DEPLOYING ADVANCED PUBLIC TRANSPORTATION SYSTEMS IN BIRMINGHAM

By

Steven L. Jones, Jr., Ph.D., Andrew J. Sullivan, P.E.,
Naveen Cheekoti, Yatin Joshi, and Hafshah K. Navarro
Department of Civil and Environmental Engineering
The University of Alabama at Birmingham
Birmingham, Alabama

and

Michael D. Anderson, Ph.D.
Department of Civil and Environmental Engineering
The University of Alabama at Huntsville
Huntsville, Alabama

Prepared by

UTCA

University Transportation Center for Alabama
The University of Alabama, The University of Alabama at Birmingham, and
The University of Alabama in Huntsville

UTCA Report Number 01216
August 2003

Technical Report Documentation Page

1. Report No
FHWA/CA/OR-

2. Government Accession No.

3. Recipient Catalog No.

4. Title and Subtitle

Deploying Advanced Public Transportation Systems in Birmingham

5. Report Date

August 2003

6. Performing Organization Code

7. Authors

Steven L. Jones, Jr., Andrew J. Sullivan, Michael D. Anderson, Naveen Cheekoti, Yatin Joshi, and Hafsah K. Navarro

8. Performing Organization Report No.

UTCA Report 01216

9. Performing Organization Name and Address

Department of Civil & Environmental Engineering
The University of Alabama at Birmingham
1075 13th Street South
Birmingham, AL 35294-4440

10. Work Unit No.

11. Contract or Grant No.
DTRS98-G-0028

12. Sponsoring Agency Name and Address

University Transportation Center for Alabama
The University of Alabama
P.O. Box 870205
Tuscaloosa, AL 35487-0205

13. Type of Report and Period Covered

Final Report: January 1, 2001 – August 20, 2003

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Advanced Public Transportation Systems (APTS) technologies have been deployed by many urban transit systems in order to improve efficiency, reduce operating costs, and improve service quality. The majority of these deployments, however, have been in medium to large transit markets where the transit systems in turn operate within fairly sophisticated intelligent transportation systems (ITS) environments. Birmingham, Alabama has a relatively small transit system, employing only 77 vehicles, that operates within an immature but rapidly growing ITS environment.

The purpose of this study was to identify APTS technologies appropriate to the Birmingham market and to develop alternative deployment scenarios that would address the immediate needs of a smaller transit system while maintaining potential for future ITS growth. The Birmingham Regional ITS architecture is addressed along with potential funding sources for APTS deployment in Birmingham. Three deployment scenarios are developed and offered along with specific implementation recommendations.

17. Key Words
APTS, bus, AVL, ATIS

18. Distribution Statement

19. Security Class (of report)	20. Security Class. (of this page)	21. No of Pages	22. Price
Unclassified	Unclassified	64	

Form DOT F 1700.7 (8-72)

Table of Contents

Table of Contents iii
List of Tables vi
List of Figures vi
Executive Summary vii

1.0 Introduction 1
1.1. Background and Problem Statement 1
1.2. Purpose and Scope 3

2.0 Current Status of APTS in Birmingham 5
2.1. Current APTS Applications in Birmingham 5
2.2. Planned APTS Applications in Birmingham 5

3.0 Literature Review 7
3.1 Description of Applicable APTS Technologies 7
3.1.1 Communications Technologies 7
3.1.2 Automatic Vehicle Location (AVL) 8
3.1.3 Automatic Passenger Counting (APC) Systems 10
3.1.4 Computer-Aided Dispatch (CAD) 11
3.1.5 Transit Information Systems 12
3.1.6 Transit Priority at Traffic Signals 13
3.1.7 Electronic Fare Payment Systems 15
3.1.8 Geographic Information Systems (GIS) 16
3.1.8.1 Operations and Control 17
3.1.8.2 Information Dissemination 18
3.1.8.3 Planning and Market Development 18
3.2 Benefits of Applicable APTS Technologies 22
3.2.1 Benefits of Advanced Communications Systems 22
3.2.2 Benefits of Automatic Vehicle Location Systems 23
3.2.3 Benefits of Automatic Passenger Counters 25
3.2.4 Benefits of Computer-Aided Dispatch Systems 26
3.2.5 Benefits of Transit Information Systems 26
3.2.5.1 Benefits of Pre-Trip Information Systems 26
3.2.5.2 Benefits of In-Terminal/Wayside Information Systems 27
3.2.5.3 Benefits of In-Vehicle Transit Information Systems 28
3.2.5.4 Benefits of Advanced Traveler Information Systems 29
3.2.6 Benefits of Transit Priority at Traffic Signals 31
3.2.7 Benefits of Electronic Fare Payment Systems 32
3.2.8 Benefits of Geographic Information Systems 32

3.2.8.1 GIS Benefits to Operations and Control 32
3.2.8.2 GIS Benefits to Information Dissemination 33
3.2.8.3 GIS Benefits to Planning and Market Development...............................33

3.3 Current Deployments of Candidate Technologies 33
3.3.1 Communication Systems 33
3.3.2 Automatic Vehicle Location (AVL) Systems 34
3.3.3 Automatic Passenger Counter (APC) Systems 34
3.3.4 Computer-Aided Dispatch (CAD) Systems 34
3.3.5 Advanced Traveler Information Systems 35
3.3.6 Electronic Fare Payment (EFP) 35
3.3.7 FTA Peer Cities...35
3.3.8 Similar Transit Agencies...36

4.0 Birmingham Deployment...38
4.1 Overview of Methodology for Selecting Candidate Technologies............................38
4.2 Alternative 1 Deployment – Automated Counting Equipment.................................39
4.2.1 System Requirements – Alternative 1..39
4.2.2 System Costs and Benefits – Alternative 1...40
4.3 Alternative 2 – Real-Time Transit Information for Users 41
4.3.1 System Requirements – Alternative 2..41
4.3.2 System Costs and Benefits – Alternative 2...43
4.4 Dynamic Fleet Management 44
4.4.1 System Requirements – Alternative 3..44
4.4.1.1 Information for Transit Users 44
4.4.1.2 Information for Transit Operators..46
4.4.2 Summary – Alternative 3 47
4.5 Transit Priority 47
4.6 Electronic Fare Payment (EFP) Systems 47
4.7 Geographic Information Systems 48

5.0 Regional ITS Architecture 49
5.1 Birmingham Regional Architecture..50
5.2 Function of APTS Alternatives within ITS Architecture 51

6.0 Funding Sources for APTS 52
6.1 Federal Transit Administration (FTA)...52
6.2 State Funding 53
6.3 Local Funding 54

7.0 Transit ITS Education and Training 55
7.1 Training of Management and Staff 55
7.2 Training for Maintenance Personnel 56
7.3 Training for Bus Operators 57
7.4 General Training Issues 57

8.0 Conclusions and Recommendations 58

9.0 References 60

Appendix 64

List of Tables

1-1 Characteristics of the Birmingham-Jefferson County Transit Authority..................1
3-1 Advantages and disadvantages of automatic vehicle location technologies.............10
3-2 Typical functions performed by Computer-Aided Dispatch Systems 12
3-3 Summary of available technologies for dissemination of transit information...........13
3-4 Transit priority types...15
3-5 Types of transit data stored in GIS 17
3-6 Transit/GIS related websites...22
3-7 Example benefits of AVL deployment 24
3-8 Advantages/disadvantages of APC deployments...25
3-9 Example benefits of APC deployments 25
3-10 Example benefits of pre-trip planning systems...27
3-11 Example benefits of in-terminal/wayside information systems...............................28
3-12 Example benefits of in-vehicle information systems...28
3-13 Advantages and disadvantages of transit information system technologies.............30
3-14 Example benefits of transit priority at traffic signals...31
3-15 Benefits of Benefits of Electronic Fare Payment systems 32
3-16 Comparison of Birmingham peer cities 36
3-17 APTS deployments among agencies with 100 or less fixed-route buses..................37
4-1 Relationship among Birmingham transit needs and APTS technologies 38
4-2 Daily bus transfers at key stops 43
6-1 Federal transit funding programs...53
7-1 Sample transit ITS management courses available...56

List of Figures

1-1. Fixed-route bus service in Birmingham 2
3-1 Automatic Passenger Counter schematic 11
3-2 Schematic of traffic signal operation with bus priority 14
3-3 Example of smartcard and reader 16
3-4 Example of magnetic stripe fare card reader 16
3-5 Example of regional employment data overlaid on transit routes within a GIS............19
3-6 Example of regional child care center data overlaid on transit routes within a GIS 20
3-7 Example of regional census data in relation to transit boardings within a GIS.............21
5-1. Interrelationship of ITS system functions 50

Executive Summary

Advanced Public Transportation Systems (APTS) technologies have been deployed by many urban transit systems to improve efficiency, reduce operating costs, and improve service quality. The majority of these deployments, however, have been in medium to large transit markets where the transit systems operate within fairly sophisticated ITS environments. Birmingham, Alabama has a relatively small transit system, employing only 75 vehicles, that operates within an immature but rapidly growing ITS environment. The purpose of this study was to identify APTS technologies with applications to the Birmingham market and to develop alternative deployment scenarios that would address the immediate needs of a smaller transit system while maintaining potential for future growth.

Candidate APTS technologies were evaluated based on the needs and characteristics of the Birmingham transit system. Through meetings and discussions with BJCTA and local transportation officials, the following needs in the Birmingham transit system were identified:

- Inadequate route and schedule information,
- Inadequate real-time information for passengers and operators,
- Poor schedule adherence,
- Cumbersome data collection and reporting, and
- Inadequate fleet management.

Important characteristics of the system and its service area include:

- 75 bus fleet, 64 of which operate during peak service periods,
- Service is primarily fixed-route bus,
- Mostly intra-urban trips, and
- Limited service to suburbs but future expansion possible.

The most promising APTS technologies identified for the Birmingham transit systems include Automated Passenger Counters (APC), Automatic Vehicle Location (AVL) systems, in-vehicle information displays, wayside information displays, and fleet management software. The potential benefits and costs of each are described in detail in the body of the report. The study developed three implementation scenarios of varying degrees of complexity:

1. <u>Deployment of automated passenger counters (APC) and limited automatic vehicle location (AVL) equipment</u> – Under the simplest scenario the Birmingham transit authority would deploy automated passenger counters and AVL on approximately 15% of its bus fleet. The counters would automate the collection of *Section 15* ridership data for the FTA. Ideally, the AVL equipment deployed under this scenario would be scalable to allow for fleet-wide deployment in the future. This alternative is intended to be a small scale initial deployment to give the transit agency experience with APTS.

2. <u>Deployment of Real-Time Passenger Information Systems</u> – This alternative would employ AVL systems, in-vehicle information systems, and wayside information systems to provide real-time transit status information to passengers. Information provided could include bus arrival times, service disruptions, and system announcements. The anticipated benefits would be improved service quality and customer satisfaction. It is intended that this alternative would serve as the backbone for future APTS deployments in the City.

3. <u>Deployment of Advanced Transit Information Systems</u> – This alternative would build on the systems deployed in Alternative 2 to provide advanced trip planning services for system users and fleet management functions for transit operators. Whereas the traveler information services described in Alternative 2 would be largely static, passengers would be able to interactively request transit information and plan trips under this scenario. Operators would be able to gather and utilize information on system performance and make adjustments in real-time to maintain schedule adherence and minimize disruptions. This alternative envisions a full scale APTS deployed within a mature ITS environment and is not intended to be an initial deployment. It is, rather, one vision of what APTS could eventually be in Birmingham.

What these three alternatives highlight is the importance of long-term APTS planning. Although APTS in Birmingham will likely start with a few basic systems and services, these systems will need to work and interface with future APTS and ITS deployments. The early deployments will, in effect, serve as the backbone for future systems and technologies and will therefore need to be designed carefully. This study presents a brief discussion of the Birmingham Regional ITS Architecture and how APTS technologies will need to function within it.

APTS deployments will require training for system managers, operators, and maintenance personnel. Training for operators and maintenance staff will ensure that the systems operate efficiently and that their full potential is realized. Just as important, and often overlooked, training will be required for transit system managers so that they can effectively develop long range plans for APTS deployment and ensure that the technologies will effectively address system needs.

Finally, there is a brief discussion of potential funding sources for deploying APTS technologies, including Federal, State, and local agencies. At this time there are a number of Federal and State programs available to fund APTS deployments.

After examining the various issues (possible scenarios, funding, etc), the report offers the following recommendations:

1. Consider deploying an AVL/APC system on 10% to 15% of the bus fleet as described under proposed Scenario 1. This is sufficient to automate the collection of ridership data by rotating the buses through the system.

2. Develop a data management plan to ensure that the data collected from the AVL/APC devices are appropriate for NTD reporting as well as system planning purposes.

3. The AVL system deployed under Scenario 1, although initially limited to only a portion of the fleet, must be expandable to a fleet-wide system.

4. It is recommended that BJCTA perform an assessment of the initial AVL/APC deployment to evaluate its impact on planning and operations (cost/benefit, training requirements, equipment reliability, user acceptance, etc.).

5. Upon successful deployment of Scenario 1 (and availability of funding), it is recommended that all BJCTA and CLASTRAN vehicles be equipped and integrated into a fleet-wide AVL system. The fleet-wide AVL systems will then serve as the foundation for deploying Scenarios 2 and 3 or any combination of elements therein. At the time of this deployment, it is recommended that BJCTA seek a consulting firm or other system design input rather than rely on equipment vendors and manufacturers for input. At this stage it would also be essential that BJCTA work with ALDOT and the RPCGB to ensure that all APTS deployments are consistent with the regional ITS architecture.

6. As the Regional Transportation Alternatives Analysis concludes, it is strongly recommended that BJCTA consider working with ALDOT to provide transit priority (preemption) at traffic signals along major express bus corridors (e.g., U.S. 280, U.S. 31).

7. Finally, it is recommended that BJCTA work out an arrangement to continue to utilize the GIS resources at RPCGB, or develop and maintain their own, in-house GIS capabilities.

Section 1
Introduction

1.1. Background and Problem Statement

The project presented herein examined the feasibility of Advanced Public Transportation Systems (APTS) deployment in the Birmingham-area. The research addresses the existing fixed-route bus system and, to a lesser extent the paratransit system, as well as other public transportation modes currently under consideration for Birmingham as identified in the 1999 Strategic Regional Multimodal Mobility Plan (SRMMP) (RPCGB, 1999). Consideration has also been given to transit projects being considered under the Birmingham *Regional Transportation Alternatives Analysis*[1] project (RPCGB, 2003). It is intended that the results of the research will serve as technical guidance for political officials, public transportation decision makers, and transportation planners as they strive to improve the quality of transit operations, reduce congestion, and improve air quality in and around Birmingham.

Public transportation services in the Birmingham-area are currently provided by the Birmingham-Jefferson County Transit Authority (BJCTA). Transit in Birmingham primarily relies on fixed-route bus service. BJCTA has 77 vehicles, 64 of which operate during peak operation periods (FTA, 2002). Transit in Birmingham serves mostly intra-urban commuters with limited service to and from some suburban areas outside the Birmingham city limits. A map of the service area for fixed-route bus service is shown in Figure 1-1. Demand-responsive paratransit services in the Birmingham area are provided by CLASTRAN. Characteristics of the transit system in Birmingham are presented in Table 1-1 (FTA, 2002).

Table 1-1. Characteristics of the Birmingham-Jefferson County Transit Authority (2000)

Characteristic	Bus	Demand Responsive
Operating Expense	$9,462,718	$1,479,261
Annual Passenger Miles	13,076,651	1,233,339
Annual Vehicle Revenue Miles	1,713,026	524,417
Vehicles Available for Maximum Service	75	18
Average Fleet Age in Years	9.9	4.0

[1] Often referred to as the "New Starts" project.

