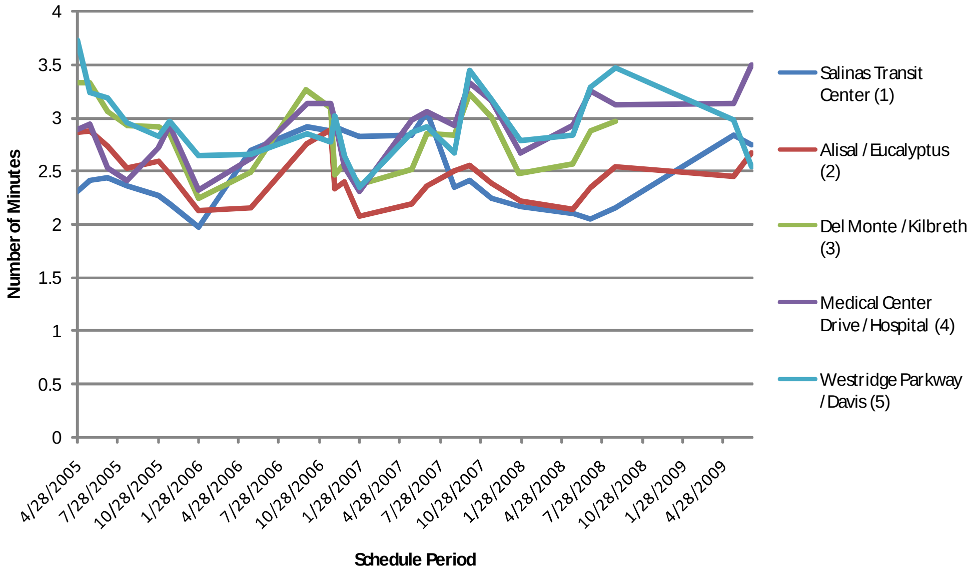

Figure 91: Average Lateness at Route 42 Timepoints in the Outbound Direction

Appendix D: Questions Used in On-Site Interviews in August 2008

Questions for Each Department

1. Which technologies are currently being used by your department?
2. What overall changes have you noticed in the agency over the last five years due to the implementation of technology?
3. Please describe the biggest challenges that you have faced in implementing and using technology in your department.
4. What was the cost of the technology that you are using? Are there any recurring costs associated with the technology your department is using?
5. What benefits have you perceived from using the technology? Can you describe those benefits in quantitative or monetary terms?
6. Has there been any change in your department's staff and resources since the technology implementation? Was this change planned?
7. Please provide a brief summary of your lessons learned from the technology implementation and usage.

Questions for Management

1. Please provide the current status of the following projects:
    - Transit Signal Priority
    - Real-time information
    - Web-based trip planner
    - Integration with Translink
2. What were the most significant challenges faced during the implementation of the ITS technologies?
3. What changes have you experienced in terms of staff (e.g., turnover, necessary increases, reduction) due to the implementation of each technology?
4. Please provide information on overall lessons learned from the ITS implementation.
5. Please provide information on the overall financial savings from the ITS implementation, if any.

Questions for Planning Department

1. Have you noticed significant time and resource savings after the implementation/update of scheduling software and other planning software (e.g., HASTUS, automatic passenger counter [APC] management software)?
2. What changes have you noticed in route planning and scheduling due to the implementation of the computer aided dispatch/automatic vehicle location (CAD/AVL) and APC systems?
3. Do you use archived AVL data to make schedule adjustments (e.g., by performing running time analysis)?

4. How does APC data help in planning activities? Which reports do you use regularly? Please provide a sample of these reports.
5. Have there been any changes in ridership in recent years that can be attributed to technology implementation?
6. Please provide monthly ridership information for the time period 2003 through 2007.
7. What changes have you noticed in productivity (passengers per vehicle-hour or vehicle-mile)? Which aspects of the CAD/AVL system have helped the most in the changing the productivity in your perception?
8. Have there been travel time savings due to the implementation of the CAD/AVL system? Do you have any quantitative figures on the travel time savings since the implementation of the CAD/AVL system?
9. Have there been impacts to performing comprehensive operational analyses (COA) studies in terms of the following since 2003?

- Has the time needed to complete COA studies changed?
- Has the cost of COA studies changed?
- Have there been any changes to implementing route/service modifications (as a result of COA studies)? and
- Have there been changes to the costs to operate the modified routes/services?

10. Have there been any changes to the amount of time it takes to generate annual National Transit Database (NTD) reports due to the technology implementation?
11. What are the annual boardings per hour for each year during the period from 2003 through 2007?
12. 12. Please share your experiences with any other changes that have taken place in the process of conducting COA studies, as well as performing other planning activities.

Questions for Operations Department

1. Please provide current information for the following items:
    - Number of drivers
    - Number of road supervisors
    - Number of dispatchers
    - Number of revenue and non-revenue vehicles
2. Have there been any changes in recent years to these numbers which can be attributed to technology implementation?
3. Which functions of the CAD/AVL system have helped you the most in managing daily operations?
4. Do road supervisors have access to the CAD/AVL system when in the field?
5. What changes have you noticed in the efficiency of communication between dispatch and road supervisors since the CAD/AVL implementation?
6. Have there been significant changes in the volume of voice radio traffic over the last five years? Do you think that the CAD/AVL system has contributed to reducing the number and length of calls among dispatchers, drivers and road supervisors?

