EVALUATING ITS INVESTMENTS IN PUBLIC TRANSPORTATION: A PROPOSED FRAMEWORK AND PLAN FOR THE OMNILINK ROUTE DEVIATION SERVICE

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ABSTRACT

When implementing an intelligent transportation system (ITS), stakeholders often overlook the importance of evaluating the system once it is in place. Determining the extent to which the objectives of an investment have been met is important to not only the agency involved, but also to other agencies, so that lessons are learned and mistakes are not repeated in future projects. An effective evaluation allows a transit provider to identify and address areas that could use improvement. Agencies implementing ITS investments often have different goals, needs, and concerns that they hope their project will address and consequently the development of a generic evaluation plan is difficult to develop. While it is recognized that the U.S. Department of Transportation has developed guidelines to aid agencies in evaluating such investments, this research is intended to complement these guidelines by assisting in the evaluation of a site specific ITS investment. It presents an evaluation framework and plan that provides a systematic method for assessing the potential impacts associated with the project by defining objectives, measures, analysis recommendations, and data requirements. The framework developed specifically addresses the ITS investment on the OmniLink local route deviation bus service in Prince William County, Virginia, but could be used as a basis for the evaluation of similar ITS investments. The OmniLink ITS investment includes an automatic vehicle location (AVL) system, mobile data terminals (MDTs), and computer-aided dispatch (CAD) technology.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ADA	Americans with Disabilities Act
APTS	Advanced Public Transportation System
AVL	Automatic Vehicle Location
CAD	Computer Aided Dispatch
CAD/AVL	Computer Aided Dispatch/Automatic Vehicle Location
CDPD	Cellular Digital Packet Data
ETA	Estimated Time of Arrival
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GPS	Global Positioning System
ISTEA	Intermodal Surface Transportation Efficiency Act
ITS	Intelligent Transportation System
IVHS	Intelligent Vehicle Highway System
LAN	Local Area Network
MDT	Mobile Data Terminal
MOE's	Measures of Effectiveness and Efficiency
NTD	National Transit Database
PRTC	Potomac and Rappahannock Transportation Commission
RAM	Random Access Memory
SaFIRES	Smart Flex-Route Integrated Real-Time Enhancement System
USDOT	United States Department of Transportation
VAN	Vehicle Area Network

VDRPT   Virginia Department of Rail and Public Transportation

VRE   Virginia Railway Express

WAN   Wide Area Network

WMATA   Washington Metropolitan Area Transit Authority

CHAPTER 1: INTRODUCTION

1.1   PROBLEM STATEMENT

Often while implementing a new system, evaluating the results of the system is overlooked or underemphasized. Recognizing the value of evaluation, this research aims to assist transportation professionals in analyzing the effectiveness of specific investments. The system studied in this research is OmniLink, a route deviation local transit service operated by the Potomac and Rappahannock Transportation Commission (PRTC). PRTC is in the process of implementing an intelligent transportation system (ITS) throughout the OmniLink system. A prior effort to install a similar system began in 1993, but never achieved complete success. As a result, some of the elements are already in place, and a current effort is being undertaken to install the elements that were not completed as part of the original effort. The complete system is to include Automated Vehicle Location (AVL), Computer-Aided Dispatch (CAD), and Mobile Data Terminals (MDTs). Together these components will work to accomplish multiple objectives including improving communication between OmniLink dispatchers and bus operators, and providing the bus operators and dispatchers with more detailed information about routes and services.

PRTC does not currently have an evaluation approach in place to assess the impacts of this investment. Therefore, the goal of this research is to assist PRTC in the development of such an evaluation approach and to provide a framework for other transit providers with similar evaluation objectives. While it is recognized that the U.S. Department of Transportation has developed guidelines to aid agencies in evaluating such investments, this research is intended to complement these guidelines and to specifically address the evaluation of PRTC's ITS investment.

1.2   RESEARCH OBJECTIVES

The main objectives of the research directly relate to the problem statement as described above. They are as follows:

- To conduct a case study of an ITS investment that has been made by PRTC in its OmniLink route deviation transit service in Prince William County, Virginia
- To identify the specific problems and objectives that PRTC hopes to address with this ITS investment
- To develop an evaluation approach, including a conceptual framework and a detailed plan, to assist PRTC and other public transit providers in the assessment of impacts associated with similar ITS investments
- To identify data and other resources that would be required to conduct the recommended evaluation

1.3   RESEARCH APPROACH

A literature review was conducted of research projects involving ITS investments in paratransit and transit services. In particular the focus was on the use of AVL, CAD, and MDTs in transit and paratransit applications. A case study was then conducted of PRTC's ITS investment in the OmniLink route deviation service. The primary sources of information for this case study were technical reports on the OmniLink project and the ITS design. An evaluation framework and plan were then formulated and proposed for use by PRTC.

1.4   THESIS CONTRIBUTIONS

In Chapter five of *What Have We Learned About Advanced Public Transportation Systems?*, Casey (2000) states that, "Many transit agencies are still uncertain as to how APTS can be used to fundamentally change transit operations and services for the better". He also says that, "agencies need to be more informed about the relative benefits and costs of APTS technologies, which requires that continued evaluations be conducted to quantify and publicize these benefits and costs. It is imperative that transit agencies be made aware of what works and how to implement these technologies". The analysis in this report aims to assist individuals in the transportation industry, specifically transit agencies, in making more informed decisions about ITS investments.

In their *ITS Evaluation Resources Guide*, the FTA recommends the following six-step process for ITS evaluation:

(1) Form the Evaluation Team
(2) Develop the Evaluation Strategy
(3) Develop the Evaluation Plan
(4) Develop One or More Test Plans
(5) Collect and Analyze Data and Information
(6) Prepare the Final Report

This report addresses this process by developing the evaluation strategy, evaluation plan, and basic test plans. Although it does not include any data analysis, it provides detailed guidelines for evaluation that should be useful to PRTC and other public transit agencies considering implementation of technology for similar applications.

According to the *Federal Transit Administration's ITS Evaluation Guidelines*, evaluation is, "the reasoned consideration of how well project goals and objectives are being achieved". These guidelines also say that, "the primary purpose of evaluation is to cause changes in the project so that it eventually meets or exceeds its goals and objectives". This report provides an evaluation plan devised with this purpose in mind.

1.5   REPORT STRUCTURE

Following the introduction in Chapter 1, Chapter 2 will present a review of relevant literature to establish the background on which this report is based. Chapter 3 will then present the history of OmniLink while Chapter 4 will describe the OmniLink system, including the system architecture and the system requirements. Chapter 5 will present the proposed evaluation framework and plan. Finally, Chapter 6 will offer conclusions, lessons learned, and recommendations for further research.

CHAPTER 2: LITERATURE REVIEW

This chapter provides a review of recently published literature relevant to the subject of this report. The purpose of this section is to identify appropriate references that are significant to this research. The broad nature of the research conducted as part of this project required a review of literature from three general areas. The first two topic areas are included in Sections 2.1 and 2.2. Section 2.1 focuses on related ITS technologies including Automatic Vehicle Location (AVL), Mobile Data Terminals (MDTs), and Computer-Aided Dispatch (CAD). Section 2.2 discusses different approaches that have been used to evaluate public transit investments in ITS. The third significant area of information involves any resources specifically related to OmniLink. Many technical reports and other documents were reviewed in order to gather the necessary background information about the history of OmniLink and the previous ITS project. It should be noted that this information is included in Chapters 3 and 4 rather than in the literature review.

2.1   ITS TECHNOLOGIES IN PUBLIC TRANSIT

A variety of information-based technologies have been considered for use and deployed on public transportation applications in the United States including AVL, CAD, and MDTs. Several examples have been reviewed in this section.

2.1.1   The Denver Regional Transportation District CAD/AVL System

The City of Denver, Colorado installed ITS technology to provide real-time surveillance of their vehicles and to upgrade their radio communication. The Volpe Center conducted a study to identify the human factors consequences of the project. The research documents how Denver's Regional Transportation District (RTD) dispatchers, street supervisors, and bus operators became accustomed to using the CAD/AVL technology to perform their tasks. The research examined the employee's work practices before and after the new technology was installed.

An interesting result of the study is that it found that the dispatchers' workload actually increased because the CAD/AVL system allowed them to receive and transmit more calls than their previous radio system of communication. They found a 46% increase in dispatch hours per weekday. In addition, they found that the need for street supervisors did not decrease as initially predicted. The supervisors' duties actually expanded and the staffing level remained the same.

The bus operators reported that they were a little uncomfortable with the idea of being monitored, but that they liked receiving and sending text messages because they felt that it was an efficient and convenient way to receive and store instructions. One problem that they identified was that they felt that there was a lot of variability in the dispatchers' response time to calls after the system was installed.

Another problem that the bus operators identified was that they were not very clear about how to operate the Silent Alarm button. They expressed some concern about the adequacy of their training on the use of the Silent Alarm (Stearns, Sussman, and Belcher, 1999).

2.1.2   The Riverside Transit Agency ITS Demonstration Project

This report studies the effects of an ITS demonstration project on fixed-route and paratransit operations for both the Riverside Transit Agency (RTA) and SunBus (Jensen, 2001).

The major components of this project are automatic vehicle location (AVL) and computer-aided dispatch (CAD). Secondary ITS applications include information connectivity to the regional commuter rail system to improve transit-to-transit transfers, and enhanced transit and traveler information available initially on the Internet, with regional kiosks to be added later. The system allows for real-time fleet monitoring, promotes on-route/on-time performance, enhances customer information, and promotes safety. In addition, other ITS applications are being considered for inclusion in this deployment, which may be installed near the end of the evaluation period. These technologies include electronic fare payment technology using Smart Cards, a real-time maintenance monitoring system, and traffic signal priority for transit vehicles.

The emphasis of the project was not on the individual technologies being deployed, but on the integration of the technologies. According to the project description, the demonstration was intended to "bundle the technologies into systemic applications and then integrate the systems into transit operations." The primary purpose of this integration was to enhance service productivity, which can lead to substantial cost savings.

2.1.3   Advanced Public Transportation Systems (AVL, CAD, and MDTs)

A report published by the Volpe Center called *What Have We Learned about Advanced Public Transportation Systems?* reports the effects of various ITS applications on transit services around the United States.

It reported that many transit agencies have achieved improved schedule adherence as a result of AVL. Three agencies reporting improvements were:

- Milwaukee County Transit System, Milwaukee, Wisconsin – reported an increase of 4.4 percent, from 90 to 94 percent
- Kansas City Area Transit Authority, Kansas City, Missouri – reported an increase of 12.5 percent, from 80 to 90 percent
- Regional Transportation District, Denver, Colorado – reported an increase of between 12 and 21 percent on various routes

According to the same report, the Ann Arbor Transportation Authority in Ann Arbor, Michigan, and the Rochester-Genesee Regional Transportation Authority in Rochester, New York were able to reduce voice radio traffic by as much as 70 percent with the use of MDTs. Reducing voice traffic provides a less stressful work environment for dispatchers. A quantitative benefit to reducing voice traffic was that the agency did not require as many voice channels.

The same report says that the Metropolitan Atlanta Rapid Transit Authority reported $1.5 million in operational savings by making adjustments to schedules based on AVL and APC data (Casey, 2000).

2.1.4   Evaluation of Tri-Met's Automated Bus Dispatching System

The Tri-Met system includes AVL using GPS, APCs, and an on-board computer and a control head displaying schedule adherence to operators, detection and reporting of schedule and route deviations to dispatchers, and two-way, pre-programmed messaging between operators and dispatchers. Strathman and Gerhart (2001) explored the possibilities for data applications related to the new technology.

2.1.5   The NOVA Commercial Fleet Management Project

Doyle, Stough, and Allen (1998) studied the courier service, NOVA Delivery, of NOVA Group, Ltd. NOVA developed their own dispatching software to accommodate the needs of the courier industry. Doyle, Stough, and Allen worked with NOVA to design a study to quantify the changes in productivity of company drivers. In analyzing the system, the research team chose *productivity of drivers* as their measure of effectiveness. It was measured as the *number of deliveries per driver-hour*. They first collected data on certain drivers for a three month period in 1996 before the system was implemented. They then collected data on the same drivers for a three month period in 1997 after the system was installed.

They found that the productivity of the drivers improved by an average of 24% after implementation of the dispatching software. In addition to this quantitative finding, they discovered that there was an observable decrease in stress on the dispatchers and an improvement in communications between the dispatchers and office personnel. They surprisingly found that there was a reduction in stress-related illnesses and a decrease in the consumption of aspirin to relieve headaches. The company actually had three out of ten dispatchers (between the ages of 40 and 50) die from stress-related heart illnesses in a three-year period of time prior to installation of the software (Doyle, Stough, and Allen, 1998).

2.1.6   An Assessment of the METROLift AVL System

METRO and the Texas Transportation Institute (TTI) studied the impact of the AVL system on METROLift, a paratransit service in Houston, Texas. They studied the impact

of the AVL system using two general measures: on-time performance and service efficiency. Service efficiency was measured by looking at the ratio of passenger miles to vehicle revenue miles and the use of taxi back-up service. They noted a significant improvement in the ratio of passenger miles to vehicle revenue miles and a decrease in the number of taxi back-up services requested during peak hours. Both of these measures indicated that the service efficiency had improved. They also found that there was an improvement in on-time performance, which was measured as the percent of reported late trips where a late trip was defined as a vehicle that arrived more than 15 minutes after the scheduled arrival time.

In addition, they conducted interviews of METROLift dispatchers and operators to find out how they felt about the AVL system. They interviewed 12 of their 14 dispatchers, and 30 of their 220 bus operators. They asked them questions relating to the use of the system, the ease of operation, any problems or issues that they have encountered with the system, and any recommendations that they may have for improvements or changes.

They found that both groups were pleased with the system overall. The dispatchers agreed that the system was easy to use, and most said that it took them only a day or two to learn how to use the system and the different features. The key benefits that the dispatchers identified included the ability to give operators directions to find addresses without the use of radio time, the ability to provide customers with better information on the status of vehicles, and the reduced telephone and radio time with both operators and customers. Other benefits that were mentioned included less job stress, less paperwork, and less worry about making mistakes. The main problem that the dispatchers identified was that the map should be updated more frequently to include changes due to construction or traffic patterns.

Most of the operators found the system easy to use and many said that it has simplified their job. The key benefits that the operators identified included the ability to get directions quickly, and the increased feeling of security. The operators' main concern was the location of the MDTs in the vehicle. They felt that the MDT was positioned too high, which made it difficult to read and send messages. They also expressed some concern that the size of the type was too small.