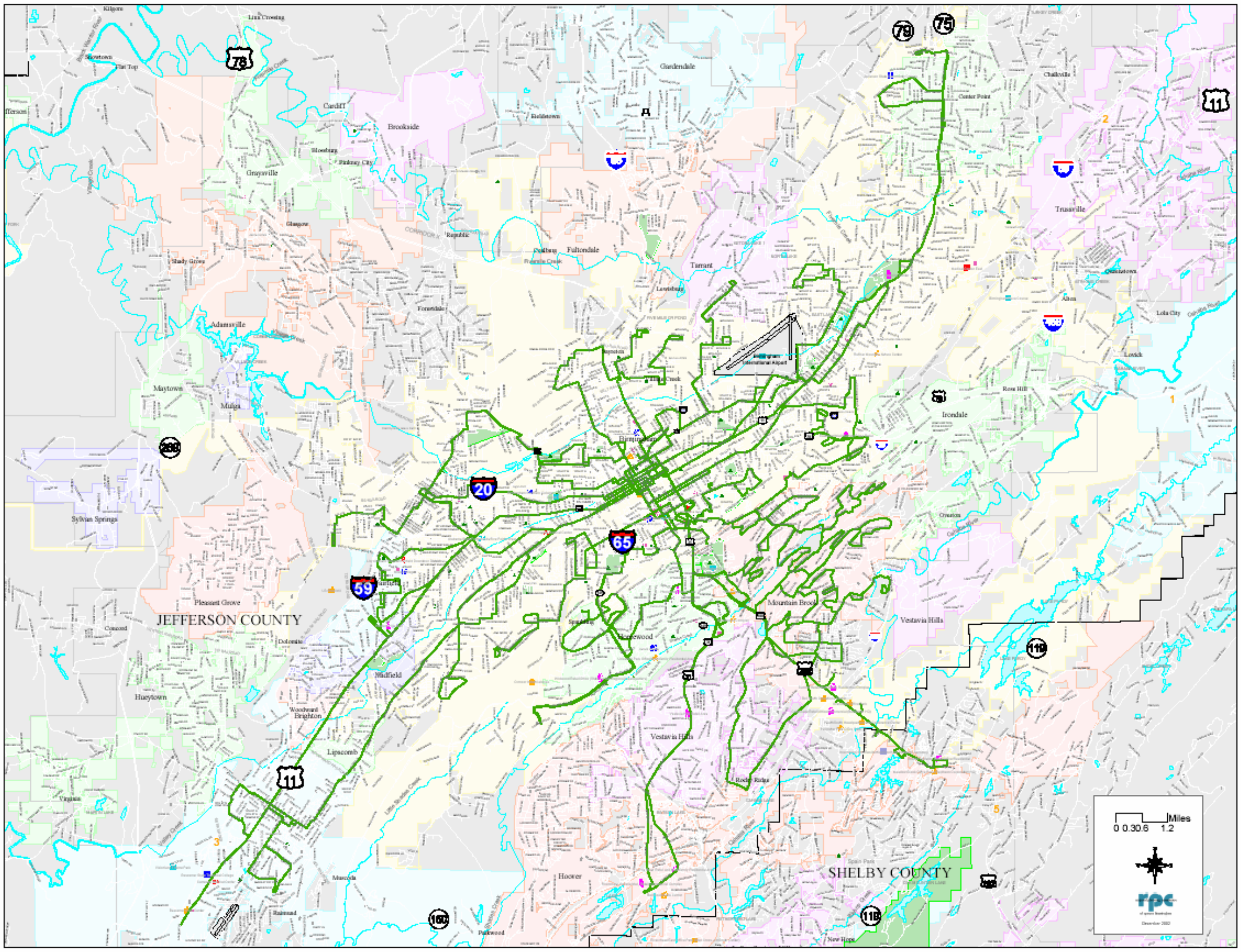

Figure 1-1. Fixed-route bus service in Birmingham (Source: RPCGB)

In an effort to expand its share of the transportation market, reduce peak hour congestion, and help mitigate some of the air quality concerns in Birmingham, the BJTCA has proposed (and recently implemented) several improvements in the FY 2000-2004 Transit Development Program (TDP). These improvements range from expanding existing services to new programs and services with the ultimate goal of increasing transit ridership in the Birmingham-area. Among the new improvements in the TDP are:

- Additional service to and from UAB,
- Extended weekday service hours,
- Extension of weekend service,
- Targeted service to and from the Riverchase Galleria,
- Express routes along major commuter corridors, and
- Increased paratransit operations and coordination (RPCGB, 2000).

Additional service improvements are being proposed under the *Regional Transportation Alternatives Analysis*:

- Bus rapid transit and increased service in the U.S. 280 corridor,
- Enhanced bus service and improved passenger facilities in the U.S. 11 corridor,
- Express bus service and improved passenger facilities on U.S. 31, and
- A downtown streetcar system (RPCGB, 2003).

Clearly, the proposed improvements will require additional commitments on the part of BJCTA. To support these additional services and maximize their effectiveness, BJCTA is examining ways of improving service quality and making transit usage more attractive to users. One approach that has been successful in other cities has been the deployment of APTS technologies. The United States Department of Transportation (USDOT) defines APTS technologies as "A collection of technologies that increase the efficiency and safety of public transportation systems and offer users greater access to information on system operations (Volpe, 1996)." In short, APTS encompass a spectrum of technologies that can enhance travel for public transit users through trip planning, real-time information, and improved system reliability while improving system efficiency for transit operators. BJCTA is currently exploring several APTS options for its buses, in particular automatic vehicle location systems and on-board traveler information systems.

1.2. Purpose & Scope

The purpose of the project is to explore the applicability of APTS technologies in Birmingham. In particular, the current project evaluated APTS technologies and their applicability to BJCTA and CLASTRAN[2]. The potential for APTS deployment was approached in terms of developing three deployment scenarios with varying levels of functionality, complexity, and investment. A general description of each of the deployment scenarios is provided below:

- Scenario 1 – a basic APTS intended to automate and improve the collection transit operations data for the *National Transit Database*[3](NTD),
- Scenario 2 – an expansion of the basic APTS to include real-time dissemination of transit data via en-route and pre-trip transit information systems (e.g., in-vehicle displays, in-terminal displays, and the internet), and
- Scenario 3 – expansion of Scenario 2 to facilitate communication of real-time transit information among vehicles, dispatchers, and passengers.

Within the context of each of the deployments scenarios, the following specific technologies were evaluated:

[2] Discussions regarding APTS technologies applicable and desirable to Birmingham were conducted with project stakeholders, both formally and informally, throughout the course of the project. The technology deployments currently in the Transit Development Program were also considered in the development of scenarios.
[3] Formerly referred to as Section 15 data for Federal Transit Administration reporting purposes.

- Communications systems,
- Automatic vehicle locations (AVL) systems,
- Automatic passenger counting (APC) systems,
- Computer-aided dispatch (CAD), and
- Transit information systems.

The following sections of the report present brief descriptions of each of the applicable technologies, benefits associated with their deployment, and their potential role in the three deployment scenarios. In addition to the technologies evaluated for the three scenarios, the research team also examined the applicability of three individual technologies that could be deployed in Birmingham in conjunction with or irrespective of the any of the proposed scenarios. These additional technologies are:

- Priority control of traffic signals for buses,
- Electronic fare payment systems, and
- Geographic information systems (GIS).

Section 2
Current Status of APTS in Birmingham

The following section presents a brief description of the existing and planned APTS in Birmingham. The information presented herein was obtained from representatives from BJCTA and CLASTRAN as well as relevant studies and policy documents obtained from the Regional Planning Commission of Greater Birmingham (RPCGB).

2.1. Current APTS Applications in Birmingham

Neither BJCTA nor CLASTRAN currently uses any systems that would be considered APTS technologies. Within the State of Alabama, no fixed-route transit system has deployed any APTS technologies, The Montgomery and Huntsville paratransit systems currently use CAD systems. It should be noted that CLASTRAN recently obtained CAD software and at the writing of the current report was using it, to a limited extent, for scheduling and dispatching paratransit trips. Based on a 1999 survey of APTS deployments in the United States, this is not unusual for a system the size and character of BJCTA (USDOT, 1999). The survey found that many of the smaller transit systems (i.e., less than 100 vehicles) either have not deployed APTS technologies or have only limited deployments. Since the unit costs for deploying advanced technologies are often higher for smaller systems they have typically lagged behind larger systems in embracing new technologies.

2.2. Planned APTS Applications in Birmingham

BJCTA has recently been investigating several APTS technologies for deployment on its fixed-route bus system. In 2002, BJCTA requested funds from the FTA for a new communication and in-vehicle passenger information system. Plans for the proposed system have since been put on hold, but the original specifications called for the installation of in-vehicle video monitors that would display current bus location, the name of the next stop, and the current date and time. Annunciators would automatically announce the name of each stop as it is reached. The system under consideration could also display transit system information (pre-programmed information on new routes and schedule changes), news headlines, weather, and advertisements. The advertisements, it was hoped, would pay for the procurement costs within approximately 5 years. Study of this type of system continues.

A similar type of system could be expanded to display information on bus status (location and estimated time of arrival) at kiosks and bus terminals. Such an expansion, however, would require an AVL system capable of broadcasting real-time bus location data back to a central control center. In Birmingham, that would require deployment of a more advanced communications system than currently exists. As previously mentioned, CLASTRAN is currently using CAD software. Such CAD systems utilize computerized scheduling algorithms and vehicle location information to automate scheduling and optimize vehicle routing. Achieving the full benefits from a CAD system requires the installation of AVL and communications equipment on all vehicles capable of providing real-time location information. At present, all proposed APTS deployments in Birmingham are only in the planning stages.

Section 3
Literature Review

The Federal Transit Administration (FTA) and the Research and Special Programs Administration[4] (RSPA) of the U.S. Department of Transportation (USDOT) conduct an annual assessment of the APTS applications throughout the nation. The annual assessment includes technological descriptions as well as some indication of the success of these deployments. The Transportation Research Board, ITS America, and other University Transportation Centers have actively pursued transit-related research over the past decade as APTS technologies have become increasingly available. Also, there is an abundance of specific technical information available from APTS equipment vendors as well as excellent examples of deployments and feasibility studies in other cities conducted by private consultants. Information from all these sources was collected, compiled, and synthesized for its applicability to APTS deployment in Birmingham.

3.1. Description of Applicable APTS Technologies

The following APTS technology descriptions are restricted to those technologies with potential applications to Birmingham (i.e., limited fixed-route bus systems, special needs paratransit). The literature suggests that several APTS technologies are directly applicable (indeed, have been successfully deployed elsewhere) to fixed-route bus systems and paratransit.

3.1.1. Communications Technologies

The success of APTS deployments rests largely on the ability of transit operators to provide effective communications between dispatch and vehicles. Although voice communication is an important link among drivers and dispatcher, APTS requires that data be transmitted in real-time to support other technologies such as advanced vehicle location systems and transit information systems.

Communication technologies have evolved considerably over the past ten years with a trend towards cellular and digital communications. Analog (i.e., radio frequency) communications, however, are still the most widely used communication technology among transit agencies. Digital and cellular technologies support rapid data transfer more readily but are considered expensive in relation to radio frequency (RF). In many cases, transit agencies have been able to maximize (increase two-way voice capacity, transmit data, etc.) their use of RF by upgrading equipment for lower frequency (below 800 MHz) bands or switching to frequencies between 800 and 900 MHz (Casey et al., 2000). Nonetheless, many agencies deploying APTS technologies have opted to go with digital or trunked radio communications systems (USDOT, 1999). As the

---

[4] Located at the John A. Volpe National Transportation Systems Center in Cambridge, MA.

industry tends to be moving towards more wide scale deployment of digital or trunked radio systems, a brief description of each is presented in the following sections.

Trunked radio is based on the sharing of a portion of the radio spectrum. In doing so, it allows multiple users to utilize a limited number of communication paths, called trunks. Computer-controlled electronics coordinate the sending and receiving of signals among various trunks – all of which is transparent to the user. The primary advantage of trunked radio is its efficiency. Several agencies (transit, fire, police, public works, etc.) are able to share transmission equipment and bandwidth. In addition to the efficiency of sharing resources at the municipal level, trunked radio offers three other advantages:

- Faster system access as communication channels are selected automatically,
- Facilitates user privacy, and
- Easily expandable – new users can be added without additional bandwidth or modifications to existing in-vehicle equipment. (Harte et al., 2000)

Digital communication systems provide greater transmission capacity than RF systems and are more readily adaptable to the data transmissions required for most APTS technologies. The disadvantage of digital systems is that they can be more expensive to install, particularly when transit agencies find it cheaper to upgrade their existing RF equipment rather than make a wholesale change to digital equipment (Casey et al., 2000). Consequently, digital communication equipment has not yet penetrated the transit market to the same extent that it has penetrated other sector of the communication industry.

An MDT is a vehicle-mounted device that communicates in text-based messages intended to replace voice communications between dispatchers and individual vehicles. MDTs are capable of sending data and can be used to transmit vehicle location, passenger counts, engine performance, mileage, etc. to the dispatcher. An MDT is equipped with a keyboard to allow drivers to compose and send messages. Drivers can also use pre-programmed function keys to send pre-recorded digital messages regarding vehicle and passenger status or to respond to questions or prompts displayed on the MDT screen (ITRE, 2002). An MDT can be used to record daily manifests and can facilitate accounting and vehicle performance analysis (Batelle, 2001).

Communication technology and bandwidth capacity is becoming more and more important to transit agencies as new APTS technologies become more prevalent. New AVL and automatic passenger counting (APC) systems, in particular, can overwhelm older communications systems with their constant transmission of location and passenger count data. Consequently, existing communications systems must be carefully examined whenever APTS technologies are deployed.

3.1.2. Automatic Vehicle Location Systems (AVL)

AVL systems use vehicle-tracking and communication technologies to continuously track and monitor the locations of fleet vehicles. Knowing the location of a bus allows operators and dispatchers to manage the bus fleet more efficiently and to provide customers with up-to-the-minute information on bus arrivals and departures. It is a powerful tool for incident detection and response, monitoring schedule adherence, run time analysis, and providing real time bus location information to passengers.

AVL in and of itself, however, only provides vehicle location information. When integrated with other APTS technologies (as described in the following sections), AVL can support broader fleet management objectives, including:

- Automatic vehicle monitoring/control (AVM/C),
- Emergency location of vehicles,
- Enhanced (spatially-based) data collection,
- Customer information activities including compliance with the Americans with Disabilities Act (ADA) and general passenger information, and
- Traffic Signal priority (Okunieff, 1997).

There are several available AVL technologies: dead reckoning, map matching, signposts, ground based radio, global positioning system (GPS), and differential global positioning system (DGPS). Each type employs different techniques to locate a vehicle and communicate its position to a central location. A full description of each type of AVL is beyond the scope of this report and is reported elsewhere (Casey et al., 2000 and Okunieff, 1997).

A summary of the advantages and disadvantages of each AVL type is presented in Table 3-1 for quick reference. It should be noted that today most new AVL installations utilize either GPS or DGPS technologies due to their superior accuracy and minimal infrastructure requirements.

Table 3-1. Advantages and disadvantages of Automatic Vehicle Location technologies

Technology	Brief Description	Advantages	Disadvantages
Signpost & Odometer	Active – Signpost beacons located at specific points along route (e.g., traffic signal poles, light poles). Each beacon transmits a unique signal to the vehicle. Vehicle determines location then transmits location to dispatcher. Passive – Each vehicle transmits a unique signal to signposts along route. Signposts report vehicle position (from passing vehicle) to dispatcher. In both cases, the vehicle tracks its position relative to beacons via the odometer.	• Proven technology • Low in-vehicle cost • No signal interference • Repeatable accuracy (good for measuring time points against performance)	• Requires extensive infrastructure (i.e., Need beacons along route) • Not effective for vehicles off-route or paratransit • Location is given only when the vehicle passes the signpost • Frequency of updates depend on density of the signposts
Wayside Automated Vehicle Identification (AVI)	Similar to signpost and odometer method. Vehicle reports locations from an onboard transponder to receiver located along route. Receiver communicates to dispatch via microwave link or landline.	• Low in-vehicle cost • No signal interference • Repeatable accuracy (good for measuring time points against performance) • Possibility for shared infrastructure costs	• Requires extensive infrastructure (i.e., Need receivers along route) • Location is given only when the vehicle passes the signpost • Frequency of updates depend on density of the signposts • May incur high communications costs
Ground-based Radio	Uses a network of radio towers on the ground to transmit signals (location determined by measuring the time difference of signal reception from vehicle among towers). Receivers placed on vehicles read signals and triangulate to determine location. Can be supplemented with the odometer readings to interpolate between signal receptions.	• Limited only by radio signal availability • Does not require purchase, installation, or maintenance of wayside equipment • Low cost • Moderately accurate	• Can be blocked by hills and tall buildings • Incomplete coverage • Possibility of monthly service fees
Global Positioning Systems (GPS) & Differential GPS	Vehicle transmits position (coordinates) to satellite. Satellite determines the vehicle location and relays information to dispatcher. DGPS receiver corrects for bias of satellites by determining differences between observed signals and predicted signals. Results in increase accuracy.	• Can be operated anywhere GPS signals are received • Does not require purchase, installation, or maintenance of wayside equipment • Very accurate	• Signal attenuation by foliage, tunnels, and tall buildings • Must be within range of differential signal • Differential correction must be updated frequently (adds to infrastructure costs)

3.1.3. Automatic Passenger Counting Systems (APC)

Automatic passenger counters are devices used to keep track of the number of passengers that board and alight buses at each stop along a route. APC systems are typically based on one of two technologies, either treadle mats or infrared beams. Treadle mats are simply mats placed in the ingress/egress points of a bus that have pressure sensors embedded in them to sense passenger stepping. An infrared beam works in a similar fashion except that the passenger movement is sensed when the beam between the infrared transmitter and receptor is "broken" by a person passing by. In the case of both technologies, a signal is sent to a computer on board the bus to record the event of someone boarding or alighting the bus. In the case of vehicles that have only one door, two detectors (mats or infrared) may be required to discern whether a passenger is getting onto or off of the bus. Figure 3-1 is a schematic of how an APC would discern between a passenger boarding or alighting the bus. For example, when a signal is sent from detector 1 followed by a signal sent immediately from detector 2, the on-board computer would record that a passenger had boarded the bus. The opposite sequence would indicate that a person had alighted from the bus.