7. Have there been any changes in dispatcher's response time to incidents and accidents? Has emergency communication improved with the use of silent alarm monitoring (if that is part of the CAD/AVL system)?
8. What changes have you seen in recording/reporting incidents and accidents over the last five years? Are the changes attributable to the CAD/AVL system or other technology?
9. Has the on-board surveillance system helped in improving operations? What are the significant impacts of this technology (e.g., resolving accident/ passenger disputes regarding on-time arrival of a vehicle)? Please provide anecdotal information, if possible.
10. Please provide the following annual statistics for each year of the period 2003 through 2007:
    - Total non-revenue vehicle hours;
    - Total non-revenue vehicle miles;
    - Total revenue vehicle hours; and
    - Total revenue vehicle miles.
11. Do you think that the technology has helped improve the reliability of MST transit services? Is there any documentation available on service reliability both before and after the implementation of the CAD/AVL system?
12. Does on-time performance vary significantly 1) seasonally; 2) over a week; or 3) during the day?
13. Please describe how the following functions have changed over the last five years since the implementation of technology:
    - On-time performance management;
    - Daily recording and reporting procedures;
    - Answering customer queries in the field;
    - Performing required next-stop announcements; and
    - Performing passenger counts (ride checks).

Questions For Maintenance Department

1. Is the inventory management system linked to the financial management system? How much has the new CAD/AVL system changed your job functions?
2. Please describe a typical vehicle maintenance procedure in terms of the process you use to initiate a maintenance action and to record all of the activities performed as part of that maintenance activity. Does technology play a role at any point during a maintenance action?
3. Does technology help you manage your time and resources? What technology has helped you the most in managing your time and resources?
4. What is your experience with the remote diagnostics system in terms of the following:
5. Your general perceptions associated with using remote diagnostics and the accuracy of the remote diagnostics system;

6. The total number of alarms/messages that are generated by the system during the course of an average day;
7. The alarms that you monitor;
8. The number of false remote diagnostic messages that are generated during the course of an average day;
9. The process associated with handling false messages/alarms; and
10. Cost savings since the remote diagnostics system was implemented, if any.
11. Please provide us anecdotal information on how the remote diagnostics system has helped vehicle maintenance activities since the system was implemented. What are the most significant issues with the remote diagnostics system, and how would you suggest the system be improved?

Questions for Safety and Security Department

1. Please provide the annual number and types of incidents (on-board and transit center) before and after the implementation of the surveillance system.
2. Please provide anecdotal information on investigations of reported incidents using archived videos since the implementation of the surveillance system.
3. If possible, please provide the following information annually for the period 2003-2007:
    - Annual number of on-board incidents
    - Annual number of on-board incidents where the perpetrator was identified
    - Annual number of transit center incidents
    - Annual number of transit center incidents where the perpetrator was identified
    - Annual number of registered cases of theft
    - Annual number of registered cases of theft where the trespasser was identified
    - Annual trend of customer complaints related to safety and security

Questions for Customer Service Department

1. What changes have been made to customer service hours/shifts, if any over the last five years?
2. How long, on average, does it take currently to find an answer to a customer query compared to the time it took before the implementation of technology? Has the process used to answer customer questions changed due to the use of technology?
3. Please describe the following with respect to technology implementation:
    - The change in the number of customer calls;
    - Changes in nature of calls; and
    - The change in the number of complaints.
4. Have you received any customer feedback on technology (e.g., automated next-stop announcements, on-board and transit center surveillance)?

5. Have you conducted any surveys since the technology implementation to determine customer satisfaction with the "customer-facing" technologies? If yes, please provide the survey findings.

Questions for Finance Department

1. Please provide the annual statistics for the following for each year from 2003 through 2007:
    - Number of passengers;
    - Total platform hours (time spent by vehicle in service between pull-in and pull-out);
    - Total vehicle miles;
    - Total annual revenue;
    - Passenger-miles per employee;
    - Passenger-miles per revenue dollar;
    - Total cost of operations and maintenance; and
    - Cost per passenger-mile;
2. Please provide information on the changes in the volume and dollar amount of financial claims over the last five years due the availability of data from ITS technologies (e.g., video clips and images, and on-time performance data).

Questions for Information Technology Department

1. Please describe how various ITS systems are integrated (e.g., CAD/AVL and scheduling). If possible, please provide a system diagram that shows how systems are integrated. If possible, please identify (on a system diagram) the data flows among the various ITS systems.
2. What changes have taken place in terms of daily reporting (e.g., number and nature of reports) before and after the technology implementation? Please describe the benefits of reporting in terms of the following:
    - The number of reports by category;
    - Ad-hoc reporting capability;
    - System capability to report in various formats (e.g., graphically, map-based and tabular);
    - The resources needed to generate reports; and
    - The operational benefits perceived by other MST departments.
3. Do you manage ITS hardware, software and data in-house? If any items are outsourced, which functions were outsourced and why?
4. Which technology has helped the most in improving overall operational efficiency and productivity?
5. How long did it take to "stabilize" each of the ITS subsystems? Please provide anecdotal information on the challenges and problems that were encountered with each system/subsystem during and after the implementation.
6. Have you faced any challenges in training the staff on technology usage?