Since METRO conducts customer satisfaction surveys periodically, customer service ratings were used as a qualitative measure of the success of the system. Improvements included a five percent increase in the number of respondents indicating that the service was *much better* than the previous year, and a three percent increase in the number of respondents indicating that it was *somewhat better*. In addition, they had a three percent increase in the number of customers reporting an *excellent* rating for the on-time performance of METROLift (Turnbull, Higgins, and Vaidya, 1995).

2.1.7   *Miami Case Study of AVL and Paratransit*
The Center for Urban Transportation Research (CUTR) at the University of South Florida in Tampa conducted a study in 1995 to test whether AVL technology could be used to

improve paratransit productivity. The study looked at a paratransit service in Miami, Florida with AVL technology that was designed and developed as a theft-deterrent device. The AVL system was originally installed as a security precaution to protect against vehicle theft and related crimes. Zuni Transportation, Inc. operates the paratransit service for the Metro-Dade Transit Agency. The study looked at whether productivity could be improved, "through more efficient and effective scheduling and dispatching, vehicle monitoring, and driver accountability". It looked at three performance measures of system productivity: on-time performance, vehicle dwell time, and average travel time. The results of the research indicated that AVL technology can, in fact, benefit paratransit systems by providing better and more accurate information regarding productivity, and real-time service monitoring.

CUTR also developed a checklist to be used by paratransit agencies that are considering the implementation of an AVL system. This checklist includes considerations for determining the need for AVL, selecting an AVL system, and implementing an AVL system.

CUTR interviewed bus operators to find out how they felt about the AVL system. The operators mentioned that they sometimes forgot what they were supposed to be doing with the terminal or they forgot to push the buttons until they were already moving. They also mentioned that they sometimes completely forgot to use the status message terminals. Many operators felt that their training was not as comprehensive as it should have been.

Zuni found the AVL tracking information to be helpful for several reasons. One reason was that a vehicle was stolen shortly after the technology was implemented and the AVL system enabled authorities to quickly recover the vehicle. Another reason is that Zuni is fined for any trip that is not completed unless a passenger no-show can be documented. They no longer have a problem with this because whenever an operator presses the no-show button, the system records the time along with the location of the vehicle so that there is no question of whether or not the driver was there. Another benefit is that Zuni receives several requests for estimated time of arrivals (ETAs) each day. The AVL technology allows the dispatchers or customer service representatives to report accurate information to the customer without disrupting the operator. Zuni also found the AVL technology helpful in monitoring new or problem drivers (Hardin, Mathias, and Pietrzyk, 1997).

2.1.8   Transit User's Perceptions of AVL Benefits

This report involves a survey that was conducted on riders' perceptions about the importance of various features of an AVL system. The surveys were conducted in the cities of Manitowoc and Racine in Wisconsin. The transit systems in these two cities are classified as *small or medium sized transit systems* according to the Federal Transit Administration's definition.

The study showed that transit riders place a lot of value on increased on-time performance and improved schedule reliability. It is expected that both of these measures can be improved with the use of AVL technology.

The surveys showed that 40% of survey respondents would ride more if they had better information about the system or if the schedule was more reliable. However, the survey only included current transit riders. Improvements that result from AVL may attract new riders who are currently unhappy with the system. The surveys showed that there would be expected to be a moderate increase in ridership as a result of the AVL technology. They concluded that transit riders are extremely sensitive to schedule reliability, so the increased arrival reliability could potentially improve customer satisfaction and therefore increase transit ridership (Peng, Yu, and Beimborn, 2001).

2.2   EVALUATION APPROACHES FOR ITS IN PUBLIC TRANSIT APPLICATIONS

Several evaluation approaches have been employed to assess the performance of intelligent transportation systems in public transportation. Among these include the FTA's *APTS Evaluation Guidelines*, and reports entitled *Evaluation of AVL Technologies for Paratransit in Small and Medium Sized Urban Areas*, and *Measuring the Performance of Transit Systems*. The approaches presented in these papers are briefly described in the following sections.

2.2.1   *The Advanced Public Transportation Systems Evaluation Guidelines*

The Advanced Public Transportation Systems (APTS) Program of the Federal Transit Administration (FTA) was created as part of the USDOT Intelligent Vehicle Highway Systems (IVHS) initiative in the early 1990's. The term *IVHS* has since been changed to *Intelligent Transportation Systems*, or as it is more commonly called, *ITS*. The goal of the APTS Program was to help public transportation systems meet customer needs and to provide the industry with information on innovative applications of available technologies from a coordinated operational test and evaluation program. As part of this program, operational tests were conducted on systems all over the United States to learn more about the functionality of ITS systems. The USDOT and FTA developed evaluation guidelines to assist key players in conducting these operational tests. These guidelines are also useful in developing an evaluation framework and plan for a current ITS investment (Casey and Collura, 1994; TEA-21 Evaluation Guidelines).

2.2.2   *Evaluation of AVL for Paratransit in Small and Medium-Sized Urban Areas*

Spring, Collura, and Black (1997) presented an evaluation framework for small and medium-sized city AVL-based paratransit applications. They applied this framework to a specific system in Winston-Salem, North Carolina. Of the seventeen vehicles in the fleet, only three were outfitted with MDT-AVL technology.

A "before and after" study was conducted to evaluate the effectiveness of the AVL system. It was found that the paratransit system's efficiency improved slightly with AVL. The performance measure used to measure efficiency was time deviation, which was calculated as the difference between the agreed upon pick-up time and the actual pick-up time. In addition they found that the performance measures for effectiveness and user acceptance did not show any significant improvement but that demand variables did not change significantly when compared to other vehicles not equipped with AVL (Spring, Collura, and Black, 1997).

2.2.3   Measuring the Performance of Transit Systems

Over the last several decades, a wealth of information has been made available on the subject of measuring transit performance. Fielding (1987) addresses the subject within the broader context of transit management. Collura (1996) reviews transit performance as it relates to small transit systems. Dajani and Gilbert (1978) present a framework for the development of transit performance measures. According to Dajani and Gilbert, "the development of an evaluation framework demands that the various inputs, outputs, and impacts of transit service be organized in a meaningful manner." After the characteristics of the transit service are characterized, the data can be collected and performance measures can be used to measure these characteristics.

CHAPTER 3: BACKGROUND INFORMATION ON OMNILINK

This chapter describes the OmniLink service area and operational characteristics, and gives some background information on the history of the OmniLink SaFIRES project. It also briefly describes the intelligent transportation system that is currently being implemented.

3.1   THE OMNILINK SERVICE

This section contains background information about the OmniLink service including the service area, the ridership, and the operational characteristics.

3.1.1   *The Provider of OmniLink - PRTC*

OmniLink is a local weekday bus service that is operated by the Potomac and Rappahannock Transportation Commission (PRTC), which is located in Woodbridge, Virginia. PRTC was created in 1986 by the Virginia General Assembly under the Transportation District Act, and it has adopted the motto of *"Providing Transportation Solutions for a Quality Future"*. The commission is made up of elected officials from its five member jurisdictions, which are Prince William and Stafford Counties, and the Cities of Manassas, Manassas Park and Fredericksburg. Membership in PRTC allows for the collection of a two percent motor fuels tax, which is used for transportation improvements in the PRTC region.

3.1.2   *The Service Area*

OmniLink serves Prince William County, Virginia, along with the cities of Manassas and Manassas Park. This suburban and rural area is located just south of the Occoquan River in Northern Virginia, about 25 miles south and west of Washington, D.C., between the heavily traveled corridors of I-95 and I-66. Prince William County encompasses 348 square miles as well as the independent cities of Manassas and Manassas Park. The total area of the three entities is 360 square miles. The map in Figure 3.1 below shows the location of Prince William County in relation to Washington, D.C., and the state of Virginia.

Figure 3.1: Map of Virginia Identifying Prince William County

3.1.3   Ridership

According to the U.S. Census Bureau, the total population of this area was 326,238 in the year 2000. The county grew by about 90 percent between 1980 and 2000, making it one of the fastest growing counties in the state of Virginia during those two decades (Prince William County Population Data). The population of the each portion of the OmniLink service area according to the 2000 Census is given in Table 3.2 below. The population of the service area is expected to continue growing rapidly over the next several years as the population spreads further from the center of Washington.

Table 3.1: Population of the OmniLink Service Area

Area	Population in the Year 2000
Prince William County	280,813
City of Manassas	35,135
City of Manassas Park	10,290
Total	326,238

OmniLink currently serves about 2,500 passengers per day, or about 13 passengers per hour per vehicle (the number of passengers per hour ranges from 4.6 to 23.7). It serves the needs of the community with six routes and sixteen 30-foot, medium-duty 28 passenger vehicles (2001 Champion Model CTS). Thirteen of these vehicles are in use during the peak period. Three of the routes serve Eastern Prince William County (adjacent to the I-95 corridor) in Dale City, Dumfries/Quantico and Woodbridge/Lake Ridge. The two additional routes serve Western Prince William County (adjacent to the I-66 corridor) in the cities of Manassas and Manassas Park. Maps of the OmniLink routes are included in Appendix A.

According to a survey that was conducted by PRTC, 68% of customers use OmniLink to get to work and 18% use it to get to school, while the other 14% use the service for shopping and other local needs. The survey shows that 17% of workers and 26% of

college students are captive riders, which means that they do not have an alternate way to get to work or school. In addition, 34% of customers claim to be choice riders, which means that they have access to a personal vehicle, but choose to use OmniLink instead. According to the survey, 24% of customers say that they use the route deviation feature, and 74% say that they like the deviation feature *very much* or *somewhat* (CJI Survey, 2001).

3.1.4   Operational Characteristics

OmniLink began operation in April of 1995. The service was established with the help of funding from the Intermodal Surface Transportation Efficiency Act (ISTEA), which allocated federal funds for new and innovative transit services. The OmniLink service was considered to be innovative in that it combined paratransit service with local service to form a system that could meet the transportation needs of the entire community.

PRTC had three main reasons for choosing to implement a route deviation service: fairly low demand in the service area, requirements of ADA, and the structure of the roadway network. Since it was believed that the demand was not sufficient to justify traditional local transit service, PRTC developed a service that would combine traditional transit service with human services transportation.

The goal of OmniLink was to create a service that would successfully serve the two needs of the community: the need for local general public transit service, and the need for human services transportation. The need for human services transportation became imperative when Congress passed the Americans with Disabilities Act of 1990 and required full compliance by January of 1997. It required that fully accessible paratransit be provided within three-quarters of a mile of each side of any fixed route transit service, and that all fixed-route buses be fully accessible (Americans with Disabilities Act of 1990). Morlok, Bruun, and Vanek (1997) cites a survey conducted by Rosenbloom (1994) in which it was found that some agencies were actually reducing conventional service in order to finance the more costly complementary paratransit service for ADA compliance. PRTC avoided this and accomplished their goal of serving the community by allowing buses to deviate from their fixed routes up to three-quarters of a mile to pick up and drop off passengers. For this reason OmniLink is termed a *flex-route* transit service. It should be noted that there is a limited amount of time available for route deviation within each trip, and that deviations are only permitted when there is time available in the schedule. Both of these ensure that route deviations will not cause buses to be very far behind schedule at any point in time.

Another reason that Prince William County benefits from route deviation is that the development of much of the County does not lend itself to transit service. Traditional fixed route transit service does not work as well in the suburbs as it does in cities because populations are not as dense and it often becomes costly to provide the level of service and convenience that is needed to attract new riders. Much of OmniLink's service area is formed of a few major roads that traverse the county with small roads stemming from them. The design of the roadway network succeeds in reducing through-traffic in

residential areas, but makes it difficult to provide transit service efficiently. Prior to OmniLink, Prince William County was said to be the most densely populated county in Virginia with no local bus service. In addition there was no feeder bus service to the Virginia Railway Express (VRE) stations, which are widely used to commute into Washington D.C. OmniLink's route deviation service succeeds in creating a larger service area without increasing the number of vehicles needed (Wilkins, 1995).

Prior to July of 2000, OmniLink service was only provided between the hours of 7:30am and 6:00pm. However, PRTC realized the need for extended service and OmniLink is now provided from around 5:30am to around 10:45pm, depending on the route. The vehicles operate on headways ranging from 45 to 55 minutes.

OmniLink presents customers with several options. They can catch the bus at either an OmniLink bus stop or an on-demand bus stop, or they can call to reserve an off-route trip. The OmniLink bus stops are listed in the published schedules and are designated with a dot on the route map in Appendix A. On-demand bus stops are locations where OmniLink buses will stop if a customer calls ahead and requests that a bus stop there, or if a customer requests that a bus operator drop them off there. On-demand bus stops are designated with a triangle on the route map in Appendix A. Customers can call to schedule off-route trips between the hours of 7:30am and 7:00pm Monday through Friday if they would like to be picked up or dropped off at a location that is within three-quarters of a mile of an OmniLink bus stop. Off-route trips must be scheduled no less than two hours in advance of the requested pick-up time. The shaded areas surrounding the routes on the route map in Appendix A designate areas that are accessible through this service. In addition to these services, standing orders are accepted for repeat trips. Fifty percent of OmniLink's route deviation trips are standing order.

Customer Service Agents take pick-up and drop-off requests from customers and work to identify a location that is reasonably close to the requested location but remains within three-quarters of a mile of an OmniLink route. In an effort to increase operating efficiency, bus operators are able to select the route they use between stops when deviations are required, and they are not required to return to the route at the point of deviation. It should also be noted that OmniLink bus stops have been strategically placed at locations where the street network requires the vehicle to pass the stop regardless of the path traveled. In addition, as new stops are needed due to changes in demand, the only locations that are considered are those that would not negatively impact the route deviation.

A one-way trip on OmniLink generally costs $0.75, and the fare can either be paid with cash or with tokens that can be purchased at the Manassas City Hall or at the PRTC/OmniRide Transit Center in Woodbridge. Discounts are offered for passengers transferring from OmniRide or the Virginia Railway Express (VRE), which is the local commuter rail service to Washington, D.C. The various OmniLink fares are listed in Table 3.1 below.

Table 3.2: OmniLink Fares

One-Way Fare	$0.75
Reduced Fare *	$0.35
Children under 6 years (with a fare-paying adult)	FREE
Regular Fare Transfer	$0.25
Reduced Fare Transfer *	$0.10
OmniRide Transfer	$0.25
* Between 9:30am and 3:00pm, and from 7:00pm until closing, adults 60 years and older, persons with a disability, or persons presenting their valid Medicare card are eligible for reduced fares.	

3.2   AN EARLIER ATTEMPT AT IMPLEMENTING ITS CONCEPTS

Prior to the current project, PRTC attempted implementation of a similar intelligent transportation system. ITS enhancements were added to the OmniLink system beginning in October of 1997 after PRTC responded to a Federal Highway Administration (FHWA) call for projects. FHWA was interested in testing ITS concepts with the use of operational tests. OmniLink's proposed ITS enhancements included Global Positioning System automatic vehicle location technology, Trapeze-Flex Scheduling and Dispatching Software, Mobile Data Terminals on the vehicles, and a Digital Radio communications system (Farwell and Marx, 1996; SaFIRES, 2001).