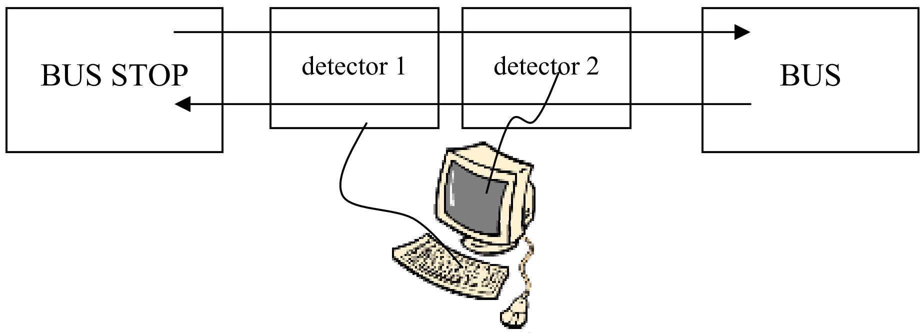

Figure 3-1. Automatic Passenger Counter schematic

Typically, an APC is deployed in conjunction with AVL equipment to allow the collection of location-specific passenger data. Location information allows the boarding and alighting to be associated with individual stops and is much more useful for planning and monitoring schedule adherence (Furth, 2000). The collected passenger information is downloaded from the on-board computers at regular intervals (generally daily) to a database at the central dispatching facility. The information is then available for generating NTD reports as well as schedule adjustments and route planning.

3.1.4. Computer-Aided Dispatch (CAD)

As the name implies, computer-aided dispatch (CAD) systems rely on computer software applications to augment and automate, where applicable, scheduling and dispatching functions within a transit agency. CAD can be deployed for both fixed-route bus systems as well as paratransit operations. Typical functions performed by CAD are presented in Table 3-2.

Table 3-2. Typical functions performed by Computer-Aided Dispatch Systems

Fixed-route bus systems	Paratransit
• When combined with AVL (see Section 2.1.2.) can monitor and adjust headways, dwell times, etc. to improve schedule adherence • Allow bus drivers or in-vehicle information systems (see Section 2.1.4.) to inform passengers of transfers based on schedule adherence (e.g., passengers on a bus that is running late can be notified if they will miss a planned transfer) • Enhance service restoration by serving as a database rules, procedures, and historical experience of service disruptions and solutions • Dispatching to replace disabled vehicle • Allow for customer itinerary planning. Can be used by customer service personnel when assisting customers or can directly serve customers when linked to transit information systems such as web-based interfaces and kiosks (see Section 2.1.4.) • Can support data collection and reporting requirements • Can support service planning by supporting storage and analysis of performance data (e.g., average running time between time points, running time variability, headways). Can provide input to GIS for visualization of performance measures by location (see Section 2.1.7.) • Performing traffic signal priority (see Section 2.1.8.) • Rerouting vehicles due to service changes, incidents, special events, etc.	• Automatic passenger registration • Automatic location and mapping of pick-up and drop-off points • Scheduling and batching of trips • Brokering among multiple carriers (e.g., CLASTRAN to BJCTA) • Allow for customer itinerary planning. Can be used by customer service personnel when assisting customers or can directly serve customers when linked to transit information systems such as web-based interfaces and kiosks (see Section 2.1.4.) • Can support data collection and reporting requirements • Dispatching to replace disabled vehicle • Rerouting vehicles and/or adjust schedules due to incidents, trip cancellations/additions, etc. • Accommodate shared-ride trips • Accommodate advanced trip reservations, standing orders, and immediate requests • Dispatch can be integrated into management information, billing and accounting functions

3.1.5. Transit Information Systems

Transit information systems provide passengers with information on one or more modes of transportation to facilitate decision-making while planning a transit trip (pre-trip) or while already traveling (en-route). En-route transit information can be disseminated to riders as they travel on a bus (in-vehicle) or while waiting or transferring at a station/stop (wayside). Implementation of a transit information system entails gathering, processing and disseminating information on transit routes and schedules. The use of transit information systems may imply either static or dynamic information, or both. A system or route map is an example of a static pre-trip transit information system – it informs potential riders when and where they may use transit services. An example of a dynamic pre-trip information system would be a website that shows routes and schedules but also provides information on whether or not individual routes are operating on schedule. Devices that announce when the transit vehicles are approaching a station or inform riders how long they must wait for the next available vehicle are examples of dynamic en-route transit information systems. Dynamic transit information systems require real time information on transit vehicles and operations. The real time information for these systems is generally derived from the use of other APTS technologies (e.g., AVL and APC systems). Generally, information is collected from individual vehicles and processed in a central control system (dispatch) and then disseminated via different media to the transit management and transit riders. For example, based on real-time information transmitted from the AVL aboard Bus X, a message could be broadcast at a bus stop that the bus is delayed due to an incident. Riders could use this information to make a decision whether or not to wait on Bus X or take Bus Y that might get them close to their destination (but not as close as Bus X) at a more acceptable time.

There are several technologies and media available for disseminating transit information. Table 3-3 presents a summary of the various available media and technologies. All of the technologies listed in Table 3-3 support both static and real-time transit information (Peng and Oliver 1999).

Table 3-3. Summary of available technologies for dissemination of transit information

Types of Transit Information Systems	Media		
	Audio	Video	Multimedia
Pre-trip	• Television/radio • Interactive telephone systems • Cellular phones • Pagers • Handheld computers • (PDA) • e-mail notification	• Closed-circuit TV • (CCTV) • Handheld computers (PDA)	• Website • Kiosk
In-terminal (Wayside)	• Annunciatiors • Pagers • Handheld computers (PDA)	• Variable message signs (VMS) • Closed-circuit TV • (CCTV) • Handheld computers (PDA)	• Kiosks
In-vehicle (On-board)	• Annunciators • Pagers • Handheld computers (PDA)	• Variable message signs (VMS)	• Audio/video terminals

In addition to the transit information systems previously described that offer information to the general public, some transit agencies have recently begun experimenting with personalized, subscription-based transit information. In other words, agencies provide traveler information that is tailored to meet an individual's needs (e.g., travel profile). Information may include incident notification, transit vehicle arrival alert, or other information. The information can be received by the transit rider via e-mail, cellular telephone, personal digital assistants, pagers, etc. on a pre-trip or en-route basis.

3.1.6. Transit Priority at Traffic Signals

Traffic signal priority refers to the practice of giving certain, pre-designated vehicles priority at traffic signals. There are three types of signal priority that can be given to transit vehicles: *passive*, *active*, and *real-time*. An example of active transit priority is presented in the diagrams shown in Figure 3-2. Additionally, each of the three types is briefly described in Table 3-4 along with a list of advantages and disadvantages associated with each.

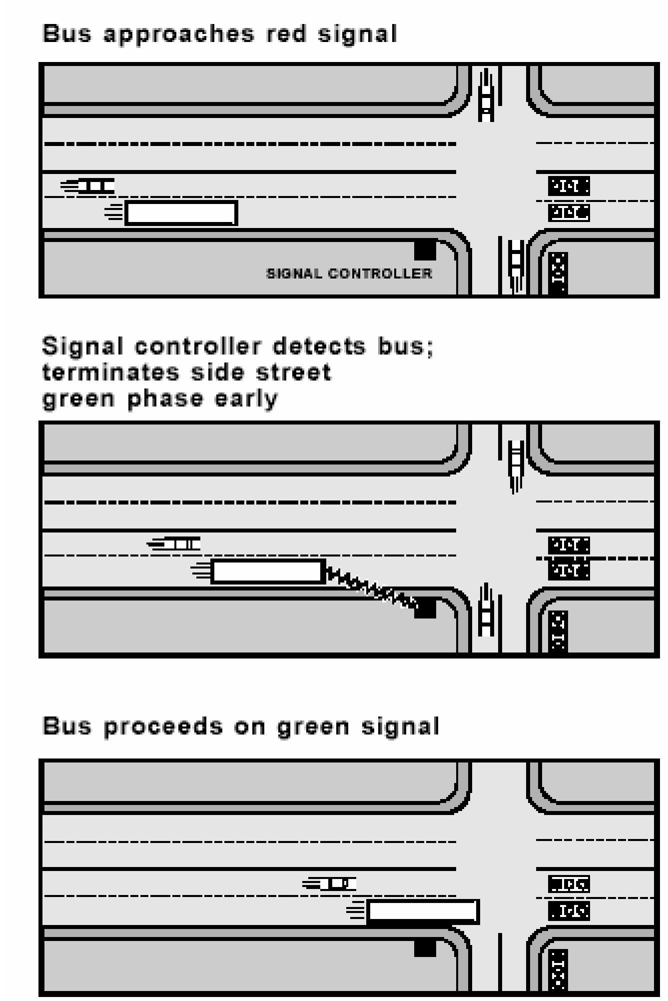

Figure 3-2. Schematic of traffic signal operations with bus priority
(Source: *Transit Capacity and Quality of Service Manual*, TCRP, 1999)

Table 3-4. Transit priority types

Type	Description	Advantage	Disadvantage
Passive	Intended to provide priority treatment to transit vehicles on a regional basis. Involves timing traffic signals along transit routes in conjunction with transit schedules.	• Does not require additional equipment on vehicles or at intersections	• May result in delay to non-transit traffic • Signals follow set pattern whether transit vehicles present or not
Active	Transit vehicles are detected as they approach intersections, then given priority (a green light).	• Responsive to individual transit vehicles	• Requires additional equipment on vehicles and at intersection • Will pre-empt signal even if transit vehicle is on-time or ahead of schedule • Requires additional equipment on vehicles and at intersection
Real-time	Strategy to give transit vehicles priority only under certain conditions (e.g., vehicle is running behind schedule).	• Pre-empts signal only when needed, minimizing disruptions to other traffic	• Requires additional equipment on vehicles and at intersection • More expensive than other types of pre-emption

A *passive priority* strategy seeks to favor roads with significant transit use in the area-wide traffic signal timing scheme. Timing coordinated signals at the average bus speed instead of the average vehicle speed can also favor transit vehicles. By contrast, an *active priority* strategy involves detecting the presence of a transit vehicle and, depending on the system logic and the traffic situation then existing, giving the transit vehicle special treatment. The system can give an early green signal or hold a green signal that is already displaying. An active system must be able to both detect the presence of a bus and predict its arrival time at the intersection. Near-side stops can complicate the prediction of intersection arrival times. *Real-time* control strategies can consider not only the presence of a bus but the bus adherence to schedule and the volume of other traffic. One common strategy is to give priority only to late buses (compared to the scheduled time) but not to early buses. This strategy optimizes schedule adherence (and therefore waiting time) rather than running time (TCRP, 1999).

3.1.7. Electronic Fare Payment Systems

Electronic fare payment systems utilize electronic data processing and storage to perform and record transit fare payment transactions. The goal behind the deployment of electronic fare payment system is the reduced usage of cash or tokens by transit passengers. Cash-based systems are cumbersome and often contribute to transit delays as passengers fumble for proper change while boarding a bus, holding up passengers behind them. Processing and operating a cash-based fare collection system is also labor intensive and theft-prone. A transition to electronic payment systems would largely eliminate cash transactions on the bus (when riders can purchase cards or other media in stations and other locations). Electronic payment systems are capable of handling a variety of fare media including coins, bills, magnetic strip paper or plastic cards and integrated circuit or radio frequency smart cards. Advances are also being made toward applications with stored value smart cards and credit cards issued by banks and other financial institutions.

Figure 3-3. Example of a smartcard and reader (Source: MARTA, 2002)

Figure 3-4. Example of a magnetic fare card reader (Source: MTA-NYCT, 2002)

3.1.8. Geographic Information Systems (GIS)

Geographic information systems (GIS) are simply interactive, computer-based maps linked to databases of information. GIS allows users to visualize and analyze relationships among spatial data (as presented on a map) and various information attributed to different locations (region, city, intersection, etc.). The GeoGraphics Laboratory at the Moakley Center for Technological Applications at Bridgewater State College is conducting an ongoing study of the use of GIS among Transit agencies in the U.S. While the study is not yet complete, it does provide useful information on the role of GIS in transit. Table 3-5 presents some types of transit-related information that agencies reported using GIS to store and analyze (Harman and Shama, 2002).

Table 3-5. Types of transit data stored in GIS

Transit Information (e.g., physical elements)	Attribute information
Routes	Political boundaries
Bus stops	Traffic Analysis zones
Bus timepoints	Census information
AVL communication points (e.g., beacons, signposts)	Zip codes
Park-and-Ride lots	Transit accident locations
Transit facilities (e.g., maintenance, storage)	Locations of incidents requiring police response

The Center for Urban Transportation at the University of South Florida has identified four general categories of potential applications of GIS to public transit (CUTR, 1995):

- Operations and Control – performance monitoring, passenger loadings, running times, scheduling, bus assignments, dead-head routings, customer complaints, vandalism and other facilities management needs,
- Planning and Market Development – land uses, employer sites, demographic data, and travel patterns (O-D),
- Information Dissemination –route maps, pre-trip planning, route choice, on-time performance data, multi-media displays,
- ADA Compliance – customer locations, customer eligibility/determination, and service statistics, and
- Other –ridesharing coordination, paratransit, and HOV lane violations.

3.1.8.1. Operations and Control GIS can be used to facilitate scheduling and dispatching activities and can be especially useful in the context of demand-responsive (paratransit) operations. With the appropriate data, GIS can provide detailed directions for drivers and the ability to update directions en-route due to cancellations. Updates could be made through conversing with the dispatcher or simplified further using AVL system integrated with the GIS. GIS could also be used as a reference to aid customer service/information employees. Integration of transit data (e.g., passenger loadings, running times, schedule adherence) into the GIS allows for more detailed and reliable performance monitoring. GIS can also be applied to facilities and real estate management activities within a transit property – develop and maintain an inventory of properties and its locations. The GIS allows detailed information about each property to be stored and readily accessed for decision-making purposes. Other information that would be useful for operational purposes if tied to specific locations via a GIS includes:

- Monitoring passenger loading,
- Monitoring running times,
- Customer complaints, and
- Bus assignments.

3.1.8.2. Information Dissemination Information dissemination is primarily the production of maps that can quickly convey information to patrons, management, board members, and the general public (CUTR, 1995). Such maps might include the destinations along routes to facilitate trip chaining via transit, and the spatial relationship of routes to specific activity generators (e.g., schools, senior centers, hospitals, and human service agencies) (Shawn, et al. 2001). Integration of real-time information (e.g., arrivals, delays) into a GIS is necessary to support advanced transit information systems.

3.1.8.3. Planning and Market Development Transit planning covers a very broad range of activities and "has the largest number of potential uses for GIS" (CUTR, 1995). A 1992 survey showed that of 67 transit properties interviewed, 30 used GIS in transit planning applications (Schweiger, 1992). Traditionally, the transportation planning process consists of four steps: trip generation, trip distribution, modal split, and network assignment. In general, these steps deal with how many trips are produced and where they will originate from, the destination of each trip, what mode will be used to make the trip (walking, personal or public transportation, etc.), and what path each trip will take to reach its destination. In the case of transit planning, the mode of transportation is already decided, but the other three steps can be simplified using a GIS. In particular, GIS can be utilized to identify and determine the size of target populations of existing and potential riders. GIS can also be applied to service planning (Schweiger, 1992). Route structure, roadway network, traffic conditions, and ridership information can be integrated to within the GIS to determine the shortest path among specific locations and the estimated travel time along individual segments, which could then be used to determine headways. Figures 3-3, 3-4, and 3-5 are examples of demographic and transit route information integrated in a GIS that can be used for planning and market development.

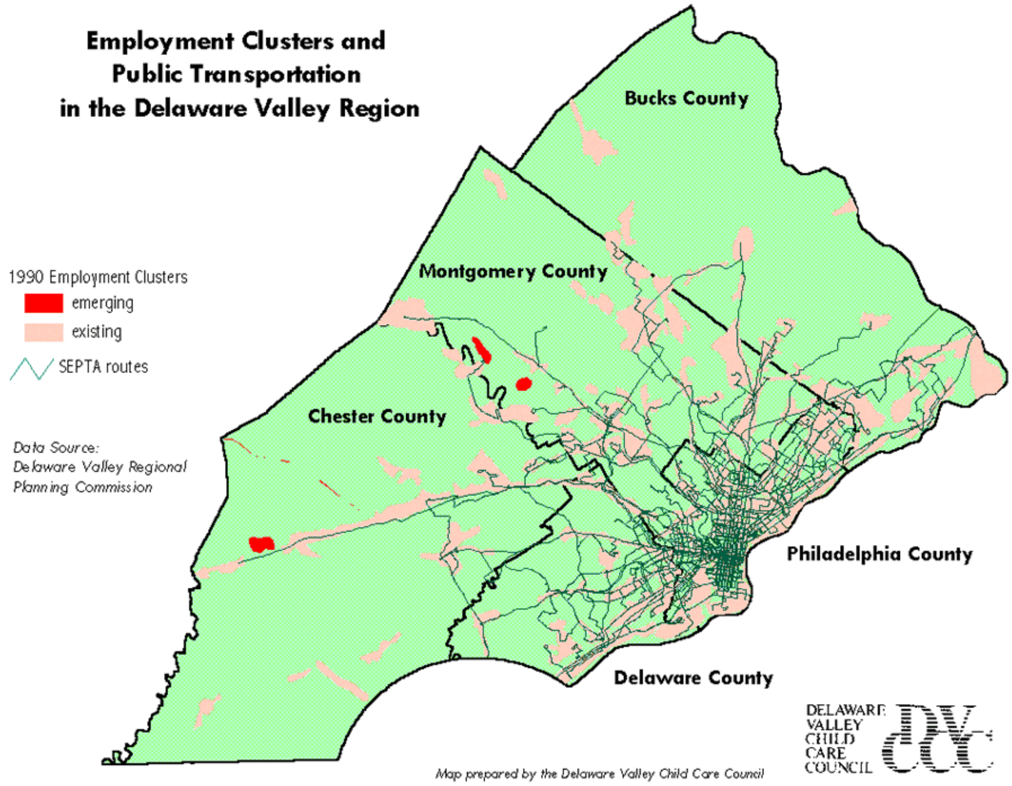

Figure 3-5. Example of regional employment data overlaid on transit routes within a GIS (Source: ESRI, 2002)

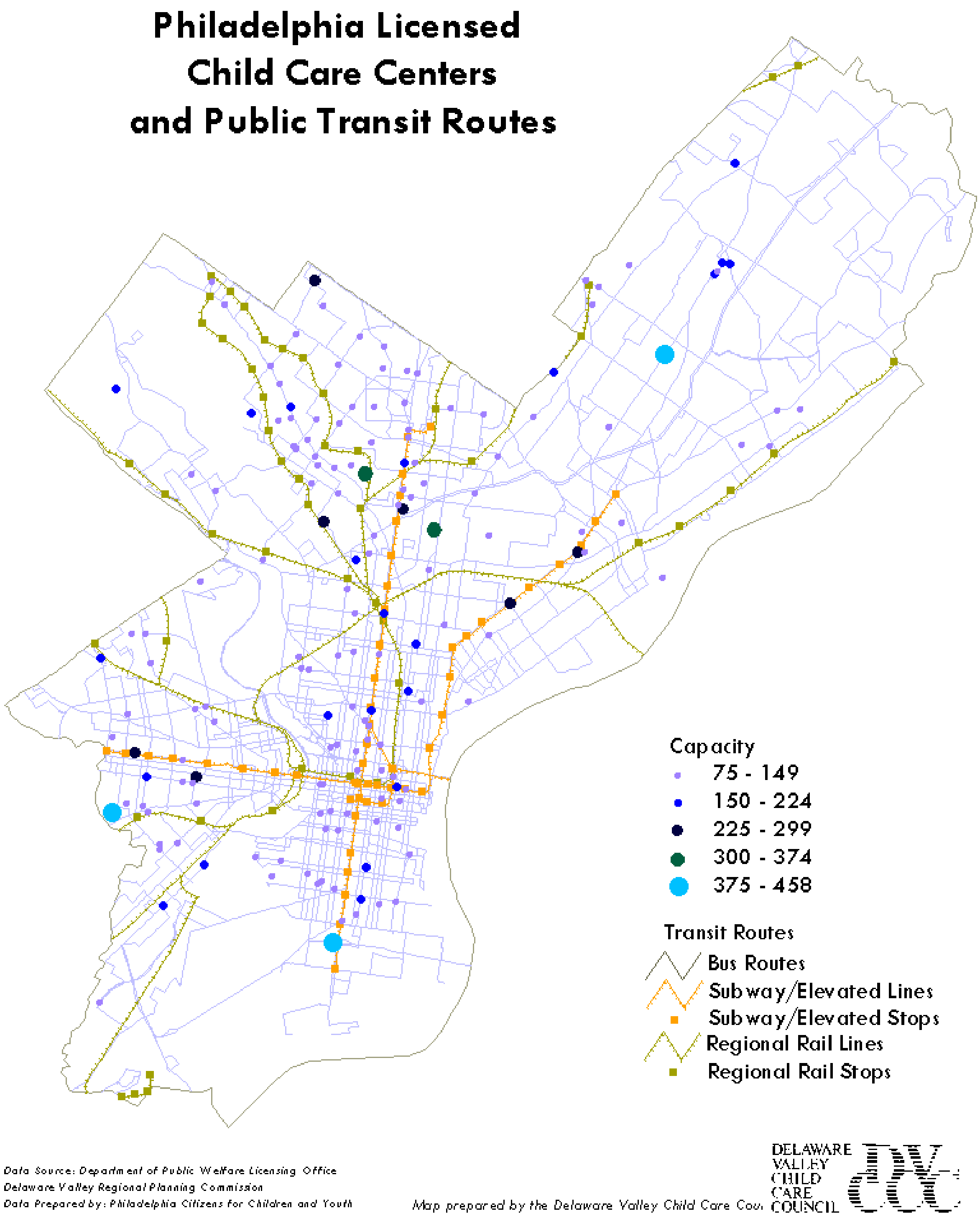

Figure 3-6. Example of regional child care center data overlaid on transit routes within a GIS (Source: ESRI, 2002)

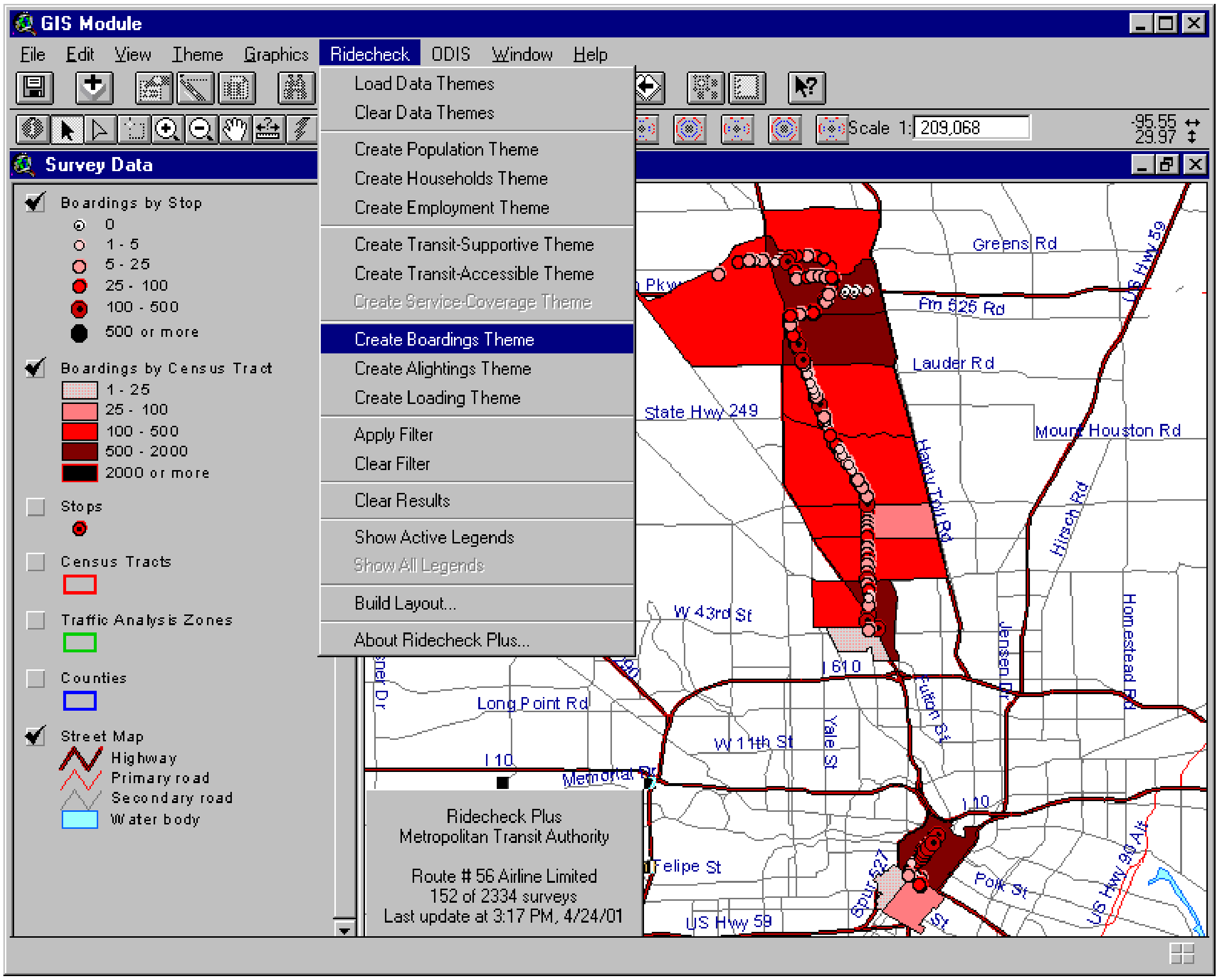

Figure 3-7. Example of regional census data in relation to transit boardings within a GIS (Source: ESRI, 2002)

Many researchers and individuals within the transit industry have recognized the importance and potential of GIS to transit. As an additional resource concerning GIS application within the transit industry, a listing of helpful websites is provided in Table 3-6.

Table 3-6. Transit/GIS-related websites

Source	Website address
ESRI GIS & Mapping Corporate website	http://www.esri.com/industries/transport/transit.html
FTA - Transit Geographic Information System Part of the National Spatial Data Infrastructure	http://www.fta.dot.gov/library/technology/GIS/TGIS/TGIS.HTM
The Florida DOT Statewide GIS for Transit Technical Assistance Program	http://www.nctr.usf.edu/projects/473-10.html
Description of GIS Deployment within New Jersey Transit	http://www.intergraph.com/gis/customers/articles/njtransit3.asp
FTA National Transit GIS: Data Standards, Guidelines and Recommended Practices	http://www.fta.dot.gov/research/fleet/pubs/gis/ntgisds/ntgisds.htm
Short Range Transit Planning and Marketing Using Desktop Geographic Information Systems	http://www.fta.dot.gov/library/planning/CULP/CULP.html

3.2. Benefits of Applicable APTS Technologies

The following sections present a summary of various benefits associated with APTS technology applicable to Birmingham. The information was adapted from an online database maintained by Mitretek Systems for the USDOT (Mitretek, 2003)[5] as well as numerous case studies.

3.2.1. Benefits of Communication Systems

Surveys in recent years have found the conversion to digital communication systems has been slower in the transit industry than in other industries. The primary reason cited has been expense, with many transit agencies finding it is more economical to upgrade older analog systems than it is to convert to digital (Casey, 2000). This has been true of both large and small systems. The Chicago Transit Authority, for instance, recently upgraded its older analog equipment rather than replace it with digital equipment, citing ease and cost of maintenance as one of the primary factors.

Nonetheless, many transit agencies have deployed advanced communication systems, including mobile data terminals (MDT's). One operational test in Ann Arbor, MI used MDT's in buses to display complete schedule and time information so that drivers could continually monitor schedule adherence and receive dispatch messages from the control center. The test found that the number of on-time departures nearly doubled with this new equipment, jumping from 26% of all departures to 44% of all departures in just a 2 year period (Levine, 1999). Overall, upgrading communication systems, even if they remain analog, can improve communication between driver and dispatcher or driver and driver, if vehicle to vehicle communication is provided. The latter is useful for timed transfer operations, so that a driver of a vehicle which is running late can request that another driver delay his departure in order to make a transfer.

[5] The information presented in the following sections does not represent all of the information in the database, but rather is intended to represent the types and magnitude of benefits derived from other APTS deployments.

Many transit agencies have upgraded their communication systems in concert with APTS deployments, most commonly in support of new AVL systems. In these cases it is difficult to separate the benefits of the communications upgrade from the larger benefits provided by the APTS deployment because the two are interdependent. APTS systems such as AVL, automated dispatch, and in-vehicle information displays rely on the communication system to transmit data to and from the control center and so they must be considered in terms of the overall benefits of the system. In the APTS environment, communication systems frequently support and enhance the benefits generated by other APTS technologies rather than generate benefits of their own.

3.2.2. Benefits of Automatic Vehicle Location Systems

Some of the most widely cited operational benefits of AVL include:

- Improved dispatch and operational efficiency,
- Improved overall reliability of service,
- Quicker responses to disruptions in service (i.e., such as failure or unexpected congestion),
- Quicker response to threats of criminal activity, and
- Extensive information provided at a lower cost for future planning purposes (Okunieff, 1997).

Examples of specific benefits derived from previous deployments are presented in Table 3-7 (Mitretek 2003, Levine 1999, and Boldt 2000).

Table 3-7. Example benefits of AVL deployments

Category	Description	Examples
Capital Cost Savings	• Lower fleet requirement • Reduced service vehicles and equipment	• Kansas City, MO - KCATA reduced the number of buses serving its routes by 7 vehicles saving $1,575,000 (@ $225,000/bus).
Operation & Maintenance Costs Savings	• Reduced data collection costs • Improved fleet utilization	• Atlanta, GA - MARTA estimates $40k savings per survey due to the reduced need for adherence and travel time surveys. • London, Ontario – Eliminated $40k - $50k costs of conducting a schedule adherence survey • Kansas City, MO – saved $189,000/yr ($27,000/bus/yr) in maintenance costs and total labor cost savings of $215,000/yr due to fleet size reductions attributable to using fewer buses more efficiently with AVL. • Baltimore, MD - MTA predicts $2-3 million savings per year from reduced fleet requirements (i.e., purchasing, operating, and maintenance) as a result of using fewer buses more efficiently with AVL. • Prince William County, VA - PRTC estimates annual savings of approxi9matelty $900k due to AVL system
Safety & Security	• Incident response • Crime deterrence • Situational awareness	• Kansas City, MO - KCATA's reduced average response time to bus operator calls by 8 minutes due to AVL. • Denver, CO - Denver RTD attributes emergency response time less than 8 minutes to AVL
Service Quality	• Schedule adherence • Reliability • Service control • Operator monitoring • Management and maintenance	• Kansas City, MO - KCATA improved on-time performance from 80% to 90% after implementing AVL (21% reduction in late buses, 12% reduction in early buses). • Portland, OR - After implementing its AVL/CAD system, Tri-Met improved on-time performance from 61.4% to 67.2% (37% reduction in early buses, 14% increase in late buses). • Milwaukee, WI - Milwaukee County Transit System improved on-time performance from 90% to 94% due to AVL. • Denver, CO - Denver RTD improved on-time performance from 88.0% to 89.6% after implementing its AVL/CAD system. The percentage of routes late decreased from 7.12% to 4.5%; however, the percentage of routes early increased slightly from 5.19% to 5.3%. • Portland, OR - Bus bunching (headways below 70% of their scheduled values) declined by 15% for eight routes due to AVL/CAD system. • Denver, CO - Denver RTD reported 13.2% reduction in hours of service loss due to maintenance road calls as a results of AVL/CAD.
Customer Satisfaction	• Service reliability • Passenger information • Knowledge of bus position • Anxiety reduction	• Denver, CO - Customer complaints have fallen by 26% since Denver RTD installed AVL • Milwaukee, WI - Schedule related public complaints decreased 24% between 1993 and 1997 for the Milwaukee County Transit System. The agency attributes the improvement to its CAD/AVL system.
Efficiency	• Dynamic dispatching & road control • Demand response, and flexible routing benefits • More efficient schedules	• Kansas City, MO - KCATA reduced scheduled travel times 10% due to AVL.
Productivity	• Reduced supervisors • Dispatcher efficiency and effectiveness • Improved system oversight • Improved road call response	• Denver, CO - Denver RTD reported dispatch hours per weekday increased 46% and vehicle hours increased 14% dues to AVL/CAD. • Milwaukee, WI - Milwaukee County Transit System decreased supervision staff 24% due to AVL/CAD.
Data Provision	• Real-time and historic data • Operator performance review • System and route performance review • Data available for dissemination • Vehicle performance data	• Milwaukee, WI - Milwaukee County Transit System's reported AVL system disproved 50% of customer complaints. • Milwaukee, WI - Milwaukee County Transit System reported schedule adherence data accuracy improved from 70% using manual checks to 95% using AVL. • Atlanta, GA - MARTA saved $1.5 million through schedule adjustments using APC and AVL data.