The original integrated ITS operational test was termed Smart Flex-Route Integrated Real-Time Enhancement System, or SaFIRES. The stakeholders involved in the project included FHWA, the Federal Transit Administration (FTA), PRTC, the Northern Virginia Planning District Commission (NVPDC), the Virginia Department of Rail and Public Transportation (VDRPT), GMSI, Inc., ManTech International, UMA Engineering Ltd., SG Associates, Trapeze Software, Inc., and Tidewater Consultants, Inc. As part of the APTS program, the SaFIRES project was evaluated by the Volpe National Transportation Systems Center (the Volpe Center). Castle Rock Consultants, Inc. performed the evaluation and operational test under contract to Battelle (Harris, 1996).

The SaFIRES project was accepted by FTA as an APTS operational test, and the test was scheduled to last for thirty months. According to the *National Evaluation Plan for PRTC*, the primary goal in conducting the operational test was to determine whether an ITS-based system could be a cost-effective way to reduce traffic congestion, gasoline consumption, air pollution, and mobility problems for residents of low-density suburban and rural areas. According to the same report, it was hypothesized that the system would provide greater effectiveness and efficiency in serving the public transportation needs of the community than would be the case in a non-ITS enhanced environment (PRTC, 1995).

As a result of this project, OmniLink currently uses the "FLEX" Computer Aided Dispatching and scheduling system, Version 4.3.1 Patch 14 from Trapeze Software

Company. Although the Trapeze computer-scheduling system was installed, the development and integration of the communications elements of the project were never completed after the commercial communication provider went bankrupt in the spring of 1998 (PRTC ITS Operational Test, 1995).

Some of the problems that PRTC identified as stumbling blocks to this initial project were developmental difficulties, the loss of two communications providers, turnover and corporate changes, and the lack of scheduling software enhancements as expected. They also identified the following lessons learned as a result of these and other challenges (SaFIRES Lessons Learned, 2001):

- As it takes longer to implement a project, the employee confidence will decrease.
- It is important to designate a project manager and other managers responsible for particular phases of the project.
- It is important to educate employees about the purpose of the project and its intended outcomes.
- Having comprehensive training on the ITS components enables employees to overcome initial implementation and operational difficulties.

3.3   A NEW SYSTEM: THE CURRENT CHALLENGES AND GOALS OF PRTC

After experiencing the first project's failure, PRTC managers were understandably hesitant to become involved in another ITS project. However, they realized that an intelligent transportation system could address many of the challenges they face in providing quality service to their customers. In October of 2001 they issued a request for proposal for a new system to work in conjunction with their existing flex scheduling software (PRTC's Request for Proposal, 2001).

3.3.1   The Need for an Intelligent Transportation System

PRTC's current process for dispatching involves a system of radio communications between the PRTC dispatchers and the OmniLink bus operators. Since this is the only method of communication available, it is often challenging for an operator or dispatcher to get the attention of another operator or dispatcher when necessary. While it is preferred that pick-ups and drop-offs be scheduled two days to two hours in advance, there are circumstances in which dispatchers accept unscheduled trips and fit them into the current fleet manifests. In this case they then need to communicate this new trip to the appropriate operator. In addition, there are unforeseen events such as when a vehicle requires immediate maintenance. In times such as this, radio contact is required to communicate the problem to the dispatcher and to work out a solution. Sometimes the solution is relatively quick, but often it will involve either a detailed explanation of a route or the vocal communication of a manifest change. When the one line of radio communication is tied up during a call between one operator and the control center, none of the other operators can communicate with the dispatcher. This results in a demanding

working environment for the dispatcher as they identify solutions to the many problems that arise during the course of providing service.

In addition to these challenges, OmniLink currently has limited ways to measure the effectiveness of the service that they provide. Their current methods of evaluation rely solely on data collected by bus operators. Since it is in the operators' best interest to appear to be on-schedule, and there is no way to monitor their behavior, the data is not likely to be very accurate.   Because a government agency is often rewarded if they can prove that investment of public funds in their service has provided benefit to the population, it is important to have an accurate reflection of the service provided in order to identify areas that need improvement and to report favorable results accurately to the appropriate budget agencies.

Another challenge PRTC faces is that the OmniLink bus operators are contracted through WMATA (the Washington Metropolitan Area Transit Authority), and are actually WMATA employees. These operators come from all over the metropolitan area and are therefore not usually familiar with the service area. In addition, there is a high turnover rate among the operators since WMATA rotates the employees throughout the metropolitan area.

As a result of these operator challenges and the other challenges cited earlier, the OmniLink service would benefit from an intelligent transportation system that would make the system easier to use for all involved and would provide the operators with more information.

3.3.2   The Project Status

PRTC resumed discussions about an intelligent transportation system for OmniLink in January of 2001, two and a half years after the initial ITS project failed. They are now in the process of implementing a new system to improve the quality of service that they provide to their customers. The three major ITS components of the OmniLink project are in-vehicle Mobile Data Terminals (MDTs), integrated Automatic Vehicle Location (AVL) facilitated by a Global Positioning Satellite System (GPS), and an established interface between these and the existing Computer Aided Dispatch (CAD) and Trapeze FLEX software. The project is scheduled for completion in November of 2002.

Recently, there has been much interest in determining if investing in intelligent transportation system technologies can provide an economically viable alternative to investing in physical infrastructure. In this case, PRTC believes that investing in ITS technology will allow them to improve OmniLink's quality of service without requiring any additional buses. It is expected that by improving the amount of and quality of information that is provided to the bus operators, the service will be improved without the need for more vehicles.

Based on input from PRTC management, information gained from the literature review, and other sources, the following objectives were identified as being key to the success of this ITS investment:

- Improve Service Reliability (Transit Schedule Adherence)
- Enhance Service Efficiency (Transit Travel Time Savings)
- Improve Safety and Security
- Improve Communications between Dispatchers and Operators
- Improve Operators' Knowledge of Routes
- Improve Customer Satisfaction
- Improve Working Conditions for Dispatchers (Specifically Noise Level)
- Ensure Utilization of System Features
- Ensure System/Equipment Reliability
- Improve Performance Monitoring (Improve Accuracy and Quantity of Data)
- Improve Labor Efficiency
- Improve Ability to Monitor Operator Behavior

Each of these objectives is addressed in great detail in Section 5.1 – Evaluation Objectives and Measures. This section also identifies appropriate corresponding measures for each objective for the purposes of evaluation.

CHAPTER 4: DESCRIPTION OF THE SYSTEM TO BE EVALUATED

This chapter describes the various aspects of the Intelligent Transportation System (ITS) project that is being implemented on OmniLink. The system involves a fully integrated CAD/MDT/AVL system. Although the system will not be completed and operating until the fall of 2002, this section describes the system as it will be once it is in operation. It describes the system, the system architecture, and the system requirements. It should be noted that much of the information in this Chapter was obtained from ARINC's Proposal of work for the OmniLink project.

4.1   STAKEHOLDERS

The stakeholders of a transit project are those persons or organizations who stand to gain or lose as a result of the implementation of the technology. The key stakeholders are committed to the success of the project. In the case of this project, PRTC is the primary stakeholder. Additional major stakeholders include the following:

- ARINC Incorporated - serving as the project coordinator and systems integrator
- Greyhawk Technologies, Incorporated - supplying the MDT hardware and software
- Trapeze Software Group - providing modifications to the flex-route scheduling and dispatch system that PRTC currently owns
- Dynamic Concepts, Incorporated - providing installation services
- IBI Group - acting as the farebox project consultant

4.2   DESCRIPTION OF THE SYSTEM

The OmniLink ITS project involves a fully integrated CAD/MDT/AVL system. The CAD system dispatches OmniLink vehicles with the MDTs, automatically tracks the vehicles' locations with a Global Positioning Satellite (GPS) system, and provides the dispatchers with real-time information about the on-time performance of the vehicles. The various subsystems are described in the sections below.

4.2.1   *Automatic Vehicle Location System*

Automatic Vehicle Location (AVL) is a computer-based tracking system that was originally developed for military purposes. AVL is now commonly used to monitor vehicles in transit and paratransit fleets, as well as trucking companies. In transit applications, the real-time position of each vehicle is calculated and then relayed to a control center.

The three principal methods of automatically tracking vehicles are using signals from signposts, dead reckoning, and using signals from global positioning systems (GPS).

GPS is the most commonly used technology for AVL. In order to use GPS, each vehicle must be equipped with a satellite receiver. At regular time intervals the receiver scans the signals from at least three satellites and determines the location of the vehicle by measuring the distance from the receiver to the satellites. The vehicle's location is then automatically sent to the central control facility where the location is displayed on a map. In some cases GPS-based AVL systems are supplemented with dead reckoning systems that use compass and odometer readings to maintain location references when the line of sight to the GPS satellites is obstructed by buildings or other obstacles (Casey, 2000; Riverside, 2001).

The GPS unit on-board each vehicle is an eight-channel GPS receiver that updates at least once per second. The common synchronized clock used is the GPS satellite-supplied time. GPS is used to determine each vehicle's location, time, heading, and speed. This information is then transmitted over the communications network to the dispatch center at the following specified times:

- When a regularly scheduled predetermined interval of time has passed
- When the vehicle has moved a predetermined distance
- When the vehicle operator sends a status message via the MDT
- When there is any change in the vehicle status (including when the operator activates any of the buttons on the MDT)
- When an operator change takes place
- When the covert alarm has been depressed by the operator (in this case the GPS reports the vehicle's location to the control center at least every 15 seconds)

The AVL Tracker System uses GPS-based technologies to allow customer service, dispatch, and management personnel to visually track on a map the vehicle location and the on-time performance of all bus operators. It provides the dispatchers with information about where each of the vehicles are and in which direction they are traveling, allowing them to more efficiently manage the fleet. In addition it allows dispatchers to convey new trip assignments and ride cancellations in an efficient and dependable manner. The system provides the dispatchers with the following information about each vehicle:

- Vehicle ID
- Operator/Operator ID
- Run ID
- Logged On Status – On/Off
- Longitude
- Latitude
- On-time Status
- Sector ID
- Last Update Time
- Vehicle Direction (Heading)

Each vehicle is also equipped with an odometer interface that provides the MDT with mileage information. The odometer readings are captured with the use of GPS. This data is transferred to the dispatchers with each 'arrive' and 'perform' transaction. Tracking odometer readings allows for distance-based methodologies to be used in evaluation. It should also be noted that AVL information is used for the automatic passenger counter and the covert alarm functions of the OmniLink system.

4.2.2   *Mobile Data Terminal System*

A Mobile Data Terminal (MDT) is an in-vehicle device with a small screen that displays messages, along with the time. It allows bus operators to write custom messages and send canned messages to the dispatch center. Once installed, MDTs are the primary method of communication between the operators and dispatchers.   When used in conjunction with an AVL system, MDTs generally have the ability to calculate the vehicle's location, and compare the location and time to the schedule. The system then determines the vehicle's schedule adherence and displays it on the MDT screen.

In-vehicle MDTs handle digital dispatching by serving as the interface between the vehicle operators and the dispatchers. The MDT program is designed to work very similarly to the way in which the operator manually completes the route, but it automates the process and does much of the operator's work for him. Route insertions and cancellations are automatically incorporated into the route. Bus operators are dispatched via MDTs and they can query the system to obtain routing instructions from their existing location to their next scheduled location, or between two upcoming scheduled locations. The MDT shows the operator the location on a map, along with line by line turning instructions of the route.

When an operator logs into the system, the software automatically downloads their manifest for the day. The manifest shows fixed stops and deviations on their run in chronological order. While the operator is completing his assigned run, the MDT automatically updates the manifest with stop and trip data for the next "X" period of time or "Y" number of events (scheduled bus stops and deviations), where "X" and "Y" are programmable at system set-up. In addition the system automatically updates the manifest by removing each stop after it has been serviced and the vehicle has departed. When the operator pulls into a geographically defined area surrounding the fixed stop, and then leaves that area to travel to the next stop, the system identifies that a stop has been responded to and serviced. The reasons that this determination is not linked to any other event, such as the vehicle stopping, the door opening, or the operator taking action, is that not every bus stop will have boarding and/or departing activity.

Another feature of the MDT is the "no show" clock. Each time an operator arrives at a scheduled pick-up, and the customer is not immediately present, the operator can press the "no show" button and the timer will begin to count down five minutes. Once the five minutes has elapsed, the system automatically sends a message the dispatcher requesting approval for a no-show. Once receiving approval, the operator is permitted to leave and

continue on his or her route. This feature eliminates arguments regarding how long a vehicle waited for a customer.

It should be noted that the MDT does not immediately respond with location information when an operator logs into the system. Once an operator has logged into the system in a vehicle, the 'Time to First Fix' is generally as listed below for each of the following states:

- Cold start – less than 120 seconds
- Warm start – less than 45 seconds
- Hot start – less than 20 seconds

In order to save time on the road and to increase safety while driving, there is a terminal in the operator lounge at the transit center that bus operators can use to preview their manifest before beginning their route. In this way they can become familiar with their schedule for the day prior to getting into the vehicle.

Whenever the system determines that a vehicle is at a fixed stop, the MDT automatically presents the operator with a data entry screen so that they can enter any passenger boarding and departing information. After pressing the "Arrive" button on the MDT, a timer begins to count down the amount of time spent waiting on the client. After a set amount of time elapses (in the case of OmniLink, this time is five minutes) the operator is able to press a "No Show" button to alert dispatch that the operator has waited the designated period of time. The dispatcher then approves the "No Show" and a message is sent back to the operator allowing them to proceed to service the next item on the manifest. If the client boards the vehicle before the time has elapsed, the operator pushes the "Perform" button to notify dispatch that the client has boarded and that they are proceeding with the manifest.

At any point in time the dispatcher has the ability to send either free form text or canned messages to the operator. When this happens the operator receives visual and audio notification that they have received a message and they must press the acknowledgement key to let the dispatcher know that they have received the message. In addition the operator can send either free form text or canned messages to the dispatcher. PRTC will work with GreyHawk to identify a list of canned messages that will be available to the operators. It should also be noted that for obvious reasons the bus operators are not encouraged to send or read messages unless the vehicle is stationary.

The MDT unit automatically sends AVL records every X minutes. In addition, the unit alerts dispatch whenever the following events occur:

(1) A vehicle is more than X minutes behind schedule.
(2) An operator has performed a route out of sequence.
(3) An operator has pressed the covert alarm button.

(4) An operator has pressed the "arrive" button signifying that they have serviced a deviation, but the system has detected that the vehicle is not at the correct location.