3.2.3. Benefits of Automated Passenger Counter Systems

The primary advantage to APC deployment is the improved efficiency and accuracy of the data collection process for NTD reporting as well as internal performance monitoring and planning purposes. While automatic passenger counts will have inaccuracies, they can be adjusted with correction factors and have been shown to be far more accurate than manual counts (Kimpel, 2002). The costs savings associated with reducing (or eliminating) the need for human data collectors generally pays for the APC equipment. A list of general advantages and disadvantages of APC deployment is presented in Table 3-8 (Boyle, 1998 and Casey et al., 2000).

Table 3-8. Advantages/disadvantages of APC deployments

Advantages	Disadvantages
Reduced data collections costs	May result in more data than the agency can effectively use
Ability to collect large amounts of ridership data	Requires computer capacity to retrieve, store, and process large amounts of data
Reduce (or eliminate) the need for manual checkers	May create human resource difficulties as a result of eliminating manual checker positions and duties
Greater accuracy	Hardware must be calibrated and maintained

It is also worth noting that the Metropolitan Atlanta Rapid Transit Authority (MARTA) cites its APC equipment as the most difficult to maintain (due to calibration) of the APTS technologies it currently operates. MARTA has indicated that only 60% of its APC devices are providing "good" data (Mitretek, 2003). A description of benefits derived from APC deployments is from the Mitretek database and is presented in Table 3-9 (Mitretek, 2003).

Table 3-9. Example benefits of APC Deployments

Category	Description	Examples
Operation & Maintenance Costs Savings	• Reduced data collection costs	• London, Ontario - London Transit reported $50k savings by eliminating manual system-wide counts.
Safety & Security	• Know how many people on board during accident	• Not reported
Service Quality	• Provide service where it is needed most – optimize vehicle allocation, headways, routes	• Not reported
Customer Satisfaction	• Better data available for service planning • Monitor load factor real-time and dispatch additional vehicles as needed	• Not reported
Efficiency	• Increase throughput by optimizing routes/stops based on need •	• Not reported
Productivity	• Optimize rates and schedules to ridership needs • Reduce time to collect data • Reassign passenger checkers to other duties	• Atlanta, GA - MARTA reduced the number of traffic checkers from 19 to 9.
Data Provision	• Ridership data enables route evaluation - correlation of data to routes and schedules	• Atlanta, GA - MARTA reported $1.5M in savings via schedule adjustments attributable to APC and AVL data • Atlanta, GA – MARTA reports APC data to be 80% to 85% accurate • Columbus, OH - Central Ohio Transit Authority reports APC data to be 95% accurate

3.2.4. Benefits of Computer Aided Dispatch Systems (CAD)

CAD has potentially valuable implications for both transit providers and transit users. Transit providers will be able to employ operations control, control measures in and more systematic and responsive fashion with expected improvements in service reliability and reduction in operating costs. Riders will benefit from more reliable service, which is expected to result in reductions in their waiting times (Strathman et al., 1999).

Among the cited operational benefits of CAD are:

- Improved scheduling,
- Improved fleet utilization,
- More balanced labor requirements (schedules, labor rules, etc.),
- Better management of transfers and connections, and
- Reduced demands (voice traffic) on communications systems (Mitretek, 2003).

CAD, when combined with AVL systems, will allow providers to more closely monitor fleet status, identify disruptions in service (due to incidents, congestion, or mechanical failure), and direct other vehicles to quickly restore service. Some transit systems have reported reductions in response times of up to 40% once CAD systems were implemented. CAD can also be used to monitor the on-time status of buses and notify drivers if they need to speed up or slow down to maintain schedule. In cities that have deployed CAD systems, improvements in schedule adherence of 23% and more have been reported (Goeddel, 2000).

For paratransit services, the most often reported benefits relate to system efficiency. By automating vehicle scheduling and routing paratransit providers have been able to be more responsive to their customers while improving the efficiency of their operations. It also facilitates scheduling trips such that passenger wait times are minimized when transferring between paratransit and fixed-route services. The paratransit agency in Blacksburg, VA found that they were able to increase the number of passengers served by each vehicle from 0.8 passengers/hour to 2.0 passengers/hour (Goeddel, 2000).

3.2.5. Benefits of Transit Information Systems

As described in Section 3.1.4., Transit Information Systems are generally categorized into pre-trip information, in-terminal, and in-vehicle systems. The following sections present a discussion of the benefits of each. It is worth emphasizing the importance of accurate and current information (schedule, route, fare, arrival times, maps, etc.) to a successful transit information systems deployment.

3.2.5.1. Benefits of Pre-trip Information Systems A description of benefits derived from pre-trip transit information systems is presented in Table 3-10 (Mitretek, 2003). The systems presented in Table 3-10 represent various technologies (e.g., telephone, Internet, electronic kiosks, fax machines, television). In general, support for a pre-trip information system should require a relatively small incremental cost for a transit property currently using GIS and/or AVL.

Table 3-10. Example benefits of pre-trip information systems

Category	Description	Examples
Capital Cost Savings	• Relieves some burden of the agency customer service representatives unless it doesn't work properly then it can cause more work in the form of damage control • May allow more efficient routing of buses over time if you can collect info related to travel patterns, time of day, etc. •	• Not reported
Operation & Maintenance Costs Savings	• May free up customer service representatives' time (reduced staffing costs)	• Not reported
Ridership/ Market share	• Projected ridership increase • Transit system is more user friendly and attractive	• Ventura County, CA - 56% of survey respondents indicated availability pre-trip information influenced their choose to use transit over alternative modes • London, England - A survey of users of the computerized transit trip-planning system indicated 80% of users made the trip about which they inquired, 30.4% changed their route based on information received from the system, and 10.4% chose transit because of information obtained from the system
Service Quality	• Automated systems provide access to information w/o waiting for a customer service representative • May improve the patron's trip time by finding the most optimal OD path • Adds to comfort level • Redistributes passengers during periods of interrupted service (crowd control) • Reduces wait time for transit vehicles • Personal security (e.g., lessons exposure to weather and crime) • Alerts customers of incidents/emergencies and provides instructions • Increases perception of transit reliability	• Newark, NJ - New Jersey Transit's telephone automated transit info system reduced caller wait time from an average of 85 seconds to 27 seconds
Customer Satisfaction	• Increases customer convenience and satisfaction • Reduces customer uncertainty and anxiety	• Newark, NJ - New Jersey Transit's telephone automated transit info system reduced the caller hang-up rate from 10% to 3%
Productivity	• Increases system productivity • Reduces the need for customer service personnel	• Rochester, NY - Rochester-Genesee Regional Transportation Authority's automated telephone system increased call volume by 80%. System handles 70% of calls resulting in the eliminated the need for 4 part-time customer information agent positions • San Diego, CA - Telephone system handles 21% of calls • Atlanta, GA - Telephone system handles 16% of calls

3.2.5.2. Benefits of In-terminal/Wayside Information Systems In-terminal transit information systems provide arrival/departure information of buses/trains at bus stops and terminals, and train stations and platforms. Benefits derived from in-terminal transit information systems are summarized in Table 3-11 (Mitretek, 2003).

Table 3-11. Example benefits of in-terminal/wayside information systems

Category	Description	Examples
Service Quality	• Reduces wait time for transit vehicles • Personal security (e.g., lessons exposure to weather and crime) • Alerts customers of incidents/emergencies and provides instructions • Increases perception of transit reliability	• Not reported
Customer Satisfaction	• Increases customer convenience and satisfaction • Reduces customer uncertainty and anxiety	• London, England –83% of transit riders in London stated that time passed more quickly knowing that the bus was coming and 68% reported an improved attitude and perception of transit • Turin, Italy – 75% of transit customers stated that forecasted arrival times at bus/tram stops revealed were useful

3.2.5.3. Benefits of In-Vehicle Transit Information Systems In-vehicle transit information systems provide information such as next stop, connection and transfer information, as well as special announcements (next stop, major cross road, transfer point, landmark, destination information, public service announcements, etc.) to riders traveling on the bus. The information is delivered via audio and/or visual announcements.

Experience with in-vehicle systems has been largely positive with the primary benefits cited being increased customer satisfaction and enhanced transit experience (Goeddel, 2000). In an operational test of several APTS technologies, in-vehicle information displays received the most positive ratings from passengers (Levine, 1999). Another important benefit is that in-vehicle information displays and annunciators allow transit providers to comply with the ADA requirement that all major stops be announced without placing the burden solely on the bus driver (Levine, 1999). A summary of benefits related to in-vehicle displays is shown in Table 3-12.

Table 3-12. Example benefits of in-vehicle information systems

Category	Description	Examples
Service Quality	• Complies with ADA requirements • Relieves drivers of responsibility for announcing stops • Can provide information on connecting routes • Can alert customers to changes in service	• Washington, D.C. – WMATA is installing audio Annunciators on all new buses to comply with ADA requirements. • San Antonio, Texas – VIA Metropolitan Transit is installing audio/visual next-stop announcers on its entire fleet to comply with ADA requirements.
Customer Satisfaction	• Increases customer convenience and satisfaction • Reduces customer uncertainty and anxiety	• London, England –83% of transit riders in London stated that time passed more quickly knowing that the bus was coming and 68% reported an improved attitude and perception of transit • Turin, Italy – 75% of transit customers stated that forecasted arrival times at bus/tram stops revealed were useful

3.2.5.4. Benefits of Advanced Traveler Information Systems (ATIS) Overall, implementing ATIS has the potential to increase transit ridership (by as much as 2%), improve transit visibility within the community, provide increased customer convenience, and enhance transit services for the hearing and visually impaired (Goeddel, 2000).

The criteria for assessing ATIS are accessibility, versatility and interactivity, information carrying capacity, user friendliness, costs to service providers, costs to passengers, and ease of implementation. The advantages and disadvantage are based on the above criteria. A summary of general ATIS benefits is presented in Table 3-13.

Table 3-13. Advantages and disadvantages of different transit information system technologies

Technology	Advantages	Disadvantages
Automated telephone systems	• High accessibility • Delivers a large amount of information • Low cost in equipment , infrastructure and maintenance	• Lack of interactive capability • Passengers have to actively obtain information by themselves • Modest cost to obtain information • Implemented with some difficult
Delivery via cellular telephones	• Delivers a large amount of information • Low cost to service providers	• Medial accessibility to transit users; it is available in some places and to some people • Capable of disseminating only audio messages • Passengers have to actively obtain information by themselves • Implemented with some difficulty • More expensive to transit users than other media
Pagers	• Get information almost passively without much manual operation • Low costs in equipment, infrastructure, and maintenance	• Medial accessibility to transit users • Capable of disseminating only visual messages • Delivers very short and limited information • Users pay a modest fee to purchase the devices or to use the service • Not easy to implement
Kiosk	• Disseminate all types of information, including text, images, videotape, television signals, animation, and sound • Interactive with users • Deliver a large amount of information • Users do not pay to obtain information • Implemented without too much difficulty	• Medial accessibility to transit users • Passengers have to actively obtain information by themselves • High costs in equipment, infrastructure, and maintenance
Closed-Circuit Television	• Disseminate both visual and audio information • Delivers a large amount of information • Passengers can get information almost passively without much manual operation • Users do not pay or pay little to obtain information • Implemented but with some difficulty	• Medial accessibility to transit users • Modest cost in equipment, infrastructure, and maintenance
Dynamic Message Signs	• Disseminate both visual and audio information • Needs little user intervention • Modest cost in equipment, infrastructure and maintenance • Users do not pay to obtain information	• Medial accessibility to transit users • Delivers fewer messages •
Internet	• Disseminate all types of information, including text, images, videotape, television signals, animation, and sound • Deliver a large amount of information • Low cost in equipment, infrastructure, and maintenance • Users pay a modest fee • Implemented with some difficulty	• Low accessibility to transit users • Passengers have to actively obtain information by themselves
Automated Annunciators	• Get information almost passively without much manual operation • Do not require transit users to purchase any device or pay any fee for use • Implemented without too much difficulty	• Medial accessibility to transit users • Disseminate a monotype of information, and no interaction with users • Delivers fewer messages
Personal information systems	• Receive transit information directly via cell phone, pager, or PDA. • Individuals receive only the information relevant to their trip.	• Requires greater computational and communication capacity than other methods. • Cost of pagers and PDA's may be prohibitive to many transit users.

3.2.6. *Benefits of Transit Priority at Traffic Signals*

For transit users, the primary benefit of transit priority systems is improved schedule adherence and reduced delay. By making transit service more reliable it becomes easier to use and more attractive to users. For transit providers, priority systems can improve system efficiency by reducing running times, fuel usage, and in some cases even reducing fleet requirements. Examples of these benefits are summarized in Table 3-14.

Table 3-14. Example benefits of transit priority at traffic signals

Category	Description	Examples
Capital Cost Savings	• Lower fleet requirement • Grant fundable • Reduced vehicle running time • Reduced maintenance (brakes) and fuel usage • Reduced fuel usage	Los Angeles, CA - The LADOT and LACMTA estimate a savings in operating costs of $6.67 per bus per hour due to the LADOT/LACMTA transit priority system. This translates into an approximate savings in operating costs of $66.70 per bus per day, which nearly equates to the cost of the transponder ($75.00) installed on the bus. The agencies estimate that the per intersection cost of the transit priority system would be recovered through reduced bus operating costs in the first 200 bus-days of operation. Thus, the system would pay for itself through reduced operating costs in 18 months
Service Quality	• Reduced delay • Reduced running/travel time • Improved travel time reliability • Improved schedule adherence • Reduced travel time	• Seattle, WA - Average signal delay for King County Metro buses was reduced from 7.7 seconds to 3.3 seconds. Effects to side street and overall intersection delay were reported to be insignificant • Phoenix, AZ - Signal priority reduced red light delay for buses by 16%. Impact on cross traffic was minimal • Minneapolis, MN - Metro Transit buses experienced an average reduction of 9 seconds waiting at red signals • Oakland - Berkeley, CA - Signal priority (21 signalized intersections) reduced delays by 14%. It reduced delay by up to 6 seconds per intersection per bus and increased average bus speeds by 3.4%. The system created a 1% increase in delay for the non-transit traffic stream (while the number of stops decreased by 2%) • Los Angeles, CA - LADOT/LACMTA reported delay reductions between 4 and 5 minutes% on express routes equipped with priority control • Toronto, Ontario - Signal priority reduced signal delays for buses by 32% - 50% during peak periods. Impact on cross street auto travel was mixed • London, England - Bus delay was reduced by an average of 5 seconds per signal (22%). Bus delay was reduced by 10 seconds per signal during off peak operations • Bremerton, WA - Travel time was reduced by 5-16%. • Anne Arundel County, MD - 10 minutes was saved on a 52-minute one-way trip (19% reduction in travel time) • Charlotte, NC - Transit signal priority reduced average travel time for buses by 4 minutes • Atlanta, GA - A signal priority test conducted by MARTA (1 route) revealed a reduction in run time from 41.8 minutes to 28 minutes (33% savings) for inbound buses and 33.1 minutes to 27.5 minutes (17% savings) for outbound buses • Portland, OR - Tri-Met was able to reduce bus travel time on a major arterial by 5% for morning inbound trips and 8% for afternoon outbound trips • Washington, DC - Travel times of transit vehicles were reduced by about 6% using signal priority when tested on 114 intersections with 300 instrumented buses, but total traffic performance worsened • Sapporo City, Japan – Reported reductions in the number of stops at signals by 7.1% and travel time reduced by 6.1% • Turin, Italy - The public transport priority system improved public transport travel time by 14% and increased average bus speeds by 20% with no adverse effect on private traffic intersecting the bus routes

Because transit priority systems can affect overall traffic flow within their corridors, it is important that those responsible for maintaining the roads and signals be proponents of the systems. Unlike some other APTS technologies, transit priority requires the cooperation of other agencies to be effective and to minimize impacts to other modes of transportation.