4.2.3   Electronic Fareboxes

For effective planning and operation, transit agencies need to have information on not only how many passengers they are carrying, but also on where passengers are boarding and alighting. Many transit agencies are finding that electronic fareboxes are an excellent way to automatically collect data on passenger boardings and alightings. OmniLink's electronic fareboxes will perform the following functions:

(1) Count each passenger boarding
(2) Determine the vehicle's location when a boarding occurs
(3) Determine the time when a boarding occurs
(4) Determine what type of fare media is used
(5) Transmit the data in real time
(6) Categorize this information according to route

PRTC will be receiving GFI/Cubic Odyssey fareboxes in late 2002 or early 2003. They will be integrated into the rest of the intelligent transportation system at that time. The fareboxes will accept cash and tokens like the current fareboxes; in addition they will accept *SmartTrip*, the smart card that is used on Washington Metro. In an effort to encourage use of smart cards, the fareboxes will no longer accept discounts for transfers unless the customer uses a *SmartTrip* card as their fare media.

4.3   SYSTEM ARCHITECTURE

The system architecture is the framework that provides the structure to facilitate the formulation of an ITS design. It involves the set of components that make up the system. There are two parts that form the system architecture: the logical architecture and the physical architecture. The logical architecture depicts the flow of data through the system, while the physical architecture depicts the relationships between the subsystems in a diagram commonly called a 'sausage diagram'.

An important aspect of the OmniLink system architecture is that in order to meet Federal guidelines with respect to the National ITS Architecture, it is expected that a vehicle area network (VAN) will eventually need to be installed on all PRTC vehicles. For this reason it should be noted that all of the in-vehicle equipment has been designed with the ability to interface with the vehicle area network (VAN) if this becomes necessary.

4.3.1   Logical Architecture

As stated previously, the logical architecture depicts the flow of data through the system in a clear and logical manner.

4.3.1.1 Automatic Vehicle Location System

Each of the sixteen buses in the fleet is equipped with a global positioning satellite unit (GPS). Satellites continuously calculate the latitude and longitude of each vehicle in order to determine where they are located. This data, which is known as Automatic Vehicle Location (AVL) information, is then transmitted to the dispatch center. It is transmitted at regular time intervals, usually from one to five minutes, according to a parameter in the vehicle system. Once the GPS latitude and longitude coordinates are transmitted from the vehicles to the dispatch center, they are plotted on a map at the dispatch center to show exactly where each vehicle is located at any point in time.

The logical architecture of the AVL system is depicted in the diagram below. It involves the transmission of the bus location information via wireless communications between the global positioning units and satellites. It also involves the transmission of data from the vehicles to the radio tower via wireless communications, and then to the Gateway System at the dispatch center via wireline communications. Once it reaches the dispatch center, the AVL data is stored in a database on a computer on the Local Area Network (LAN).
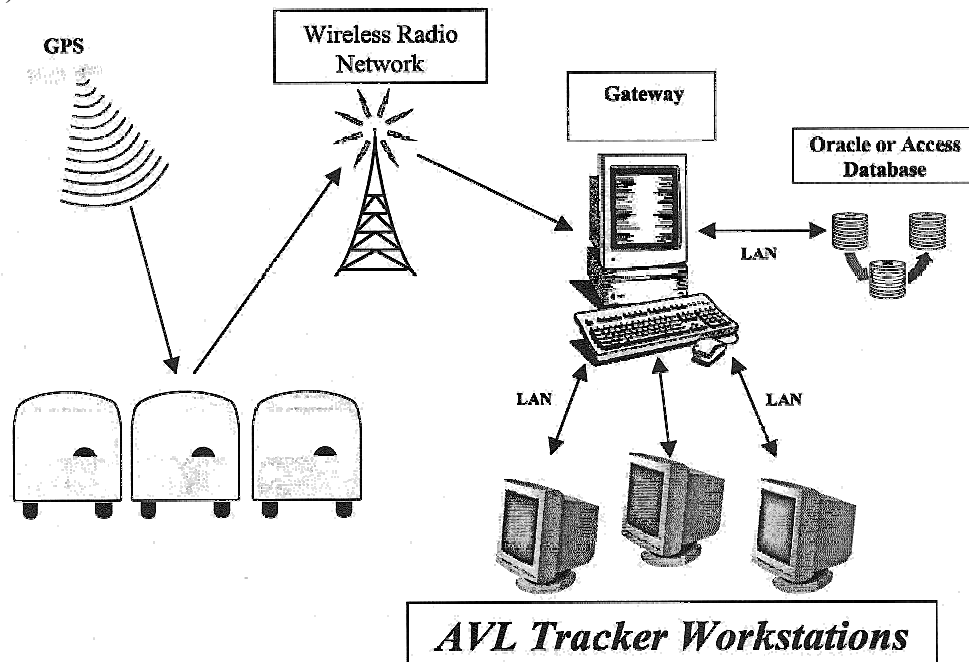
Source: ARINC Proposal

Figure 4.1: Logical Architecture of AVL System

4.3.1.2 Mobile Data Terminal System

The Gateway is a communications program that interfaces with the Trapeze scheduling and dispatching system and controls the radio transmissions to and from the MDT units in the vehicles. The Trapeze dispatching system schedules the routes and is used by the dispatchers to monitor the activities of the bus operators.

Data that needs to be exchanged between the vehicles and the dispatch center is transmitted in much the same way that the bus location data is transmitted from the vehicles to the Gateway System at the dispatch center. However, the information from the dispatcher must first pass through the FLEX MDT/AVL Interface before reaching the Gateway Server. An operator's manifest is transmitted from the dispatching system to the vehicle MDT where it is displayed on the screen. As the operator arrives at each destination and completes a trip, transactions of these events are transmitted to dispatch where they automatically update the scheduling system. In addition, messages can be transmitted to and from dispatch and the vehicles in the same manner.
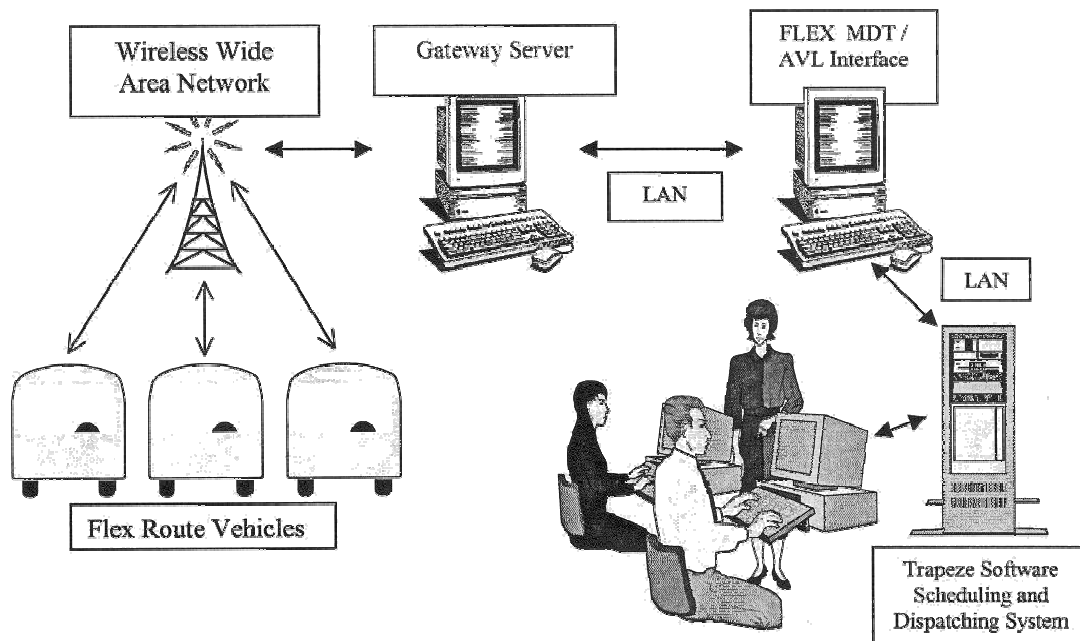
Source: ARINC Proposal

Figure 4.2: Logical Architecture of Mobile Data Terminal System

4.3.1.3 MDT/AVL Interface

The MDT communicates with the Trimble Navigation GPS receiver using the Trimble Standard Interface Protocol (TSIP).
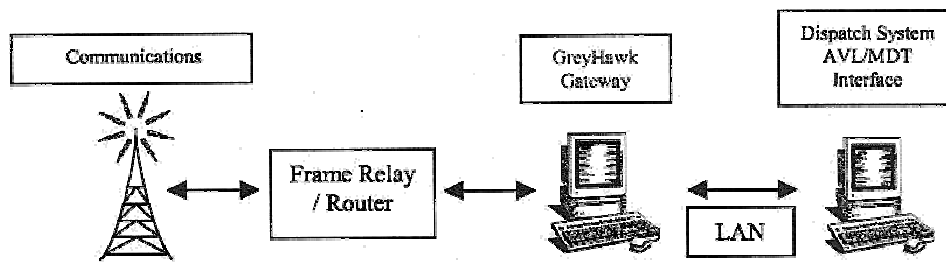
Figure 4.3: Logical Architecture of MDT/AVL Interface

Cellular Digital Packet Data (CDPD) communications transmit data to and from the MDTs in the vehicles. The data is transferred via a wireless network to and from the transit vehicles and the communications tower. From the radio tower the information travels to a base station or frame relay connection and is routed to the Internet Protocol (IP) address of a computer at the transit center. A network interface card then routes the data to the PRTC Local Area Network (LAN) where static IP addresses control the destination of the data records to the dispatching system. The interface between the Gateway program and the dispatching system monitoring program is via the LAN.

Data communications traffic to and from the MDTs in the vehicles and the dispatching system are controlled by a combination of MDT and dispatching system Application Interfaces (APIs). These applications run on separate computers at the dispatch center. The function of these programs is to reformat data into the required record structures needed by the receiving system and to transmit the data using the proper protocol. Since the data is sent and received, it must be reformatted when it is transferred in each direction so that the destination system receives it in the proper format.

4.3.2   Physical Architecture
The physical architecture is depicted in the 'sausage diagram' below showing the interconnections between the various subsystems. As shown in the diagram, the GPS Units and MDTs are vehicle subsystems, which must be accessed via wireless communications, while the rest of the components are subsystems at the transit center. As the diagram shows, the OmniLink project does not involve any traveler or roadside subsystems.
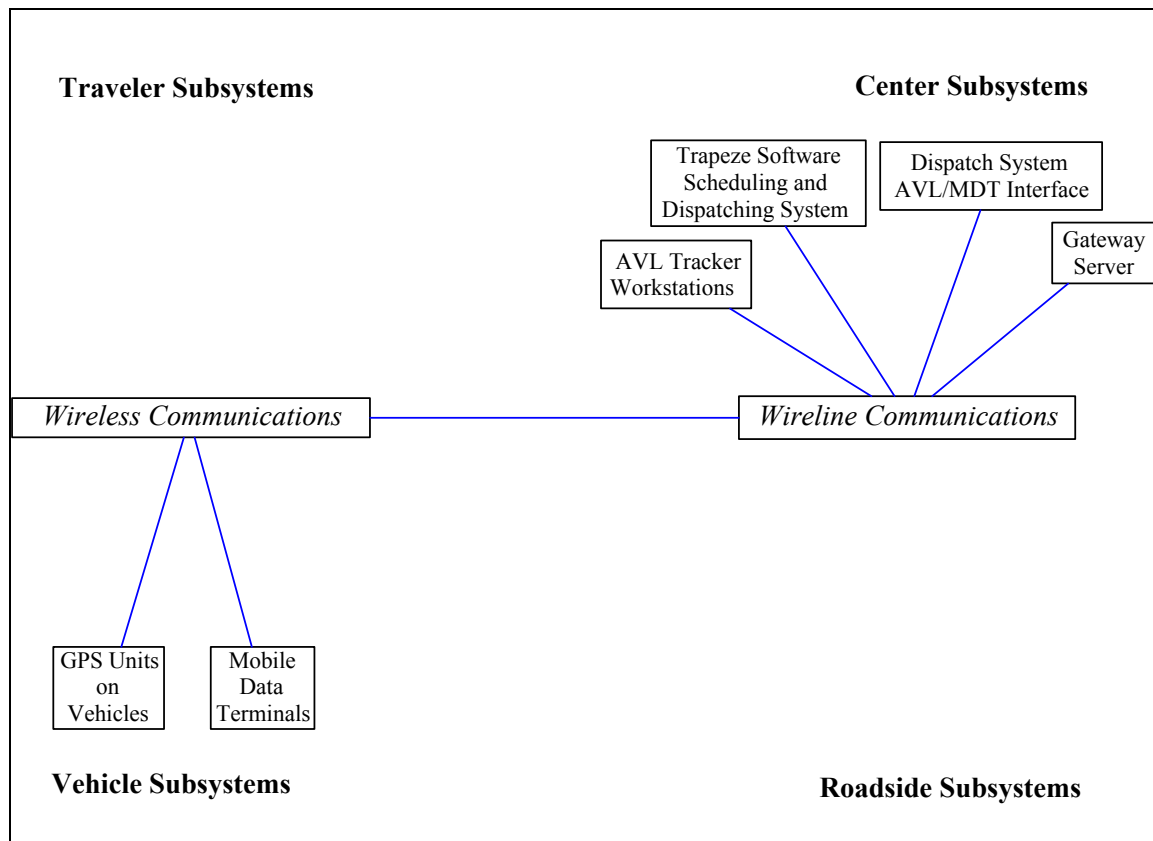
Figure 4.4: Physical Architecture

4.4   SYSTEM COSTS
Costs are an important aspect of any transit system. This section defines the costs involved and presents a cost efficiency analysis.

4.4.1   Fixed and Variable Costs

System costs can be divided into two basic categories: fixed and variable costs. Fixed costs, which can also be referred to as non-recurring costs, are costs that are accrued once at, or near, the beginning of the project and are not required again. Fixed costs remain constant regardless of the transit service demand. Examples of fixed costs are capital costs such as hardware and hardware installation. These costs are accrued as the system is installed, and the cost to install the system will be the same regardless of how many passengers are using the service. The items involving capital costs in the OmniLink project are the GPS units, the MDT units, the computer facilities upgrades, the hardware installation fees, and the initial operator and dispatcher training fees.

Variable costs, which can also be referred to as recurring costs, are costs that continue for a number of years after the project is installed and operational. In some cases the

variable costs are related to the demand in that they increase as the demand increases. An example of this could be that as the ridership increases, the operators use the MDT equipment more frequently causing it to require more maintenance. However, in many cases, maintenance costs are determined in advance according to an agreement regardless of the amount of time the contractor spends maintaining the system. Variable costs for OmniLink include monthly fees to lease the communications lines and to maintain the hardware systems.