3.2.7. Benefits of Electronic Fare Payment Systems

For transit providers, the most commonly cited benefits of electronic fare payment (EFP) systems are improved security, reduced fare collection costs, increased revenues, and ability to institute more flexible fare plans. For transit users, electronic fare media can facilitate transfers between different modes and different public transportation operators, provided fare agreements are in place. A summary of these benefits is provided in Table 3-15 (Goeddel, 2000).

Table 3-15. Benefits of Electronic Fare Payment systems

Category	Description	Examples
Improved Security	• Reduced fare evasions • Reduced theft • Improved revenue capture	• New York, NY – NYCTA Captured an additional $45 million in revenue after installing a magnetic stripe system.
More Equitable and Flexible Fare Structures	• Allow rush hour fare structures • Allow distance-based fares • Facilitate transfer between modes	• Los Angeles, CA – Inter-operator transfers increased from 0.5% of total passengers to 2.0% after implementation of electronic fare payment systems and multi-operator fare agreements.
Reduced Fare Collection Costs	• Reduced fare processing costs	• New Jersey – NJT estimates cost savings of $2.7 million annually resulting from reduced fare processing costs associated with electronic fare media. • Ventura County, CA – Estimated $990,000 reduction in fare handling costs after implementing a smart card system.
Increased revenues	• Interest earned on pre-paid fares • Unused pre-paid fares • Increased ridership	• New York, NY – NYCTA estimates $223 million increase in revenues resulting from implementation of electronic fare media. • Seattle, WA – Central Puget Sound Smart Card study estimated increased revenues of $43,000 to $65,000 annually from interest on pre-paid fares.

3.2.8. Benefits of Geographic Information Systems

Like communications systems, Geographic Information Systems (GIS) often support and enhance APTS systems rather than serve as stand-alone transit technologies. GIS are integral components of many widely deployed APTS technologies, such as AVL, APC, computer-aided dispatch systems, and traveler information systems. The benefits of deploying GIS in transit are generally part of the larger benefits generated by these systems, so it is difficult to isolate any particular contribution. The benefits of APC, AVL, computer-aided dispatch, and ATIS are all discussed in previous sections and will not be repeated, but a brief description of how GIS can enhance APTS technologies follows.

3.2.8.1 GIS Benefits to Operations and Control - Geographic Information Systems are key components of fleet management systems and operations software. These technologies allow dispatchers to track the movement of all vehicles, monitor schedule adherence, and dynamically dispatch vehicles to cover service disruptions. Their benefits are discussed in sections 3.2.2 and 3.2.4. GIS functions within these systems to process and display vehicle location data and facilitate vehicle routing. GIS can further enhance these functions by integrating data from outside sources such as traffic management centers and incident response agencies. As an example, real-time traffic information from a local traffic management center can be combined with transit fleet data within a GIS to enhance dispatch decisions, select minimum travel time paths, and predict service disruptions before they occur.

3.2.8.2. GIS Benefits to Information Dissemination – Many Advanced Traveler Information Systems (ATIS) rely on GIS databases to disseminate traveler information. Real-time vehicle location displays, whether they be in-vehicle or wayside, require detailed GIS route maps to process and display the relevant data. As these databases become more sophisticated transit agencies will be able to communicate a wider variety of information to passengers and provide more useful trip planning services.

3.2.8.3. GIS Benefits to Planning and Market Development – When combined with other APTS technologies, GIS can greatly enhance planning and market development. APTS systems are capable of collecting vast quantities of data that are of potential use for transit planning, but these data are of little use unless they can be put into a format that is easily analyzed. GIS allow data to be used more effectively for planning purposes. An example is the use of automatic passenger counters to collect ridership data, which when combined with AVL data can record the precise locations of all boardings and alightings. GIS databases with route and stop information can then summarize these data to yield load factors by segment and identify potential changes to service. Time-stamped data can further be used to generate historical data on schedule adherence.

3.3. Current Deployments of Candidate Technologies

Upon developing a basic understanding (functions, benefits, etc.) of the various APTS technologies applicable to transit in Birmingham, a review of current deployment was conducted. The review was restricted to APTS deployment in cities and transit authorities relevant to Birmingham. The following criteria were used to select which deployments were reviewed:

- Cities designated by the FTA as Birmingham's peer cities,
- Similar service area characteristics (e.g., population, demographics, service area, fixed-route bus and paratransit), and
- Similar number of vehicles.

Information on APTS deployments was gathered for the cities and transit authorities matching any of the above criteria and used to evaluate their applicability to Birmingham[6].

3.3.1. Communication Systems

Recent surveys have found that the transit industry has been slower to convert to digital and trunked communications technologies than have other industry sectors (Casey, 2000). Nonetheless, a 1999 survey of transit agencies found that the number of advanced communications systems operating in the United States increased by 202% between the years 1995 and 1999. A total of 140 transit agencies were operating advanced communications systems, making it the most widely deployed APTS technology (Casey, 1999). Among those

[6] i.e., Some cities were included in the review that were much smaller than Birmingham but the local transit authorities operated a similar number of vehicles or had other similar service characteristics.

agencies that operate fleets with less than 100 fixed-route buses, 15% operated trunked radio systems and 22% operated digital communications systems.

Many advanced communications systems have been installed as part of larger AVL deployments. 30% of transit agencies responding to a 1997 survey said they used the procurement of new communications systems to justify the purchase of AVL equipment. With the communications components typically accounting for 30%-60% of the total cost of an AVL system, it makes sense to consider deploying both together rather than separately (Okunieff, 1997).

Nationwide, many transit agencies have been choosing to upgrade their existing analog equipment despite the promise of higher capacity and better data transmission with digital systems. The main reason cited has been cost, with many agencies finding it more economical to retain analog equipment (Casey, 2000).

3.3.2. Automatic Vehicle Location (AVL) Systems
Automatic Vehicle Location (AVL) systems are perhaps the most widely deployed APTS technology nationwide. A 2000 survey found 228 transit agencies had deployed or were planning to deploy AVL systems, with 176 of these being on fixed-route or demand responsive buses (Goeddel, 2000). Smaller transit agencies have also deployed AVL systems in significant numbers, with 11 systems under 100 vehicles employing some type of AVL. Older systems installed prior to 1992 used sign post or odometer based systems almost exclusively. Today almost all new installations utilize either GPS or differential GPS, which provide greater accuracy with less infrastructure (Goeddel, 2000).

3.3.3. Automatic Passenger Counter (APC) Systems
A 2000 study found that approximately 25% of transit agencies surveyed used APC systems, all being either treadle mat or infrared beam systems (Goeddel, 2000). Of smaller transit agencies with less than 100 fixed-route buses, approximately 20% used APC's. Another survey found that most agencies using APC's reported equipping roughly 10%-15% of their fleets with APC's, although the Portland, Oregon transit authority had equipped 55% of their buses with APC's and had plans to eventually equip 100% of their fleet (Boyle, 1998). Some of the systems used in the early deployments transmitted the passenger count data back to a control center via radio, but several agencies, including MARTA in Atlanta, found that this consumed too much bandwidth and most systems now store the count data and download it when the bus returns to the garage. Most transit agencies have reported being pleased with the accuracy of the systems (Goeddel, 2000).

3.3.4. Computer Aided Dispatching (CAD) Systems
The total number of CAD deployments increased by 30% over the past five years with the largest increase in deployments that are currently operational. Of the total 223 deployments considered by the Volpe center over 180 transit agencies, 57% are currently operational, 11% are under implementation, and the remaining 32% are planned for deployment.

The benefits of these systems are:

- Increased efficiency in transit agencies,
- Improved transit service and customer convenience, and
- Increased compliance with transit ADA requirements (Strathman et al., 1999).

3.3.5. Advanced Traveler Information Systems (ATIS)

From Volpe's survey, out of the total number of ATIS deployments, 35% of the ATIS systems are directed to pre-trip planning applications. Approximately 19% of the deployments utilize in-terminal systems technologies while in-vehicle and wayside system applications represent 13% and 8%, respectively, of the total deployments. About 25% of the total deployments have not identified the type of ATIS technology planned for implementation. Of the total 151 deployments considered over 137 transit agencies, 56% are currently operational, 16% are under implementation, and the remaining 28% are planned for deployment (Goeddel, 2000).

3.3.6. Electronic Fare Payment (EFP) Systems

According to Volpe there has been a significant increase in the number of deployments of EFP system. Of the total electronic fare payment system deployments 40% of the transit system deployments of EFP systems are using or are planning to use smart card technology and 35% of the system deployments are using or planning to use magnetic stripe cards. The application of credit card and debit card technologies represent 7% and 4% respectively of all deployments, while 14% of the deployments have not identified the type of EFP technology. Of the total 118 deployments considered by 92 transit agencies, 36% are currently operational, 6% are under implementation, and the remaining 58% are planned for deployment (Goeddel, 2000).

3.3.7. FTA Peer Cities

When evaluating potential APTS deployments, it is useful to review the experiences of transit agencies in other cities of similar size and character. For that reason, the FTA has identified "peer cities" to Birmingham which can serve as benchmarks for ITS and APTS deployments here. The FTA designates peer cities based primarily on similarities in population and market area; using these criteria, the FTA has designated five cities as peers to Birmingham:

- Charlotte, NC,
- Jacksonville, FL,
- Louisville, KY,
- Memphis, TN, and
- Nashville, TN.

For comparison purposes, a summary of transit characteristics and APTS deployments in these peer cities is provided in Table 3-16.

Table 3-16. Comparison of Birmingham peer cities

Transit system	City	Technology Employed								Comments
		Service Type	Fleet Size	Comm	AVL	APC	CAD	ATIS	EPS	
BJCTA	Birmingham, AL	FR DR	76 14				X			Considering AVL and APC systems.
CTS	Charlotte, NC	FR DR	163 50	DIG DIG			X X		MS/SC	Implemented magnetic stripe and smart cards at cost of $2 million. Operational software to assist in dispatch and routing.
Jacksonville Transportation Authority	Jacksonville, FL	FR DR	183 8	 TR		IB	 X		MS	Implemented magnetic stripe farecards and automated passenger counters on buses Computer-aided dispatch system for paratransit purchased for $150k.
Transit River Authority of River City	Louisville, KY	FR DR	280 75	TR	SP	IB				Uses signpost AVL and computer-aided dispatch. 257 buses equipped with automated passenger counters.
Memphis Area Transit Authority	Memphis, TN	FR	202	TR			X	P		Uses operational software and computer-aided dispatch. Has plans to implement advanced traveler information systems.
Metropolitan Transit Authority	Nashville, TN	FR	150					W,P		Has plans to implement pre-trip planning and wayside information systems.

Key: DIG=digital radio, TR=trunk radio, SP=sign post, IB=infrared beam, MS=magnetic stripe, SC=smart card, P=pre-trip planning, W=wayside display, X=deployed.

It is readily seen that the peer cities operate significantly larger transit fleets than Birmingham. The BJCTA has yet to deploy any APTS technologies, but that may not be unusual for a transit agency of its size. The FTA peer cities may not represent true peers to Birmingham because BJCTA operates a much smaller fleet of vehicles and serves fewer passengers.

3.3.8. Similar Transit Agencies

It is evident from Table 3-16 that the BJCTA is a significantly smaller transit property than those in its FTA peer cities. APTS deployment data from 1999 was collected and reviewed for all transit properties in the U.S. Transit agencies with fixed-route fleets of 100 vehicles or less that deployed some type of APTS technology were identified. The results are summarized in Table 3-17.

Table 3-17. APTS deployments among agencies with 100 or less fixed-route buses

Transit system	City	Fleet Size	AVCS	AVL	APC	CAD	ATIS	EPS	Traffic Signal Priority
Valley Metro	Phoenix, AZ	75		GPS		X		CC	
GET	Bakersfield, CA	72	TR	U					X
San Joaquin Regional Transit District	Stockton, CA	98	DIG	DGPS	IB	X	P	MS	
Santa Cruz Metropolitan Transit	Santa Cruz, CA	93						MS	
South Coast Area Transit	Oxnard, CA	44	TR		IB			SC	
Sunline Transit Agency	Thousand Palms, CA	40	U	GPS	U				X
Colorado Springs Transit	Colorado Springs, CO	66	U	DGPS	IB		T, P	SC	X
Des Moines Metropolitan Transit	Des Moines, IA	98	TR	GPS		X	P	MS, SC	X
Urbana Campaign Mass Transit District	Urbana, IL	85	DIG	GPS	IB	X	U		
Wichita Metropolitan Transit	Wichita, KS	53		GPS	U		U		
LEXTRAN	Lexington, KY	48	TR, DIG				T, P		
Cape Cod Regional Transit Authority	Dennis, MA	50	DIG	GPS		X	T, W, P	MS, SC	
Ann Arbor Transportation Authority	Ann Arbor, MI	77	DIG	SO	IB	X	I, T, P	SC	
Star Tran	Lincoln, NE	68	TR		IB				
Tompkins Consolidated Area Transit	Ithaca, NY	58				X	U	MS	
Metro Transit	Oklahoma City, OK	85							
Metropolitan Tulsa Transit Authority	Tulsa, OK	90		GPS					
Luzerne County Transportation Authority	Kingston, PA	39		GPS			I,T		
KAT	Knoxville, TN	80					P		

(Key: FR=fixed route, DR=demand responsive, DIG=digital radio, TR=trunked radio, GPS=global positioning system, DGPS=differential global positioning system, SO=signpost/odometer, IB=infrared beam, TM=treadle mat, I=in vehicle, P=pre-trip, T=in-terminal, W=wayside, CC=credit card, MS=magnetic stripe, SC=smart card, X=deployed, U=unspecified)

Section 4
Birmingham Deployment

The following section presents a discussion of three proposed deployment scenarios for APTS technologies in Birmingham. The presentation of each scenarios includes a discussion of the technologies involved, expected benefits and costs, and implementation issues. Also included is a brief discussion of the methodology used to select the technologies appropriate to Birmingham.

4.1. Overview of Methodology for Selecting Candidate Technologies

A common criticism of some of the early deployments of APTS technologies (indeed, of all ITS technologies) is that they are sometimes seen as a solution in search of a problem. The high technology and potential benefits can be very appealing, but with limited funds transit agencies must be judicious in selecting technologies appropriate to their system. A good deployment plan should start with a needs assessment in which a transit agency identifies system needs or deficiencies and prioritizes them (USDOT, 1997). Appropriate APTS technologies are then matched to those needs, rather than vice-versa. Through meetings and discussions with BJCTA and local transportation officials, the following needs in the Birmingham transit system were identified:

- Inadequate route and schedule information,
- Inadequate real-time information for passengers and operators,
- Poor schedule adherence,
- Cumbersome data collection and reporting, and
- Inadequate fleet management.

To ensure that the proposed deployment scenarios meet the transit needs in Birmingham, a relationship was developed between the capabilities and benefits of each of the individual technologies under consideration. Table 4-1 shows a matrix of the needs and proposed APTS technologies. These technologies (and combinations thereof) comprise the deployment scenarios discussed in the following paragraphs.

Table 4-1. Relationship between Birmingham transit needs and candidate APTS technologies

Service/Function	AVL	APC	CAD	ATIS	Transit Priority	EFP	GIS
Route schedule and information	X						X
Real-time information for passengers	X		X	X			
Real-time information for operators	X	X	X				
Schedule adherence	X		X		X		
Data collection and reporting	X	X	X			X	X
Fleet management	X	X	X		X	X	X

Additional considerations when determining whether APTS technologies are applicable to the Birmingham transit system included the following system service characteristics and its service area:

- Service is primarily fixed-route bus,
- Mostly intra-urban trips, and
- Limited service to suburbs but future expansion possible.

Based on these needs and the nature of the Birmingham system, the following candidate technologies were selected as the most appropriate for the Birmingham region:

- Automatic passenger counters (APC),
- Automatic vehicle location (AVL),
- Advanced traveler information systems (ATIS), and
- Computer aided dispatch (CAD).

Although not incorporated into any of the proposed deployment scenarios, transit priority, EFP, and GIS are also considered as potential candidates for deployment in Birmingham. The role of each of these additional technologies is described following the section on each of the three scenarios.

Three alternative deployment scenarios were developed employing the candidate technologies in graduating degrees of complexity and system maturity. The scenarios are by no means the only possible deployment scenarios for Birmingham, nor are they mutually exclusive; elements of one scenario may well be deployed as part of another. They are presented as possible scenarios for deploying applicable technologies in Birmingham to address the deficiencies and to identify some of the issues that must be considered in future APTS deployments.

4.2. Scenario 1 Deployment – Automated Counting Equipment

Scenario 1 is a limited deployment of automatic vehicle location devices, automatic passenger counters, and attendant computers and software sufficient to automate the collection of the data required for NTD reporting. The improved data collection capabilities would also contribute to route schedule and planning activities at BJCTA. A list of the NTD data collection that would be facilitated by Scenario 1 in presented in the Appendix.

4.2.1. System Requirements – Scenario 1

The system envisioned for the Birmingham transit system would consist of two integrated sub-systems: an AVL system on each bus and an APC system. Automatic passenger counters can operate as stand-alone systems, but the data collected will be much more meaningful if combined with AVL data. Combining passenger counts with location information is useful because it can provide boarding and alighting data by stop and passenger load factors on every segment of a route. These data, in turn, can be used for more sophisticated analysis and route planning.

The initial goal of this scenario would be to automate the collection of passenger data for Section 15 reporting purposes. To gather meaningful data the BJCTA would need to equip at least 10%-15% of its fleet with AVL/APC equipment. These APC equipped buses would then be cycled through all routes in the system at regular intervals. At each stop the system would record stop location, date and time, open and close time of the doors, and number of passengers boarding and alighting. The data would be stored either in internal system memory or on PCMCIA memory cards. In most modern systems, the data are downloaded automatically via short range radio link each time a bus enters the garage. By automating this process it greatly reduces the amount of labor required to operate the system.

These types of systems require that the location of every bus route and each bus stop be accurately determined and stored in a database or GIS. This allows the count data to be associated with individual stops and route segments rather that simply a set of GPS coordinates. In Birmingham this task has already been carried out by BJCTA, which has precisely located the positions of all its bus stops in the City's GIS database. Some additional work may be required to insure that all route segments are also coded into the database.

4.2.2 System Costs and Benefits – Scenario 1
The cost of installing APC equipment on buses currently averages between $1,200 and $1,500 per vehicle. This figure reflects the cost of the count equipment only and does not include the cost of associated GPS equipment. Several available APC systems do include add-on GPS receivers that can record vehicle position data along with the count data, but care must be exercised when choosing this type of AVL equipment. GPS units provided as part of counting systems can not necessarily be expanded to provide other AVL functions, such as fleet management and real time-transit information services. These GPS units are primarily "local," meaning they provide location information to the counting unit but do not transmit that information back to an operations center (that requires a communication system and attendant computer equipment to process the location data and make it available for other uses). Most transit systems that have deployed automatic passenger counters have deployed them along with fleet-wide AVL systems.

Nationally, the median cost of installing full-function AVL equipment on buses is between $10,000 and $15,000 per vehicle, however that price may be more applicable to transit systems with larger fleets than BJCTA operates (Goeddel, 2000). Smaller transit agencies will typically pay more per vehicle because the software and infrastructure costs are spread among fewer vehicles. One survey found that the minimum cost for an AVL deployment across 30-40 vehicles appears to be about $350,000 (or a minimum of $10,000 per vehicle) (Goeddel, 2000). A reasonable cost to deploy AVL in Birmingham would probably be between $15,000 and $18,000 per vehicle. A complete AVL/APC system of this type could be expected to cost anywhere from $17,000 to $20,000 per vehicle. This is a significantly higher cost than stand-alone APC systems, but it would give BJCTA the ability to expand the AVL functions in the future to include real-time transit data and fleet management.

The decision whether to implement stand-alone APC systems or more advanced APC/AVL systems will depend on BJCTA's ultimate plans for APTS in its fleet. Since automatic passenger counters need only be installed on 10%-15% of the total fleet, there would initially be no benefit to installing full-function AVL units on the buses (real-time location data on only a fraction of the fleet would be of little use to passengers or operators). Meaningful ATIS and fleet management functions require AVL deployment across the entire fleet. However, if BJCTA has plans to install fleet-wide AVL then it would make sense to install that equipment with the APC's rather than retrofit it later.

Other costs associated with an automatic counting system include customized software to analyze the data. APC systems can generate huge volumes of count data, which require labor to store and analyze. Customized software can automate much of the data analysis with respect to Section 15 reporting requirements, but the data will ultimately prove far more useful to BJCTA in terms of planning and adjusting its bus service. With the detailed ridership data the system will provide, BJCTA can evaluate the effectiveness of existing service, modify inefficient services, and plan future routes.

The expected benefits of installing automatic passenger counters on buses would be in the form of improved data quality, reduced data collection costs, and more frequent data collection which in turn will lead to improved system monitoring and planning (Boyle, 1998). It has been estimated that the reduction in data collection costs can offset the cost of the counting equipment, but that does not include the costs associated with the AVL equipment. In fact, overall cost savings may be offset by the costs of handling the additional data that are being collected. Long term benefits will result from improved planning and modifications to existing services.

4.3. Scenario 2 – Real Time Transit Information for Users

The second scenario would utilize the AVL infrastructure described in the first alternative but would add the capability of transmitting the vehicle location and passenger count data in real-time to a control center and ultimately to system users through in-vehicle information displays, wayside displays, information kiosks, and the internet. This is a logical outgrowth of AVL, given that it has potential applications far beyond collecting passenger counts. This scenario could be implemented either concurrently with Scenario 1 or be implemented at a later time using the equipment installed under Scenario 1. As discussed in the previous section; however, the ability to expand the AVL system described in Scenario 1 would depend on the type of AVL equipment installed.

Under this scenario, system users could get real-time information on the status of buses and use that information to plan their trips or alter their travel. For example, a user could check the status of his/her bus (whether it was on-time or full) before going out to the bus stop, thus improving comfort, minimizing wait time, and possibly improving security. Passengers waiting in transit terminals or at major bus stops could view the status of their bus either on message boards or video monitors. If their bus was either running late or was full, the user could also examine other bus services that would get them to (or near) their destination in better time.

4.3.1. System Requirements – Scenario 2

The main components of a passenger information system in Birmingham would include the bus AVL and communication system, in-vehicle information displays, wayside displays, and possibly an internet server. A discussion of the general requirements for each component follows:

- AVL/Communication System – The AVL system necessary for this scenario must transmit vehicle location data in real-time to a central dispatch/operations center where computer equipment would process the data and generate information displays. The communication system must handle the high volume of data that would be generated by the AVL system. As discussed under Scenario 1, the cost for such an AVL system in Birmingham could be expected range between $15,000 and $18,000 per vehicle.

- In-Vehicle Information Displays/Annunciators – At a minimum, in-vehicle information displays should be capable of communicating the following information to passengers:

    - Current time and date,
    - Current vehicle location (either map or text),
    - Current stop/next stop, and
    - Announce major stops (audio).

  Text information should be displayed in ADA compliant format, and a sufficient number of displays should be provided so that it is visible throughout the vehicle. While not essential, it would also be useful if the system could display the following information:

    - Pre-programmed system messages (route and schedule changes),
    - Live system broadcast messages (service disruptions), and
    - Information on the status of connecting buses.

  While information on stops and routes could be pre-programmed into each unit, displaying real-time system broadcast messages and connecting route information would require the units to be able to communicate with the operations center in real time. The cost for this capability would naturally be higher. Costs for in-vehicle displays range from $10,000 to $20,000 per vehicle or more.

- Wayside Displays – Wayside displays can take many forms, but the most likely candidates for deployment in Birmingham would be variable message boards and video displays. Message boards and video monitors could display schedule information, the status of arriving buses, and system alerts similar to the video and message board displays currently used in airports to convey flight information. Like the airport displays, the information conveyed would be determined by the transit operator. Smaller versions of the message boards, which typically use LED displays, could be installed at major bus stops to indicate the status of connecting buses.

  It is anticipated that the initial information displays could be provided at the Morris Avenue Central Station and at major transfer points on the system. Year 2001 transfer data at key bus stops in the City are presented in Table 4-2. These major transfer points would be good candidates for an initial deployment of variable message boards.

Table 4-2. Daily bus transfers at key bus stops (year 2001 data)

Stop Location	# Daily Transfers
18th Street at 2nd Avenue North	201
18th Street at 3rd Avenue North	73
18th Street at 5th Avenue North	16
22nd Street at 1st Avenue North	40

This, of course, would be merely an initial deployment. As the transit system expands additional displays could be installed as needed. Variable message boards at bus stops would be a valuable convenience to transit users but it should be noted that they do require maintenance and are subject to vandalism, particularly signs which are located at outdoor stops.

- Information Dissemination Via the Internet – The same real-time vehicle location data presented by in-vehicle and wayside displays could also be made available to transit users via the internet. In its simplest form, a website could provide schedule and route information and real-time status information to users in their homes or places of employment. The internet is an attractive alternative because it makes transit information available without the costs associated with the infrastructure required for in-vehicle or wayside displays. The internet should supplement rather than replace the latter, because many transit users, particularly older and lower income users, do not have access to the internet.

  The cost to develop and implement an Internet site will depend on the amount of information provided and the degree of user interactivity. For this initial scenario the types of data and services provided could be relatively simple, expanding at a later date as more services are offered. At a minimum, an initial deployment website should provide the following information:

  - System map including all transfer points,
  - Individual route maps with scheduled arrival times at key stops, and
  - Current bus status by route.

  The bus status information could be presented in several formats. The simplest form would be a text message that states, "Bus Route 72: 5 minute delay" or "Bus Route 21: On Time." These messages would not provide specifics such as individual bus location or estimated time of arrive at a particular stop, but would notify users of general route delays. More complex but more meaningful would be a map that showed current bus location and estimated time of arrival at key stops.

4.3.2. Costs and Benefits – Scenario 2

The potential benefits of such a system are described in detail Section 2.2.4 and will not be repeated here. In summary, deployment of real-time passenger information systems could enhance travel on the bus system, facilitate trip planning, and reduce wait times for passengers.

There would be additional costs associated with implementing Scenario 2 compared to Scenario 1. First, Scenario 1 would require the deployment of AVL equipment on only a 10%-15% of buses in the fleet, while Scenario 2 would require 100% fleet deployment to be effective (users would not be interested in obtaining status information for only 15% of the buses). The AVL system installed under this scenario would have to include a communication system capable of transmitting vehicle location data to a control center in real time so that it could ultimately be provided to users. Software for processing the AVL data and rendering it in a form easily understood by users would also be required. Finally, there would be increased infrastructure costs associated with the information displays and message boards in vehicles, terminals, and at major stops.

The information systems discussed under Scenario 2 would be largely passive, meaning most of the information would be of the broadcast type and determined by the transit agency. Users would have only limited control over what information they view and pre-trip planning capabilities would be limited. Nonetheless, these services would be of use to transit riders and yet be limited in scope enough to be considered as an initial deployment.

4.4 Scenario 3 – Dynamic Fleet Management

The third alternative would essentially be a more sophisticated and mature version of Scenario 2. It would employ the same basic AVL, APC, and information display technologies, but it would incorporate more advanced and more widely deployed information communications systems, more advanced user interfaces, and computerized fleet management software. Scenario 3 envisions a fully mature APTS environment and therefore should probably be viewed as a long-term goal rather than an initial deployment, but it demonstrates the possibilities for APTS in Birmingham and raises several issues that should be considered in initial deployment scenarios. The features of such a system are discussed in the following paragraphs.

4.4.1. System Requirements – Scenario 3

4.4.1.1 Information for Transit Users The backbone of Scenario 3, like Scenario 2, would be a fleet-wide AVL system. Data from the AVL transponders would be used to monitor the status and location of every vehicle in the fleet. That information would subsequently be provided to transit users through in-vehicle displays, wayside displays, and an internet website as described in Scenario 2. Data could also be made available to users in other formats, such as information kiosks, personal pagers, and personal digital assistants (PDA's). These are discussed below:

- Information Kiosks – Information kiosks have been deployed in many larger transit systems and are useful because they allow users to interactively access large amounts of transit information such as schedules, status of buses and connecting routes, trip planning services, and information about other modes or services not offered by the transit operator, such as taxis. Ideally, any information kiosks deployed would be capable of displaying data in html format, so that the same information provided on a website could be provided by kiosks with minimal additional manipulation. An information kiosk typically costs between $20,000 and $30,000 to install, and that figure comes from larger transit systems where large numbers have been deployed. For a smaller transit system considering deploying just a few, that cost can rise to as much as $50,000 each.

Kiosks are one of the most expensive information displays in use, but they do offer features not found on other types of displays. Most importantly, kiosks are interactive and allow users to select the data they wish to see, plan a trip from start to end, and receive a printed itinerary they can take with them. Furthermore, advanced kiosk systems can utilize real-time transit data when planning trips, suggesting alternatives that may save the rider travel time. Kiosk deployments have been very successful in other systems, but because of their cost their locations should be chosen carefully. In Birmingham, possible locations include:

- BJCTA Central Station,
- Riverchase Galleria,
- BJCC,
- Harbert Center, and
- Major downtown hotels.

Information kiosks are most likely a long-range technology for Birmingham, given their cost versus the current size of the system. However, with planned expansions to downtown service and possible installation of a streetcar system they may be a viable option in the future.

- Pagers and PDA's – As discussed in Section 2 of this report, transit information could also be broadcast to pagers and personal digital assistants (PDA's). The amount of information broadcast would be limited by the capacity for these devices to display it, but they could certainly provide real-time information on bus status or system alerts. Practical considerations for deploying this scenario would be the required amount of computational and broadcast equipment. Since very few of these systems have even been tested, implementation costs are unknown. Therefore, this is probably a medium to long range technology.

- Internet Website – The internet website described under Scenario 2 could be expanded to provide more dynamic access to transit data. Ideally the site would provide the following services:

    - Pre-trip planning across multiple modes (bus and streetcar) based on real-time transit data,
    - Dynamic vehicle location displays,
    - Algorithms that would estimate vehicle arrival at a particular stop based on real-time data, and
    - Information on other non-transit modes.

> The web site can be expanded incrementally, with new functions added as needed. The same information made available through the web could also be made available through information kiosks, and to a lesser extent, cell phones with web capabilities.

The key difference between the passenger information services assumed under Scenario 3 and those presented in Scenario 2 is the degree of interactivity permitted. Whereas Scenario 2 includes a limited number of passive information displays, Scenario 3 is based on a system to allow users to interactively view data from a wide variety of sources. Through pagers, PDA's, cell phones, or e-mail, passengers could be notified of (only) information that pertains to their travel patterns. Through kiosks and the internet, passengers could interactively plan trips based on real-time transit information, and that information would be shared across all modes in the City, not just transit. In short, Scenario 3 envisions a fully mature APTS environment.

4.4.1.2. Information for Transit Operators Scenario 2 focused primarily on providing real-time transit information to passengers. Scenario 3 allows transit operators to use the real-time data to improve the efficiency of their transit operations. This would be done primarily by utilizing transit operations software to process AVL data to maintain schedules and recover from service disruptions.

For fixed-route service, the computer operations software/CAD could monitor bus performance system wide and identify buses that were running behind or ahead of schedule. The system would automatically notify bus operators of their status so they could attempt to regain schedule. Signal priority systems could also be employed if available. Ideally, the system would also identify potential disruptions in service (mechanical breakdown, incident, congestion) before they occur and prompt dispatchers to take appropriate action to restore services. Ultimately the system would enhance schedule adherence, thus making the service more attractive to users and more efficient for operators. For paratransit services, CAD enhances real-time scheduling of services by optimizing vehicle routing and improving system efficiency.

The cost to deploy a CAD system varies widely, with minimum cost for a low end system averaging between \$20,000 and \$60,000, and costs for larger systems running in excess of \$100,000 (Goeddel, 2000). These costs assume that an AVL system has already been deployed in the fleet. Once the AVL equipment is installed, BJCTA would have sufficient information to interactively utilize a CAD system. The AVL/CAD system would allow dispatchers to interact with drivers to adjust dwell times and headways while vehicles are en route, thus improving schedule adherence. As previously mentioned, CLASTRAN currently uses CAD for scheduling and dispatching. Migrating BJCTA dispatch to the same CAD (or compatible) systems as CLASTRAN would facilitate the transfer of paratransit passengers to the fixed-route service. This would increase the mobility of paratransit riders while shifting some of the responsibility to the more cost effective fixed-route system.