4.4.2   Cost Efficiency Analysis

The cost efficiency analysis presented here measures the financial impacts of the system although it is realized that much of what is gained from the system is not easily measured in financial terms.

4.4.2.1 Current Capital and Operating Costs

In order to facilitate a comparison of annual costs with and without a proposed system, it is necessary to calculate the current annual operating and capital cost per bus along with the projected annual operating and capital cost per bus. The cost of the service without the proposed system can be calculated by taking the capital cost of the entire fleet and annualizing it over a period of seven years, the expected average life of a bus. This yields the current equivalent annual capital cost per bus. The current annual operating cost per bus can be determined based on OmniLink's historical data. The sum of the annual capital cost per bus and the annual operating cost per bus equals the total annual cost per bus, $184,351 as shown in Appendix B.

4.4.2.2 Projected Capital and Operating Costs

For the cost of the proposed system, the projected capital cost of the entire fleet is calculated to include the addition of GPS and AVL equipment, and new computer hardware and software. This value is then annualized over a period of seven years, the expected average life of a bus. This yields the projected equivalent annual capital cost per bus. The projected operating cost per bus includes maintenance of the system and wireless communications costs. The sum of the annual capital cost per bus and the annual operating cost per bus equals the total projected annual cost per bus, $193,446 as shown in Appendix B.

The cost to implement the system is relatively small as compared to the overall operating and capital cost. Based on the calculations, the increase in the total annual cost per bus to implement the proposed system is $9,095, which is a 5% increase over the current annual cost per bus. It is important to note that this projected increase assumes that there would be no gains in operating efficiency since such gains would result in an operating cost savings that has not been reflected in the calculations.

4.4.2.3 Cost Summary

The break-even point is the point at which the cost spent on the project would be recouped from the gain in operating efficiency. Dividing the projected annual cost increase per bus ($9,095) by the historical operating cost per bus per hour ($53) yields a result of 171 hours. This is shown in Table 4.1 below.

Table 4.1: Cost Summary Table

Item	Value
Current Annual Cost per Bus	$ 184,351
Projected Annual Cost per Bus	$ 193,446
Increase in Annual Cost per Bus	$ 9,095
Current Operating Cost per Bus per Hour	$ 53
Annual Time Savings per Bus Required to Justify Project	171
Total Annual Operating Hours per Bus	3,056
Efficiency Gain Required to Justify Project	**5.58%**

As seen in Table 4.1 above, the proposed system would pay for itself if it were to allow PRTC to realize a 5.58% gain in efficiency. This is equivalent to reducing the total bus operating time by 3,056 hours throughout the course of each year. However, there are many factors that can result in a gain in efficiency and improvements in each of these factors can justify the investment on an economic basis. However, as mentioned previously, it is realized that this analysis does not prove that the system would only be justified if the gain in efficiency were achieved because there are many benefits gained which are not captured by a purely cost-based analysis.

4.5   USER SERVICES

In their quest to develop a common nationwide structure for the design of Intelligent Transportation Systems, the U.S. Department of Transportation has identified twenty-nine user services, grouped into seven bundles, to differentiate the many ITS technologies. User services describe what a system should do, from the user's perspective.

The primary user service bundle that is employed with this project is *Public Transportation Management*, which dictates that the technology will allow the gathering of information on mileage, vehicle location, and deviations between predetermined operating condition specifications and what is actually happening. This service also requires that the APTS allow the capability to automatically issue corrective instructions to the driver including route corrections and changes in stops. The SaFIRES project clearly meets this user service

Route Guidance is another user service that is partially provided by the SaFIRES project. Route guidance provides operators with directions to selected destinations. According to this user service, these directions should be based on information about the current conditions of transportation systems, events taking place that influence travel routes, and street closures. The SaFIRES system does not completely meet the requirements for this user service because it provides operators with directions to their destinations, but the information is static and not based on current conditions.

It should be noted that this system will eventually fit into a larger one proposed by the U.S. Department of Transportation, anticipated to be a state-of-the-art information network that will provide real-time information about all modes of travel (highway, bus, rail, and air) in the metropolitan area. This information will include audio text systems for transit and road conditions (weather-related, congestion, incidents, travel times, schedules, etc.), a web-based interface for similar information, and in-vehicle systems, pagers, cable, and interactive television.

4.6   SYSTEM HARDWARE REQUIREMENTS

There are many hardware requirements for this system. They are listed in the following sections according to system.

4.6.1   *Automatic Vehicle Locator System*

The AVL Tracker System requires computer technology in each vehicle, at the dispatch center, and on every AVL Tracker terminal. Multiple computers connected to the LAN can be used to execute the AVL Tracker program. Each one can be configured separately to meet the requirements of individual bus operators so that, for example, customer service representatives can concentrate on a specific set of vehicles, while dispatchers or managers concentrate on different sets of vehicles. The AVL Tracker program must be installed on each workstation computer, and the LAN attachment is required to be able to retrieve data from the AVL database.

The AVL Tracker program reads the database on the AVL Database computer to obtain the last known location of each vehicle in the fleet. The Tracker system then uses the latitude and longitude coordinates to plot the positions of the vehicles on the street level map by placing an icon of a vehicle at that map location. The vehicle icon displays on the map pointing in the same direction as the actual vehicle.

4.6.2   *Mobile Data Terminal System*

The MDT System consists of hardware and software both at the dispatch center and in the vehicles. The dispatch center system requires a computer running the Gateway program that controls the communications to and from the vehicles and exchanges MDT data with the Trapeze interface program.

The vehicle MDT system runs two types of software: the *Paratransit MDT Application Program,* and the *MDT Communications Middleware,* which handles the radio communications with the Gateway program. In addition to the software, each vehicle contains the following hardware for the MDT:

- Touch screen computer running Windows CE operating system
- Global positioning unit (GPS) with antenna
- Wide area network (WAN) radio data modem with antenna
- Odometer capture

The MDT computer onboard each vehicle has the following specifications:

- 206 MHz Processor
- 640 MB Hard Drive
- 32 Megabytes of RAM Memory
- 16 Megabytes of Flash Memory
- 10.4" Color, Active Matrix Touch Screen Monitor
- Serial Ports and 1 Network Port
- 8 Channel GPS Unit with Trimble Navigation Internal Circuit Board
- CDPD Modem with Internal Circuit Board
- 12 Volt Vehicle Power Supply

4.6.3   *Communication Systems*

For the purposes of transmitting data to and from the MDTs in the vehicles, PRTC is using a CDPD communications system. CDPD is an Internet Protocol router-based network architecture that is actually an overlay on the surrounding cellular network. It uses idle time between voice calls on the network to transmit data. The data travels via the wireless network to and from the transit vehicles and the towers. From the radio tower it travels to a base station or frame relay connection and is routed to the IP address of the system's computer at the centralized Transit Center. A network interface card routes the data to the PRTC Local Area Network (LAN) where static IP addresses control the destination of the data records to the dispatching system. The interface between the Gateway program and the dispatching system monitoring program is via the LAN.

4.7   OPERATIONAL STRATEGIES

Some of the most important operational strategies deal with monitoring the vehicles to ensure that the system is being used to its maximum potential and that it is, in fact, providing the desired quality of service. Improving the efficiency of the service is one of the main goals that PRTC hoped to address in making this ITS investment.

The AVL tracking program provides customer service representatives, dispatchers, and management personnel with a way to visually track the vehicle location and the on-time performance of the vehicle operators. This allows them to maintain operations efficiency.

At this time there are three dispatchers employed by PRTC to work on OmniLink. At any point in time one dispatcher is in charge of monitoring all of the buses that are currently in use. The dispatcher is in charge of monitoring the buses, reviewing the reports, and contacting the operators if they detect a problem. The MDT supplies route statistics to the supervisors so that they can monitor the daily job performance of the operators. The reports that are automatically generated include the following information:

- On-time performance by route, operator, time of day, and location
- Number of passengers by route, fare type, pick-up and drop-off
- Deviation no-shows and cancellations by passenger name and location
- Transmission log including all data communications for the purposes of review
- National Transit Database (NTD) calculation of passenger miles for all or a sample of selected trips/days

The MDT also supplies the operators with route statistics to provide them with information about their own daily performance. The operator can access the "Summary Screen" at any point in time to view accumulated totals and statistics of their performance for the day. These are cumulative totals for the day beginning when they logged in. The passenger summary shows them the counts of all riders, no-shows, and cancellations for the day. The on-time performance shows them the number and percentage of on-time arrivals for the day's pick-ups and drop-offs. These calculations are based on the route's "Beginning of Window" arrive times that were originally downloaded to the MDT. For this reason, insertions, cancellations, and delays may drastically affect these performance measures. To assist the supervisors in recognizing on-time performance, the 'Promised' and the actual 'Arrive' times are updated and displayed next to each other.

Along each route there are fixed bus stops. Some of these stops have published timepoints associated with them while some do not. The system monitors the buses performance against the schedule for the purpose of providing a schedule adherence capability. As the operator travels through their run, the system automatically keeps the operator advised of the vehicle's current performance status. Monitoring this status, updating the data, storing it in memory, and collecting the data required to make these determinations, does not require any interaction from the dispatcher or vehicle operator. The vehicle icons used to plot the location of each operator are color coded to show the supervisor the "on-time" status of that operator. The status is based on the "beginning of window" time compared to the current time. The color-coding scheme is shown in the table below. It should be noted that the color-coded status does not take into consideration the distance that the operator needs to travel in order to reach their destination. The time limits listed are specified by parameters in the program. In

addition, there is a map key that the operator can use as a cross-reference for the color-coding.

Table 4.2: On-Time Status Map Key

Icon Color	On-Time Status	Description of Status
Blue	Operator is early	Current time is before the 20 minute "start of arrive window" time
Green	Operator is on-time	Current time is within the first 15 minutes of the 20 minute window
Yellow	Operator is almost late	Current time is past the 15 minute mark but before the 20 minute limit
Red	Operator is late	Current time is past the 20 minute limit

Source: ARINC Proposal

The published schedule for OmniLink service identifies all the fixed stops along each route. As mentioned previously, there are only timepoints published for certain stops on each of these routes. The bus schedule and schedule adherence are based on these timepoints or deviation reservation times. However, the system must also be able to determine route adherence, where route adherence is defined as the bus servicing each of the published stops in the correct order. The ability to monitor that the bus has properly serviced each of the stops along a route will not require any interaction from the operator or dispatcher and will keep both the operator and dispatcher informed of its current status. It should be noted that due to the flexible nature of the OmniLink service, deviation reservations can be accepted that will knowingly cause the operator to run somewhat later than the published schedule times. In addition to this, new deviations can cause previously accepted deviation times to be adjusted even further. However, as with regular fixed route services, timepoints cannot be moved earlier than published and buses cannot leave timepoints before the published schedule. The timepoints displayed or the operator must include both published times and Trapeze estimated arrival times. Additionally, as described below, the dispatcher has the capability to delete stops form the manifest and to revise the scheduled times to arrive at timepoints. The schedule and route adherence information the operator receives will be altered accordingly.

An audio and visual exception alarm is activated when a vehicle fails to be detected X minutes after its scheduled arrival time at a timepoint or deviation or if it arrives Y minutes early. When the vehicle does serve the timepoint or deviation, an alarm is also triggered. X and Y are programmable in one-minute increments and are able to be easily and quickly changed by the dispatcher.

In addition, an audio and visual exception alarm will be activated if a vehicle is detected at a stop out of sequence for the intended route as listed on the manifest. Schedule adherence will continue to be computed for all subsequent stops. An audio and visual exception alarm will be activated if a vehicle is later detected arriving at any stop in reverse sequence. In this case, schedule adherence can be disabled for all or part of the remainder of the run.

In addition to all of this, there is a software utility that allows reconstruction of the sequence of events, or "replay", of any particular run. This can be used for resolving disputes with passengers over whether a requested service was indeed performed.

When the dispatch center receives a cancellation and inputs it into the computer, the system automatically sets these trips as flashing on the operator's screen. Once the operator clicks on them to acknowledge the cancellation, the dispatcher receives a message letting them know that the cancellation was received.

4.7.1   Operations in Specific Situations

It is unlikely that an ITS project will function as expected at all times without any system failures or unusual circumstances. As a result, it is necessary to have some operational strategies in place to deal with these situations. Following are some of the specific operational strategies that have been considered on the OmniLink project.

Software Updates
In the event that there will need to be software updates to the MDTs in the vehicles, PRTC expects that they will transmit the information via CDPD while the vehicles are stationary at the transit center.

Communication Failures
The GPS system generates location data on a vehicle whenever the ignition is in the on position. When the AVL equipment cannot detect a vehicle's location due to blockage of the satellite signal, the system designates the vehicle's location as "NO LOC", and the last known location is included in the message. When a vehicle is out of the radio coverage area, the AVL equipment stores messages (including location and odometer information) until the data can be transferred. The AVL data is stored in the AVL database by the software as part of the system's historical reporting capability.

Emergency Situations
The vehicle operator has a covert alarm button on the side of his seat that can be pressed in the event of an emergency. The button has been designed so that it is easy to push but difficult to set off accidentally so that there will not be an excess of false alarms. When the button is pressed, the covert alarm automatically triggers the AVL reporting interval to be changed to 15 seconds so that the dispatcher will have more reliable information about the location of the vehicle. In addition, a message is received at the dispatch center alerting dispatchers that this vehicle is in emergency status. Once the alarm message has been received at the dispatch center, the clock display on the vehicle's MDT changes from black to red so the operator knows that his alarm message has been acknowledged. As soon as the vehicle is in emergency status there are no more 'normal' messages sent to the MDT, although the dispatcher is still able to send text messages if desired.

4.8   INSTITUTIONAL IMPACTS

The proposed system will require changes in the dispatching protocol along with changes in the operators' responsibilities. The changes for the operators will result in less work because they will merely press a button to log an arrival whereas previously they were required to log the information manually on paper. Although drivers will need to undergo training to use the system, they will reap further benefits such as receiving text messages and text directions.

The dispatchers will also require training for operating the new system as well as for maximizing the potential benefits of the system. As with the operators, the changes should result in less work for the dispatchers, as they will no longer be required to call over the radio to ascertain the locations of vehicles. With a glance at the computer screen, they will have more information than is currently available to them with the radio tracking method. As the system operation progresses, the dispatchers will be required to make more decisions. Whereas the current protocol includes a call to all operators to find out who can make a certain pick-up, the future dispatch would be a call to the operator who can make the pick-up with the least amount of disruption to the fleet. The dispatcher can select the appropriate operator with the aid of real-time tracking information. This change in dispatching protocol will need to be addressed by PRTC as part of the system implementation.

CHAPTER 5: PROPOSED EVALUATION FRAMEWORK AND PLAN

This chapter presents a proposed evaluation framework and plan and identifies the data that will be needed in order to study and monitor the system according to this plan. It also describes the analytical methods that correspond to the proposed evaluation framework and plan.

5.1   IDENTIFYING OBJECTIVES AND PERFORMANCE MEASURES

The first step in developing an evaluation framework is to identify the objectives of the system and the corresponding performance measures. This section describes how these were identified for the purposes of this work.

5.1.1   Objectives

The goals that a transit agency has for any ITS investment should be similar to the goals of the Advanced Public Transportation System (APTS) Program. The FTA has established the following four principal objectives for the APTS program (Casey and Collura, 1994):

(1) Enhance quality of on-street service to customers
(2) Improve system productivity and job satisfaction
(3) Enhance the contribution of public transportation systems to overall community goals
(4) Expand the knowledge base of professionals' contribution of public transportation systems to overall community goals

When OmniLink's APTS operational test began in 1993, PRTC identified several goals that they hoped to achieve by investing in an intelligent transportation system. Their goals, which were in line with the APTS program, were to do the following:

(1) Improve communication between dispatchers and bus operators
(2) Improve bus operators' knowledge of routes by providing them with more information
(3) Improve safety the security on the vehicles
(4) Improve the ability to monitor operator behavior

When PRTC issued their *AVL/Mobile Data System Request for Proposal* in October of 2001, they identified the key benefits that they hoped to achieve with the system. They were as follows:

(1) More information, better information, and more timely information for operators
(2) Simple operator interface to reduce paper workload
(3) Timely, useful information for dispatchers

(4) Easily retrievable/usable data to evaluate operations for future planning

For the purposes of this report, objectives of the current system have been identified after considering PRTC's previous objectives, speaking with OmniLink dispatchers and administrators about their goals for the system, and using knowledge gained from the literature review. These objectives, along with corresponding measures, data requirements, and analysis methods, are listed in Section 5.2. It should be noted that there are both qualitative and quantitative measures, and that the qualitative measures can be equally as important that the quantitative measures when evaluating a system's performance.

5.1.2   Performance Measures

Dajani and Gilbert (1978) say that a meaningful evaluative framework will, "specify the types of performance indicators and measures to be used in evaluating transit." Performance measures are key elements of an evaluation framework. The FTA (Casey and Collura, 1994) has established six basic performance measures that should be used when evaluating intelligent transportation systems. They are listed below.

(1) Costs
(2) Functional Characteristics
(3) User Acceptance
(4) Transit System Efficiency
(5) Transit System Effectiveness
(6) Impacts

Each of these performance measures are addressed to some extent in this report. The objectives and corresponding performance measures that have been identified for the OmniLink ITS project are listed in Table 5.1. The qualitative measures have been designated in blue.

Table 5.1: Summary Table of System Objectives and Performance Measures

Objective	Measure
5.2.1 Improve Service Effectiveness through Enhanced Reliability (Transit Schedule Adherence)	On Time Performance
	Perceived On Time Performance
	Arrival Reliability
	Perceived Arrival Reliability
5.2.2 Enhance Service Efficiency (Transit Travel Time Savings)	Run Time
	Trip Time
	Perceived Trip Time
5.2.3 Improve Safety and Security	Incident Response-Time
	Perceived Level of Safety and Security
5.2.4 Improve Communications between Dispatchers and Operators	Ease/Effectiveness of Communication
5.2.5 Improve Operators' Ability to Navigate Routes	Perceived Usefulness of Navigation System
5.2.6 Improve Customer Satisfaction	Number of Complaints
5.2.7 Improve Working Conditions for Dispatchers	Perceived Quality of Working Conditions
5.2.8 Ensure Utilization of System Features	Degree of Utilization of System Features
5.2.9 Ensure System/Equipment Reliability	Failure Rate of Covert Alarm Button
	Failure Rate of MDTs
	Failure Rate of GPS
5.2.10 Improve Performance Monitoring (Improve Accuracy/Quantity of Data)	Usefulness of Additional/More Accurate Data
5.2.11 Improve Labor Efficiency	Staff Time Associated with Processing Data
5.2.12 Improve Ability to Monitor Operator Behavior	Accuracy of On-Time Performance Data
	Accuracy of Arrival Reliability Data

5.2   EVALUATION OBJECTIVES

This section describes each of the objectives and measures that were identified in Table 5.1 in further detail.

5.2.1   Improve Service Reliability

In monitoring vehicle locations, AVL should promote schedule adherence. If a bus fails to adhere to its schedule, the dispatching center will obtain this information in real-time, through AVL. This will enable the dispatchers to respond quickly and appropriately to this knowledge.

Transit service reliability, which can also be referred to as schedule adherence, can be measured in terms of on-time performance, perceived on-time performance, and arrival reliability. Improving bus service reliability is an important goal for transit agencies because uncertainty about the arrival time of a bus (at both the origin and destination points) is one of the major reasons for reluctance among customers in using a bus service. If a customer knows that they can rely on a public transportation schedule, they will consider using public transportation (Greenfeld, 2000).

The on-time performance can be determined by comparing the scheduled arrival times to the actual arrival times. The arrival times include both passenger pick-ups and passenger drop-offs. It is important to note that the data collected prior to implementation of the AVL system may not be as accurate as the data after implementation since the drivers have been responsible for manually recording their arrival times in the past. Since it is in their best interest to appear to be on-schedule, and there is no way to monitor their behavior, it should be considered that the overall on-time performance may be over-estimated prior to the system implementation. However, this will be a good method for evaluating the system once the AVL has been in use for some time and the data before implementation is no longer needed for comparison purposes. The on-time performance can be calculated as (where PRTC's on-time window is 30 minutes since the bus is permitted to arrive 15 minutes prior to or 15 minutes after the scheduled arrival time):

$$on\text{-}time\ performance\ (\%) = \frac{n_{ot}}{n_{total}} \cdot 100$$

where:

n_{total} = *total number of arrivals*

n_{ot} = *number of arrivals where* $\left| t_{act} - t_{sch} \right| < \dfrac{x_{win}}{2}$

x_{win} = *value for "on-time" window in minutes*
t_{act} = *actual pick-up time*
t_{sch} = *scheduled pick-up time*

The perceived on-time performance is another important measure of bus service reliability. This can be determined by surveying customers about their perceptions of the on-time performance of the buses before and after the system is implemented.

The arrival reliability is also an important measure of bus service reliability. This can be measured by calculating the number of missed stops per hundred stops. Whenever a vehicle is detected to miss a stop, it is reported to the dispatcher, so the number of missed stops is a figure that is automatically generated by the system. The arrival reliability can be calculated as:

$$arrival\ reliability\ (\%) \quad = \quad \frac{number\ of\ missed\ stops\ *\ 100}{total\ number\ of\ scheduled\ stops}$$

Table 5.2: Service Reliability

Objectives	Measures	Analysis	Data Sources or Requirements
Improve Service Reliability (Transit Schedule Adherence)	On-Time Performance	Compare the scheduled arrival times to the actual arrival times and calculate the percentage of arrivals that are within a specified on-time window	Before arrival data from operator logs and after arrival data from AVL system reports; scheduled arrival time data from the scheduling software
	Perceived On-Time Performance	Draw conclusions about perceived on-time performance based on survey data	Data from survey of customers regarding on-time performance
	Arrival Reliability	Calculate the number of missed stops per hundred stops	Before data from operator logs and after data from AVL system reports
	Perceived Arrival Reliability	Draw conclusions about perceived arrival reliability based on survey data	Data from survey of customers regarding arrival reliability

5.2.2   Enhance Service Efficiency

Service efficiency is measured in terms of physical output per unit of input, so it can be studied in terms of run time, trip time, and perceived trip time.

The run time is a measure of the elapsed time between the start and end points as shown in the equation below. The run time should be as consistent as possible.

$$run\ time = end\ time – start\ time$$

The average trip time is a measure of the average passenger time on board a vehicle before and after the system is implemented as shown in the equation below. Another

valuable piece of information that the new technology will provide data on is ride time. The electronic farebox will provide more accurate information about ride time by recording the time and location of each passenger boarding and alighting.

$$average\ trip\ time = \frac{\sum t_{time_n}}{n_{trips}}$$

where:

   n_{trips} = total number of passenger trips

   t_{time_x} = passenger trip time of passenger x, where x is from 1 to ∞

The perceived trip time is based on a survey of the change in riders' opinions before and after the system is implemented.

Table 5.3: Service Efficiency

Objectives	Measures	Analysis	Data Sources or Requirements
Enhance Service Efficiency (Transit Travel Time Savings)	Vehicle Run Time	Calculate the elapsed time (mean) between start and end points, and compare the before and after	Before time records at check points from operator logs and after time records at check points from AVL system reports
	Passenger Trip Time	Calculate the average passenger trip time and compare the before and after	Before average passenger time on board vehicle from operator logs and after average passenger time on board vehicle from AVL system reports
	Perceived Passenger Trip Time	Draw conclusions about perceived trip time based on survey data	Data from survey of customers regarding trip time

5.2.3   Improve Safety and Security

Another objective of the system is to improve safety and security for the bus operator and passengers. The combination of the covert alarm button and the AVL should facilitate an improvement in response times to incidents, and therefore an improvement in safety and security. Denver's Regional Transportation District reported a 33 percent drop in operator and passenger assaults after installing AVL, a covert alarm, and a covert microphone (Stearns, Sussman, and Belcher, 1999). The level of safety and security can be difficult to measure.

One way to look at the level of safety and security is to compare the response time in the event of an incident before and after the system is implemented. Another way to measure

the level of safety and security is to survey the operators and passengers to find out how secure they feel before and after the system is implemented.

Table 5.4: Safety and Security

Objectives	Measures	Analysis	Data Sources or Requirements
Improve Safety and Security	Incident Response-Time	Compare average response time to incidents before and after	Records about incident response-time before and after
	Perceived Level of Safety and Security	Draw conclusions about perceived safety and security based on survey data	Data from survey of customers and operators regarding safety and security on vehicles

5.2.4   *Improve Communications between Dispatchers and Bus Operators*

One of the main goals of the system is to improve communications between the dispatchers and operators. The ease of data transmission is a good measure of the level of communication. This can be measured by surveying the change in dispatchers' and operators' opinion before and after the system has been implemented. The ease of data transmission also has a lot to do with the reliability of the equipment. If the equipment is not functioning correctly, there will not be an improvement in communications.

The objective is to allow dispatchers to convey new trip assignments and ride cancellations in an efficient and dependable manner. Rather than use radio frequency and dispatcher time to read manifests to drivers line by line, the new assignments can be presented as text messages on the MDTs, allowing the control center to respond vocally to more important calls.

Table 5.5: Communications

Objectives	Measures	Analysis	Data Sources or Requirements
Improve Communications between Dispatchers and Operators	Ease/Effectiveness of Communication	Draw conclusions about perceived ease and effectiveness of communication based on survey data	Data from survey of operators and dispatchers regarding comparison of ease and effectiveness of communication before and after

5.2.5   *Improve Operators' Ability to Navigate Routes*

The only way that the bus operator's knowledge of the routes can be measured is by taking a survey of the change in dispatchers' and operators' opinion about their knowledge of the routes before and after the system has been implemented.

Table 5.6: Bus Operators' Knowledge

Objectives	Measures	Analysis	Data Sources or Requirements
Improve Operators' Ability to Navigate Routes	Perceived Usefulness of Navigation System	Draw conclusions about perceived usefulness of navigation system based on survey data	Data from survey of operators and dispatchers regarding usefulness of navigation system before and after

5.2.6   Improve Customer Satisfaction

The implementation of any transit-related ITS system has the potential to improve the level of satisfaction experienced by the customers of that agency. However, it is difficult to measure customer satisfaction using objective data. However, statistics on the number of passenger complaints logged each quarter can be used. The "before" figure can be compared to an "after" figure once the system has been installed.

Table 5.7: Customer Satisfaction

Objectives	Measures	Analysis	Data Sources or Requirements
Improve Customer Satisfaction	Number of Complaints	Calculate the number of customer complaints per trip and compare the before and after	Number of customer complaints from PRTC records; number of trips served from operator logs before and from AVL system reports after

5.2.7   Improve Working Conditions for Dispatchers

Much like the NOVA study done by George Mason University, it is anticipated that there will be a decrease in stress on the dispatchers. NOVA actually observed a significant decrease in the stress levels of their dispatchers. The DART system in Dallas, Texas noticed a definite improvement in the dispatchers' working conditions, especially the noise level. It is not expected, however, that OmniLink will experience a significant decrease in noise level considering that they do not have several dispatchers working in a room together like the DART system does.

Table 5.8: Working Conditions

Objectives	Measures	Analysis	Data Sources or Requirements
Improve Working Conditions for Dispatchers	Perceived Quality of Working Conditions	Draw conclusions about perceived quality of working conditions based on survey data	Data from survey of dispatchers regarding quality of working conditions before and after

5.2.8 Ensure Utilization of System Features

It is important for agencies to know which features will be required and which will be desired. There is currently no way to quantitatively collect data on the usage of system features on the OmniLink system. However, a representative from GreyHawk verified that changes to the system would make it possible to monitor the keystrokes of the operators to determine which features are being used. At this time the only way to determine usage of features is to survey the operators regarding utilization of different features such as the *mapping* feature or the *directions* feature.

Table 5.9: System Features

Objectives	Measures	Analysis	Data Sources or Requirements
Ensure Utilization of System Features	Degree of Utilization of System Features	Estimate utilization of system features based on survey data	Data from survey of operators regarding utilization of system features

5.2.9 Ensure System/Equipment Reliability

PRTC learned the first time around that system reliability is key to the success of an ITS project. The initial system never performed adequately and communications problems are what eventually led to the failure of the original system (SaFIRES, 2001).

The system/equipment reliability can be measured by the failure rate of various parts of the system. One example of this is the failure rate of the covert alarm button that can be measured by looking at the number of failures per hundred incidents. A "failure" should be considered as whenever the covert button is pressed and the system does not respond to the call by sending a message to the dispatch center. The failure rate of the GPS can be measured by looking at the amount of failure time per total operation time.

$$\textit{failure rate covert alarm button (\%)} = \frac{\textit{number of times the system fails} * 100}{\textit{total number of incidents when button pressed}}$$

$$\textit{failure rate GPS (\%)} = \frac{\textit{amount of failure time}}{\textit{total operation time}}$$

Table 5.10: System/Equipment Reliability

Objectives	Measures	Analysis	Data Sources or Requirements
Ensure System/Equipment Reliability	Failure rate of covert alarm button	Calculate the number of failures per hundred incidents	Records showing the number of times that the system fails and the number of incidents when the button is pressed
	Failure rate of MDTs	Calculate the number of hours MDTs are not operational per total number of service hours	Records showing the number of hours MDTs are not operational and the total number of service hours
	Failure rate of GPS	Calculate the amount of failure time per total operation time	Records showing GPS failure time and total operation time

5.2.10 Improve Performance Monitoring

Performance monitoring allows a transit provider to analyze historical data on ridership, frequency of service, and scheduling, in order to improve the service. Improving performance monitoring can include improving the accuracy of the data collected, and having access to additional data that was previously too laborious to collect. The system automatically collects data that was traditionally collected using a manual process.

Being able to accurately reflect on-time performance, dwell times, and ride times can help to correct misconceptions about the needed time for a route. This can contribute toward the creation of schedules that more accurately reflect real conditions.

As Hardin, Mathias, and Pietrzyk (1997) note in their Miami Case Study, vehicle dwell time can prove to be valuable information for schedulers. Although accurate information on dwell time is not currently collected, the system will provide this capability. Dwell time data can allow schedulers to adjust the schedule accordingly by building time into the schedule if there is a particular location that requires more dwell time than other locations.

Another valuable piece of information that the new technology will provide data on is ride time. The electronic farebox will provide more accurate information about ride time by recording the time and location of each passenger boarding and alighting.

It is expected that the AVL data will more accurately reflect actual arrival times as compared to the information recorded manually by drivers. This is because the drivers are currently able to record their arrival information at any time and they may be "rounding" their arrival times to match the scheduled arrival times. After the technology is implemented, the system will automatically record the time and location of the vehicle whenever the operator presses a button to confirm an arrival.

Table 5.11: Performance Monitoring

Objectives	Measures	Analysis	Data Sources or Requirements
Improve Performance Monitoring	Usefulness of Additional/ More Accurate Data	Draw conclusions about usefulness of collected data based on survey data	Data from survey of PRTC administrators regarding usefulness of data collected

5.2.11 Improve Labor Efficiency

The labor efficiency can be evaluated by looking at the staff time associated with processing data. This can be measured by looking at the number of person-hours that are used to input data into the system.

As mentioned in the literature review, the NOVA system observed a 24% increase in the productivity of their drivers (Doyle, Stough, and Allen, 1998).

As mentioned in the literature review of the Denver RTD system, it is possible that the number of dispatcher hours may actually increase after installation of the system. In addition, they found that the need for street supervisors did not decrease as initially predicted. The supervisors' duties actually expanded and the staffing level remained the same.

Contradictory to this, in their study of the NOVA system, Doyle, Stough, and Allen (1998) noted that one of the company's expectations was that dispatchers would spend less time communicating with drivers. They expected this to be the case since messages could be sent with the click of a button and canned messages could save time.

Table 5.12: Labor Efficiency

Objectives	Measures	Analysis	Data Sources or Requirements
Improve Labor Efficiency	Staff Time Associated with Processing Data	Comparison of number of person-hours used to input data before and after ITS deployment	Number of person-hours used to input data before and after

5.2.12 Improve Ability to Monitor Operator Behavior

Hardin, Mathias, and Pietrzyk (1997) made the statement that, "One of the biggest challenges paratransit providers face is knowing exactly where vehicles are and what drivers are doing". The ability to monitor operator behavior can be measured qualitatively by surveying the dispatchers to determine if there is a change in their opinion on before and after the system has been implemented. This will help dispatchers greatly when they are faced with a situation in which a manifest must be reassigned or a

passenger must be fit into the current schedule. By examining a real-time display of the location of the fleet, the control center can quickly identify which bus is closest to the new rider and assign the trip rather than making a general call out to the entire fleet. If a driver is behind schedule, the dispatcher will be able to make a proactive decision about whether they should reassign the trip or allow the driver to remain on their existing schedule.

The additional benefit to being able to monitor operator behavior is that it will provide more records for potential lawsuits and/or complaints. DART (Dallas Area Rapid Transit) found this to be particularly helpful after implementing a similar system on their paratransit service. For similar reasons Zuni found it helpful in the Miami study as cited in section 2.2.6 of the literature review.

Table 5.13: Monitor Operator Behavior

Objectives	Measures	Analysis	Data Sources or Requirements
Improve Ability to Monitor Operator Behavior	Accuracy of On-Time Performance Data	Compare data recorded by observer to driver logs before, and compare to AVL system reports after	Place an undercover observer on vehicles to record actual arrival times; scheduled arrival times from scheduling software
	Accuracy of Arrival Reliability Data	Compare data recorded by observer to driver logs before, and compare to AVL system reports after	Place an undercover observer on vehicles to monitor arrival reliability

5.2.13 Additional Objectives

In addition to those already discussed, there are other general objectives that the SaFIRES project helps to address. OmniLink's current system does not allow for easy data collection or timely, efficient analysis of that data. One of the goals of the project is to give dispatchers the tools to make the system run more efficiently, so as to maximize the utility of the current resources. This would avoid the need to purchase so many new buses, which in turn avoids increased maintenance costs and environmental and traffic problems. By employing AVL and MDTs, the directions at PRTC will be able to measure the effectiveness of this implementation more reliably.

5.3   NECESSARY DATA AND ANALYTICAL METHODS

The necessary data and analytical methods were addressed in detail in the preceding section. However, this section presents additional data and analysis guidelines and summarizes the data that will be required for analysis according to the proposed evaluation plan.

In their *ITS Evaluation Guidelines – ITS Evaluation Resource Guide*, the FTA recommends that data be collected either by the partners in the project (as long as the independent evaluator maintains some oversight of the process) or by the independent evaluator, or by both.

As part of the evaluation, it is necessary to do a "before" assessment to establish a baseline to which future evaluation data can be compared. For the "before" evaluation, system operational performance data and customer satisfaction data should be collected. These data should be collected through objective and subjective means. Objective data can be in the form of system performance records. Subjective data can be collected through surveys of drivers, passengers, and dispatchers to identify user perceptions of system performance (Riverside, 2001).

The following "Before" data will be required for evaluating performance according to the proposed framework and plan:

- On-Time Performance Data from Operator Logs
- Service Reliability Data from Operator Logs
- Passenger Boarding and De-boarding Times from Operator Logs
- Incident Response Time
- Number of Passenger Complaints
- Number of Person-Hours Used to Input Data
- Actual Arrival Times from Undercover Observer
- Actual Arrival Reliability from Undercover Observer

The FTA recommends that the data analysis phase be performed independently of the partners in the project and that interim results be shared with the partners to obtain their insights. The best evaluation results are those that lead to improvements in the system itself. For this reason, documentation of results may not be as important as the improvements caused by the results in many cases.

There are some basic procedures that should be used when evaluating the performance of a transit system. One of these is that if a subset of vehicles is being used for detailed data analysis, route regularity and operator experience should be considered when selecting the vehicle sample.

When measuring the effectiveness of any new technology it is best to compare the system's productivity prior to the introduction of the new technology to the productivity after introduction of the new technology. Ideally, all other aspects of the system would remain constant to allow for a perfect before and after comparison. This type of study is commonly referred to as a "before and after" study.

When formulating the experimental design, it will be important that the "after" data be collected at the correct time. Whenever new technology is installed there is a period of

time for adjustment during which no data should be used because it will take some time for the operators and dispatchers to learn how to make the most efficient use of the equipment and information available to them. For this reason it would not be appropriate for PRTC to begin investigation into the success of their system until several months after implementation. After this point, the performance of the system should be measured periodically using similar conditions whenever possible. For example, it is preferable that the "before" and "after" periods be around the same time of year.

CHAPTER 6: LESSONS LEARNED, CONCLUSIONS, AND RECOMMENDATIONS

This chapter provides a summary of the work that was conducted, states conclusions, and outlines recommendations for further research in this area of study.

6.1   CONCLUSIONS

This report presents an evaluation framework and plan to study ITS investments in public transit. The major elements of the plan included:

- Conducting a case study of the OmniLink route deviation transit service
- Articulating the specific objectives that PRTC hopes to address with this ITS investment
- Defining specific measures related to each of these objectives
- Identifying data requirements and analysis procedures

If the presented evaluation plan is followed, the transit agency should be successful in determining if the identified objectives were met. If the objectives are successfully met, then the system is likely to have a positive impact on the transit service. Determining the impact that an investment has on a system is important to ensure that it has led to improvements in the service. Since transit provides an important public service, the entire community is served.

6.2   LESSONS LEARNED

Several important lessons about the evaluation of intelligent transportation systems were learned during the course of this research. First, it is important to get feedback from all parties involved in a project when identifying the objectives of that project. Each stakeholder will have different perceptions about the goals and objectives of the system and it is important to take all viewpoints into consideration. Similarly, it is important to look at each objective from as many different perspectives as possible to identify all of the potential impacts associated with the investment. Lastly, there is much to learn from other agencies that have undertaken similar projects and implemented similar systems. It is important to be aware of the challenges they faced and the lessons they learned.

6.3   RECOMMENDATIONS FOR FURTHER RESEARCH

During the course of this research some specific topics related to the evaluation of intelligent transportation systems in transit were identified for further study. The industry would benefit from research in these areas.

It is recommended that a "before and after" study be conducted on the OmniLink system according to the evaluation plan proposed herein. The researcher and key stakeholders should determine which performance objectives and measures to study based on available funds and time.

Another topic for research relates to the area of training dispatchers and operators in the use of mobile data terminals and the mapping software. It would be beneficial to study the different methods of training that can be used to teach transit employees how to make the most efficient use of the technology available to them. Determining the most effective methods of training would significantly benefit other transit agencies in developing their training programs.

Another area of research involves determining which ITS features are most frequently being used by the dispatchers and operators of existing systems. A transit agency operating on a smaller budget may not be interested in installing the entire system due to cost constraints, but they may be interested in installing a smaller, less expensive system. This type of research would also benefit software developers in that they could put more time and effort into further developing the features that are widely used by dispatchers and operators.

REFERENCES

Americans with Disabilities Act of 1990. *United States Department of Justice.*
http://www.usdoj.gov/crt/ada/pubs/ada.txt

Casey, R. (2000). *What have we learned about advanced public transportation
systems?. In: What have we learned about intelligent transportation
systems? Chapter 5.*

Casey, R. and Collura, J. (1994). *Advanced public transportation systems: Evaluation
guidelines.* Prepared for the USDOT, Federal Transit Administration. Technical
Publication DOT-VNTSC-FTA-93-9.

Collura, J. (1996). Evaluating the performance of transit systems in rural and small urban
areas. *Strategic management for transit agencies: A handbook for managers and
policy makers*. Prepared by Donald W. Huffmire and Gerald M. McCarthy for the
New England University Transportation Center, Cambridge, MA.

Dajani, J.S., Gilbert, G. (1978). Measuring the performance of transit systems.
Transportation Planning and Technology, Volume 4, 97-103.

Doyle, E., Stough, R., and Allen, B. (1998). *Final report: Commercial fleet management
project.*

Farwell, R.G., and Marx, E. Planning, implementation and evaluation of OmniRide
demand driven transit operations: Feeder and flex-route services. *Transportation
Research Board. 1996.*

Fielding, G. J. (1987). *Managing public transit strategically*. Jossey-Bass Management
Series, San Francisco, CA.

Greenfeld, J. (2000). Automatic vehicle location (AVL) for transit operation.
Proceedings of the Mediterranean electrotechnical conference (pp. 656-659).
Newark, NJ: New Jersey Institute of Technology.

Hardin, J.A., Mathias, R.G., and Pietrzyk, M.C. (1997). Automatic vehicle location and
paratransit productivity: Miami case study. *Merging the Transportation and
Communications Revolutions. Abstracts for ITS America Seventh Annual Meeting
and Exposition.*

Harris, M.J. (1996). Planning an evaluation of an APTS operational test in Northern
Virginia.

Jensen, M. (2001). *Riverside County transit ITS demonstration project: Phase II
evaluation final report.*

Morlok, E.K., Bruun, E.C., Vanek, F.M. (1997). *The advanced minibus concept: A new ITS-based transit service for low density markets.*

National evaluation plan for the Potomac and Rappahannock Transportation Commission ITS operational test Prince William County, Virginia. June 1995.

Onboard surveys of PRTC customers. CJI Research Corporation. Volume 2: A survey of riders served by OmniLink, a service of the Potomac and Rappahannock Transportation Commission. Dec 2001.

Peng, Z., Yu, D., and Beimborn, E. (2001). Transit user's perceptions of AVL benefits. Paper presented at the 81st annual meeting of the Transportation Research Board, Washington, D.C. January 13-17.

Potomac and Rappahannock Transportation Commission AVL/Mobile data system request for proposal. Oct 2001.

Prince William County standard data set – population data. *Prince William County Government.*
http://www.co.prince-william.va.us/demographics/dataset/datasetpop.htm

A Ride Through SaFIRES: Lessons learned from SaFIRES, an APTS operational test in Prince William County, Virginia. Interim report. May 2001.

Spring, G., Collura, J., and Black, K.B. (1997). Evaluation of automatic vehicle location technologies for paratransit in small and medium sized urban areas. *Journal of Public Transportation, Volume 1, No. 4,* 43-60.

Stearns, M.D., Sussman, E.D., and Belcher, J. (1999). *Denver RTD's computer aided dispatch/ automatic vehicle location system: The human factors consequences.* Technical Publication DOT-VNTSC-FTA-98-8.

Strathman, J.G., Gerhart, R.L. (2001). *Evaluation of transit operations: Data applications of Tri-Met's automated bus dispatching system.*

Turnbull, K.F., Higgins, L., and Vaidya, N. (1995). An assessment of the Metrolift automatic vehicle location system. *Proceedings of the Steps Forward, Intelligent Transport Systems World Congress.*

U.S. Department of Transportation. *Transportation Equity Act for the 21st Century: Guidelines for the evaluation of operational tests and deployment projects for Intelligent Transportation Systems (ITS).*
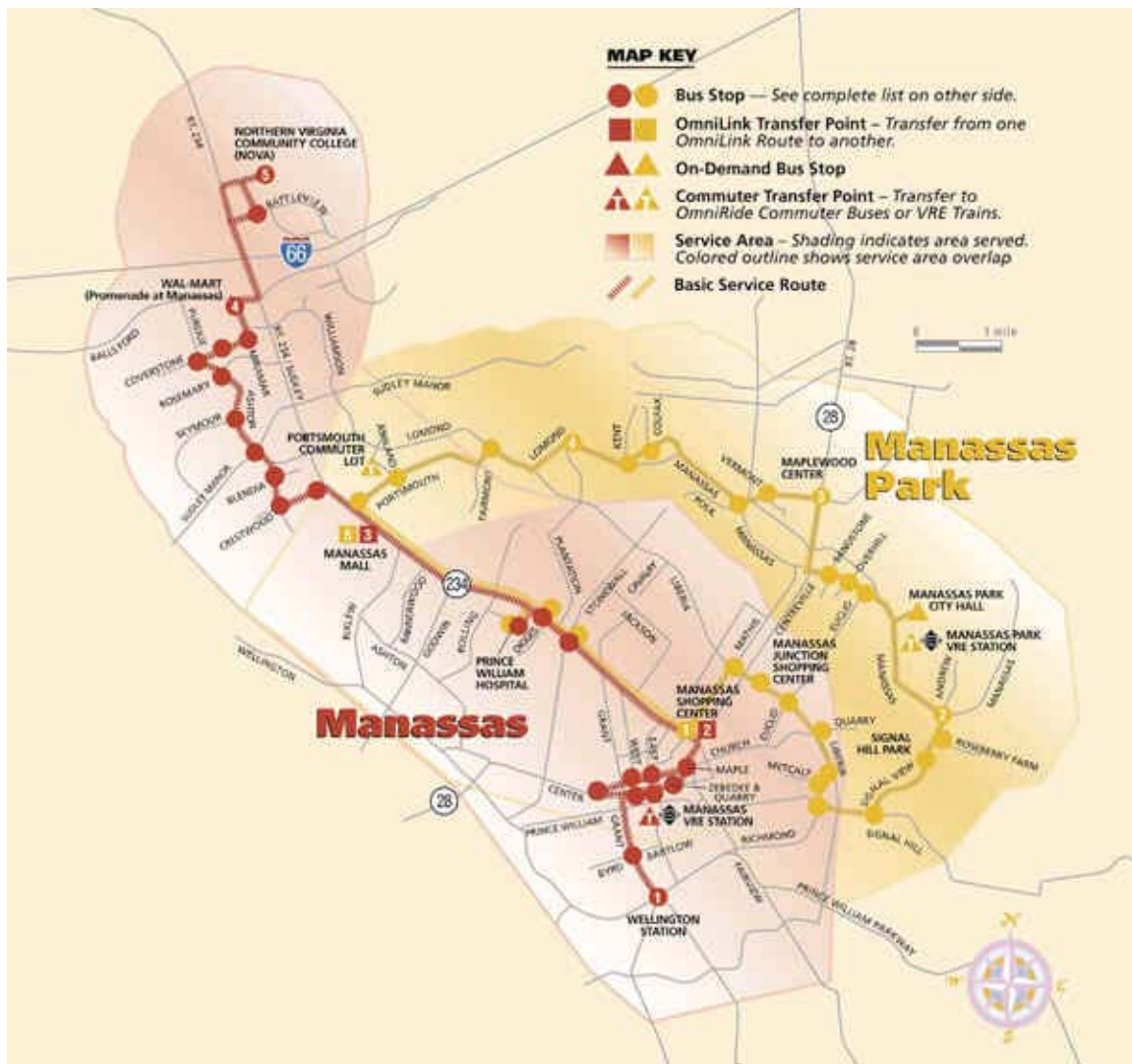
U.S. Department of Transportation. *Evaluation/Program Assessment.* ITS evaluation
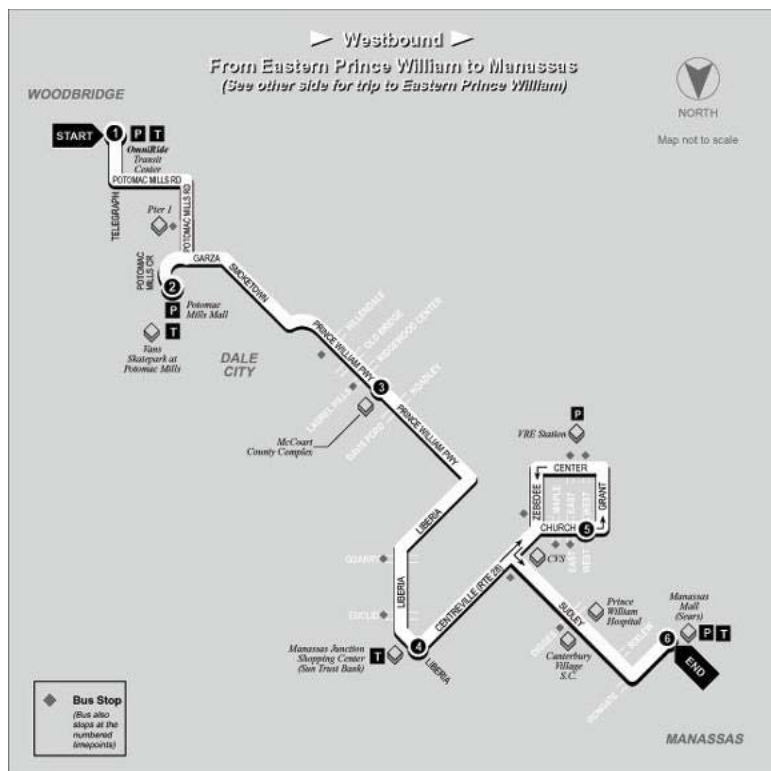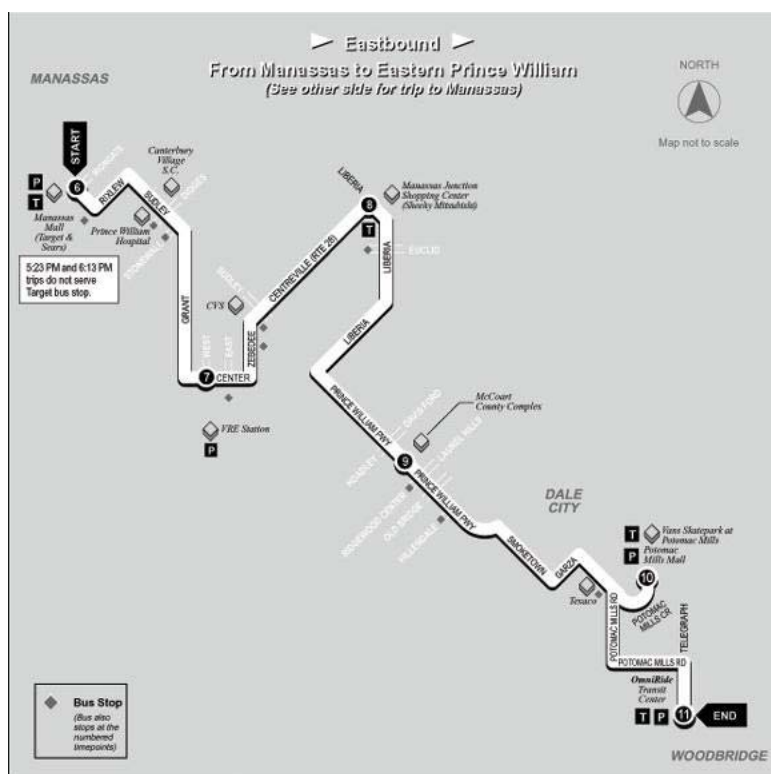guidelines – ITS evaluation resources guide.
http://www.its.dot.gov/eval/evalguidelines_tea21evalguidelines.htm

Wilkins,V. (1995). OmniLink, A ride for all reasons. *Business World, Volume 18,* 15-18.

APPENDIX A: MAPS OF OMNILINK ROUTES
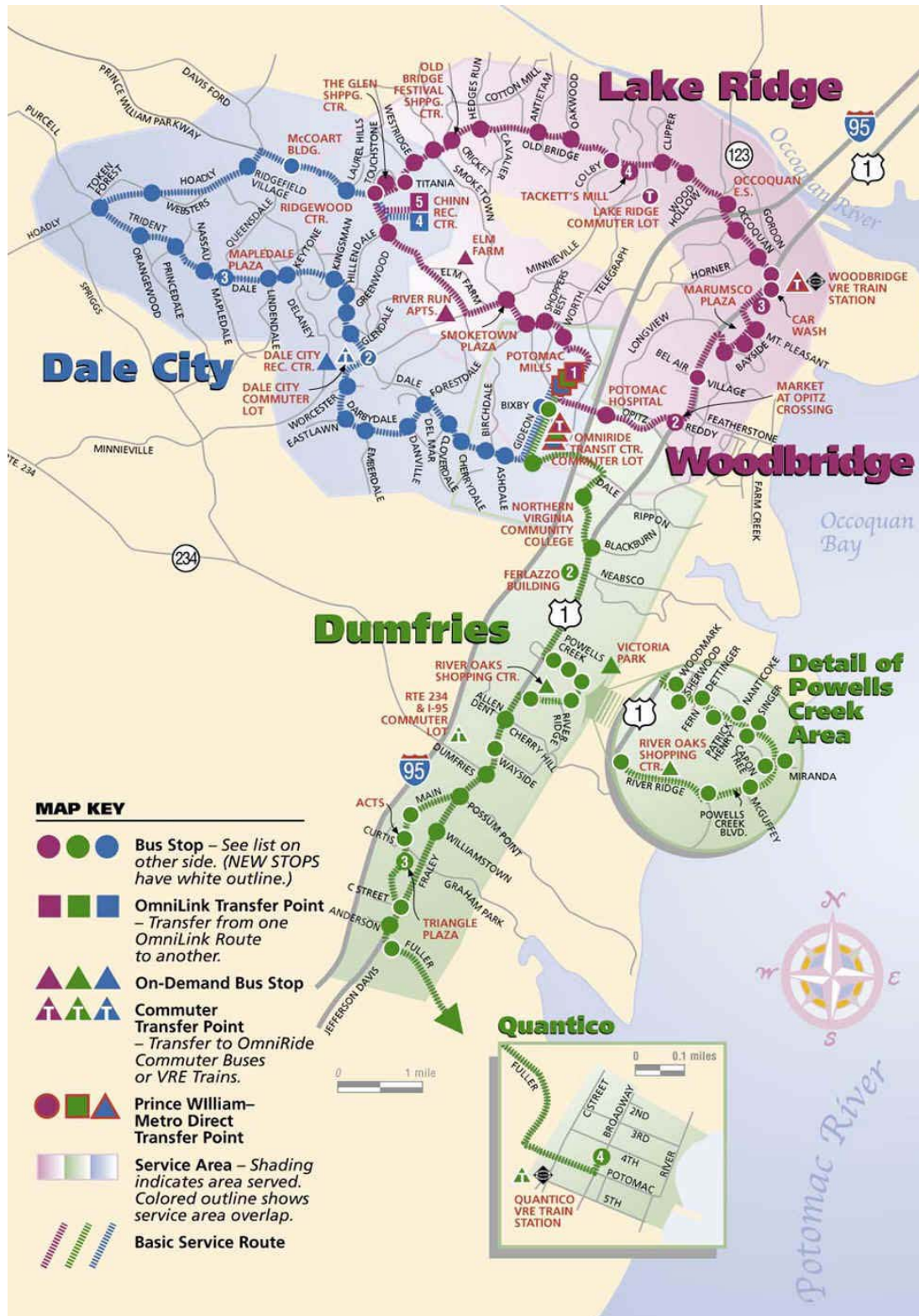
APPENDIX B: COST CALCULATIONS

Current Capital Costs				
Item	**Quantity**	**UOM**	**Unit Price**	**Total Cost**
1 New 30' Medium Duty Buses (2001 Champion Model CTS)	16	EA	$ 120,000	$ 1,920,000
2				$ -
3				$ -
4				$ -
5				$ -
Total Current Capital Costs for Entire Fleet				**$ 1,920,000**
Calculation of Equivalent Annual Capital Costs				
Total Number of Buses in Fleet	16			
Average Capital Cost per Bus	$ 120,000			
Amortization Period (Years)	7			
Annual Interest Rate	6%			
Annual Equivalent Capital Cost per Bus	**$ 21,496**			
Current Operating Costs				
Calculation of Annual Operating Costs				
Average Annual Operating Hours per Bus per Day	12.0			
Current Average Operating Cost per Bus per Hour	$ 53			
Current Average Operating Cost per Bus per Day	$ 639			
Number of Work Days per Year	255			
Annual Operating Cost per Bus	**$ 162,855**			
Total Current Annual Cost per Bus	**$ 184,351**			

It should be noted that PRTC's current operator wages are between $11.30 and $13.15 per hour and that they additionally receive approximately 30% of this wage in benefits. As a result, operator wages make up approximately 30-40% of the current operating cost.

Projected Capital Costs				
Item	**Quantity**	**UOM**	**Unit Price**	**Total Cost**
1 New 30' Medium Duty Buses (2001 Champion Model CTS)	16	EA	$ 120,000	$ 1,920,000
2 ITS Project Capital Costs				$ 535,803
3				$ -
4				$ -
5				$ -
Total Current Capital Costs for Entire Fleet				$ 2,455,803
Calculation of Equivalent Annual Capital Costs				
Total Number of Buses in Fleet	16			
Average Capital Cost per Bus	$ 153,488			
Amortization Period (Years)	7			
Annual Interest Rate	6%			
Annual Equivalent Capital Cost per Bus	**$ 27,495**			

Projected Operating Costs				
Item	**Quantity**	**UOM**	**Unit Price**	**Total Cost**
1 Wireless Communications				$ 10,000.00
2 Hardware Maintenance				$ 6,032.00
3 Software Maintenance				$ 19,500.00
4 Technical Support				$ 14,000.00
5				
Total Estimated Annual Operating Cost				$ 49,532
Calculation of Annual Operating Costs				
Total Number of Buses in Fleet	16			
Total Projected Additional Annual Operating Cost per Bus	$ 3,095.75			
Average Annual Operating Hours per Bus per Day		12.0		
Current Average Operating Cost per Bus per Hour	$ 53.29	$ 54		
Projected Average Additional Operating Cost per Bus per Hour	$ 1.01			
Projected Average Operating Cost per Bus per Day		$ 651		
Number of Work Days per Year		255		
Annual Operating Cost per Bus	**$ 165,951**			
Total Projected Annual Cost per Bus	**$ 193,446**			

VITA

Jennifer Ann Lee was born on September 14, 1978 in Charlevoix, Michigan to James and Marta Lee. She grew up in Missouri, Wisconsin, Michigan, and Virginia. In 1996 she graduated from Gloucester High School in Gloucester, Virginia and went on to pursue a Bachelor of Science degree in Civil Engineering at Virginia Tech. While pursuing her Bachelor's degree, she held internships with Mobil Oil Corporation, Gorove-Slade Associates, Michael Baker Corporation, and Bellomo-McGee, Inc. After graduating with her Bachelor's degree in May of 2001, she transferred to Virginia Tech's Northern Virginia Graduate Center to pursue a Master of Science degree in Civil Engineering under the direction of Dr. John Collura. While at the Northern Virginia Center, she became active with Virginia Tech's Chapter of the Institute of Transportation Engineers, acting as the Chapter's 2001-2002 Vice-President. In addition, Jennifer was the recipient of Washington, DC Chapter Women's Transportation Seminar (WTS) 2001-2002 Graduate Scholarship Award. In July of 2002 she began working as a Transportation Engineer with the Transportation Research Division at Science Applications International Corporation (SAIC) in McLean, Virginia.