4.4.2. Summary

Scenario 3 is essentially a more mature and widely deployed version of Scenario 2. It envisions a mature APTS environment in Birmingham and therefore is not intended to be considered as an initial deployment. The important issue is that once the key components of the APTS environment are installed (control centers, communications systems, AVL systems, and management software), the system can be expanded to incorporate new services and new functions rather easily. Thus, while initial procurement costs may be high, if the system is designed properly and equipment is selected carefully it can be adapted to future services at reasonable costs.

It should also be noted that other APTS technologies, not explicitly discussed in the three alternatives, may also be present in that mature APTS environment. Signal priority systems for transit, for example, may exist in several of the proposed corridors, utilizing the AVL and fleet management software implemented under the above Scenarios. Electronic fare payment media may also be implemented at some point in the future. The overall APTS environment will be continually evolving and it is impossible to determine what services will be available at any given time. This emphasizes the importance of long range planning so that when these new services and functions do become available, at whatever time, they can be easily incorporated into the overall APTS and ITS systems.

4.5 Transit Priority

Transit priority was not considered explicitly in the three alternative deployment scenarios because it was felt there is not currently a high enough frequency of bus service in the major arterial corridors around Birmingham to justify its deployment. The cost of installing and maintaining transmitters and detectors at each signal is not trivial and must be weighed against the number of buses actually serving a given corridor. Transit priority could, however, be an important APTS technology in the future if service frequencies increase in key transit corridors such as U.S. 31, U.S. 280, or U.S. 11. The New Starts proposal has recommended providing express bus service in the U.S. 280 and U.S. 31 corridors and, if implemented, these could be good candidates for transit signal priority. Both corridors experience significant peak hour congestion and have high numbers of traffic signals. Furthermore, both corridors either have or are scheduled to have emergency optical pre-emption equipment installed that could be used for transit priority as well, greatly reducing installation costs. If and when express bus service is considered, we recommend that these corridors be evaluated for the feasibility of transit signal priority. Transit priority schemes should be evaluated using a traffic simulation model so that reasonable estimates of time savings can be made. Next, a limited pilot study could be run using existing pre-emption equipment to confirm the potential benefits to transit users and the overall impacts it would have on traffic flow in the corridor.

4.6 Electronic Fare Payment (EFP) Systems

Electronic Fare Payment (EFP) systems were not considered in the alternative deployment scenarios because it was felt that current system ridership would not justify the associated costs. Deployment of electronic fare payment media would require modification of the fare collection devices on every vehicle in the BJCTA fleet. There are additional costs associated with the distribution of the fare media (smartcards or magnetic stripe cards). With smartcards in particular, users typically must pay an additional charge for the card itself, so there need to be clear incentives for riders to make this investment. At present these incentives do not appear to be strong enough to justify the overall cost of the project.

However, EFP media may be appropriate for the Birmingham system in the future, particularly if ridership increases and a streetcar system is constructed under the New Starts program. Electronic fare media facilitate transfers between modes and would offer incentives for users to purchase smartcards or magnetic stripe cards. Furthermore, the cost of deploying electronic fare media could be rolled into the overall New Starts program, reducing many of the direct costs to BJCTA.

4.7 Geographic Information Systems

Geographic Information Systems are not specifically discussed in the alternative deployment scenarios, although they would be an integral part of several of the systems described. In the first alternative, some type of GIS will be required to process the automatic passenger counter data and associate boardings and alightings with specific routes and stops. A transit GIS database must be part of any AVL deployment, to convert the coordinate data transmitted by the AVL equipment into actual route and map displays that can be easily read by a dispatcher. Likewise, GIS will be required for some ATIS systems, particularly those that display real-time vehicle location, routes, and trip planning.

The BJCTA does not currently have a transit specific GIS database, but much of the necessary basic information is contained within the Jefferson County GIS. The RPC of Greater Birmingham recently concluded a project that located all MAX bus stops in their GIS. This data could be immediately used as part of an APC deployment. It is recommended that BJCTA explore ways of using the Jefferson County GIS until such time as I is able to develop its own database.

Section 5
Regional ITS Architecture

This section addresses how an APTS deployment would relate to the Birmingham Area ITS Architecture. Any APTS deployment in Birmingham must be designed so that it is consistent with the regional ITS architecture. The Regional ITS architecture, of which APTS are a part, is the approved framework for developing and integrating intelligent transportation systems in the City. The Birmingham Area ITS architecture is not a system design, rather it defines the functions that will be required for a mature regional ITS (e.g., data collection, surveillance, traveler information), describes the entities or subsystems where those functions will reside, and identifies the information and data flows that will connect these functions to each other in an integrated system (Iteris, 2002). ITS in Birmingham is not intended to be a collection of isolated sub-systems, rather it will be a unified system where real-time data will be exchanged between highway modes, transit modes, commercial vehicle operations, emergency response agencies, and system users to produce a more efficient transportation network. The Birmingham Area ITS Architecture encompasses traffic management, transit management, emergency vehicle response, and traveler information services and any APTS deployments will have to function within that environment.

It is important to remember that the APTS technologies considered for deployment in this report may ultimately have applications beyond their initial intended purpose. AVL equipped buses will allow BJCTA to monitor system status and provide real time schedule data to transit users, but AVL data transmitted by buses could also one day be used by local traffic management centers to monitor traffic flow on major arterials. AVL equipped buses could serve as vehicle probes, relaying data about travel speeds and congestion to traffic managers and allowing them to implement congestion management plans.

Transit signal priority systems are another example of a transit APTS deployment that will have to function within the larger ITS framework. In the near future, traffic management agencies will be able to respond to incidents and congestion by implementing changes to signal system timings on major arterials. During these special periods it may be undesirable to operate transit priority systems since the signals have been carefully timed to address a specific traffic pattern. The traffic management agency will need to be able to communicate this to the transit agency and the drivers in the field.

It is also anticipated that BJCTA will one day have access to real-time traffic data from regional transportation management centers. With this information BJCTA will be able to identify incidents and congestion and adjust its schedules accordingly. It will also be able to route transit and paratransit vehicles around congestion points and thus better maintain schedule adherence.

It should be noted that information provided at transit kiosks or wayside displays may also be made available through other transportation information services being developed in the region. Transit information, for example, may also be displayed on ALDOT or City of Birmingham transportation websites.

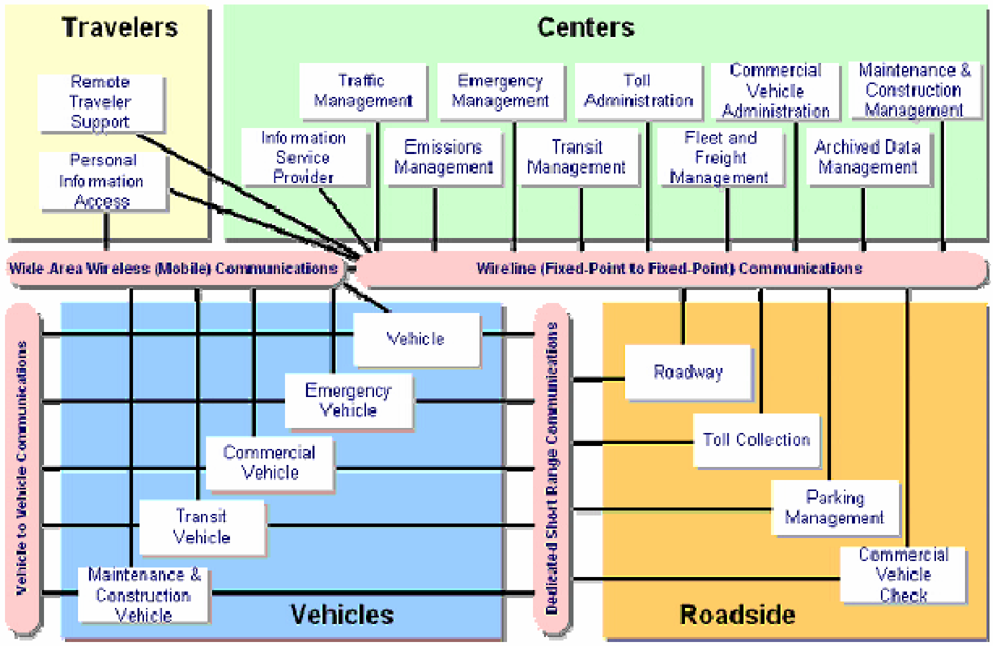

Figure 5-1. Interrelationship of ITS System Functions (Source: USDOT, 2002)

5.1. Birmingham Regional Architecture

Figure 5-1 shows the interrelationship of various ITS system functions within the national ITS architecture (Casey et al., 2000). The Birmingham Area ITS Architecture, based on the national architecture, identifies several functions for the Birmingham transit system. For transit vehicles it states that they "shall:

- Automate planning and scheduling by collecting data for schedule generation,
- Automatically determine optimum scenarios for schedule adjustment,
- Support two-way voice communication between transit vehicle driver and a facility, on-board safety sensor data transmissions from the transit vehicles to a facility, and data transmission from individual facilities to a central facility for processing and analysis,
- Forward paratransit dispatch requests to the driver and forward acknowledgements to the center, and
- Assist the driver in managing multi-stop runs associated with demand responsive, flexibly routed transit services." (Iteris, 2002)

With regard to the BJCTA transit operations center, it "shall:

- Allow fixed-route services to develop, print, and disseminate schedules and automatically update customer service operator systems with the most current schedule information,
- Use current vehicle schedule adherence and optimum scenarios for schedule adjustment,
- Automate trip planning and scheduling, allowing improvements in paratransit routes and services to develop, printing and disseminating schedules, and automatically updating customer service operator systems with the most current schedule,
- Assign drivers to routes in a fair manner while minimizing labor and overtime services, including driver preferences and qualifications, and automatically tracking and validating the number of hours worked by each driver, and
- Automate and support the assignment of transit vehicles and drivers to enhance the daily operation of transit service." (Iteris, 2002)

Specific system interactions described in the Birmingham architecture include communicating with the regional traffic management centers about traffic and transit conditions and communicating transit emergency data to the Birmingham Police Department.

5.2. Function of APTS Scenarios within ITS Architecture

The three deployment scenarios considered in this study would each fulfill part of the vision for transit ITS in Birmingham as outlined in the regional architecture. Scenario 1 would partially fulfill the goal of collecting transit data automatically, initially for data reporting needs and ultimately for generating improved schedules and schedule information automatically. Scenario 2 would provide for some degree of real-time trip planning and scheduling. Scenario 3 would address the goal of having real-time dispatch and schedule adjustment capabilities.

Each of the three scenarios are consistent with the regional architecture, however during procurement and deployment the BJCTA will need to ensure that equipment specifications are consistent with regional ITS protocols. Specific agencies with which the transit system will communicate include:

- Alabama DOT,
- Local municipalities (Cities of Birmingham, Hoover, Vestavia, etc),
- Fire and Rescue, and
- Police.

BJCTA should ensure that its communication systems are compatible with other transportation and incident management agencies in the region. The various standards and protocols for APTS and broader ITS technologies are described in the regional architecture and are not repeated here; however, it is an issue that must be considered carefully before and deployment.

Section 6
Funding Sources for Transit ITS

This section addresses potential funding sources for APTS deployments in Birmingham. As with any transit procurement, before any APTS deployment is considered funding sources need to be identified. The primary sources of funding (outside of fare revenues) for transit operations in Birmingham are:

- Federal Transit Administration,
- State Funding, and
- Local Funding.

Funds for APTS planning and deployment are potentially available through all these sources, although they would be limited to certain funding programs within these sources. A brief description of each follows.

6.1. Federal Transit Administration (FTA)

Federal funds for ITS planning and deployment are available from the Federal Transit Administration through a number of funding programs. The primary source of APTS funding for Birmingham would be Capital Investment Grants for Bus and Bus Related expenditures; however, other potential sources exist for planning and implementing APTS programs. These include Urbanized Area Formula Grants, Transit Planning and Research Grants, and National Planning and Research Programs. These funding programs are summarized in Table 6-1.

The majority of funds for any large scale APTS deployment would likely come from capital investment grants, but it is possible that support for some deployments could come from the other categories. Specifically, the Urbanized Area Formula Grant program does allow appropriated funds to be applied toward education and training, computer hardware and software, and ITS applications. These funds can also be applied directly to ADA expenditures in the form of a 90/10 match. In-vehicle information displays and annunciators could fall under the ADA umbrella and thus would be eligible for this type of funding. APTS applications to paratransit operations might also fall under this category. We further recommend exploring the use of planning funds to develop a long-range APTS deployment plan and conduct further research into candidate technologies.

Table 6-1. Federal transit funding programs

Program	Eligible Purposes	Potential Birmingham Applications
Bus and Bus Related Capital Investment Grants (Typically 80/20 match)	• Bus acquisition • Bus maintenance • Passenger shelters and bus stop signs • Bus accessories and equipment • Computers • Shop and garage equipment	• Automated passenger counters (APC) • Automatic vehicle location (AVL) • Communication systems • In-vehicle and wayside displays
Urbanized Area Formula Grants (80/20 match, 90/10 match for ADA expenditures)	• Design and evaluation of transit projects • Education and training • Capital investment in bus and bus-related activities • Computer hardware and software	• Development of APTS deployment plan • In-vehicle equipment • Fleet management software • APTS training
Transit Planning and Research Grants (Typically 80/20 match)	• Planning to enhance the integration and connectivity of the transportation system	• Development of APTS deployment plan
National Planning & Research Programs (No match but limited funds)	• Safety and security • Transit bus innovations • Transit infrastructure • Dissemination of new knowledge	• Evaluation of new technologies

6.2. State Funding

There are currently two sources of State funding that could be used for capital investment in APTS technologies: the Surface Transportation Program – Birmingham (STPBH) and the Congestion Mitigation and Air Quality (CMAQ) program. Most of the money for these programs is, in fact, federal funds apportioned by the federal government to the State or local MPO based on preset criteria. These are flexible spending funds administered by ALDOT through the regional Planning Commission. Each program is described briefly below.

- The Surface Transportation Program – Birmingham (STPBH) provides federal funds to states and localities for a variety of transportation related projects ranging from federal aid highway projects to bridges and public transit. Provisions in the program allow funds to be spent on transit capital projects such as APTS deployments for buses. STPBH programs typically require a 20% local match.

- The Congestion Mitigation and Air Quality (CMAQ) program funds projects in air quality non-attainment areas (ozone, carbon monoxide, and small particulate matter) which reduce transportation related emissions. Since the Birmingham region is in non-attainment, these funds are available for local congestion management projects including transit capital projects. According to USDOT guidelines, CMAQ funding may be used for all projects eligible under FTA programs. CMAQ projects are administered by the Alabama DOT and typically require a 20% local match.

Many transit agencies across the country have used STP and CMAQ funds for APTS deployments through the FTA flexible spending program (Stanley, 2002). In some cases the State may pay a portion (up to 50%) of the local match, although that varies by project. BJCTA would be required to have an APTS deployment project programmed in the local transportation improvement program (TIP) in order to access funds from either of these sources.

6.3. Local Funding

Although local municipalities provide substantial funding to BJCTA, there are no specific sources of funding for deployments of advanced technologies. As indicated previously, the Regional Planning Commission of Greater Birmingham is responsible for programming funds allocated through ALDOT. In addition, local matching funds will be required on most federal or state funded projects and those might come, in part, from local sources.

Section 7
Transit ITS Education and Training

This section addresses education and training needs that will accompany the deployment of APTS technologies. New technologies will require new knowledge and skills in all segments of transit operations, not just for those will operate the equipment directly. Experience in other transit agencies has found that the deployment of APTS technologies requires education and training for:

- Management personnel,
- Maintenance personnel, and
- Vehicle operators.

For the purposes of this study, training requirements are broken into these three groups.

7.1. Training of Management Staff

Often ignored when training requirements are considered, training management staff on the application and maintenance of advanced technologies is essential to a healthy system. To ensure a successful APTS deployment management should be aware of:

- What training will be required for operations and maintenance personnel,
- Costs associated with the procurement, operation, and maintenance of this equipment,
- Capabilities and limitations of the equipment, and
- Knowledge needed to develop long-range plans.

A lack of training at the management level can lead to situations where equipment is procured but ultimately does not function properly due to insufficient support. Examples of insufficient support include inadequate funding for maintenance and insufficient training for those operating the equipment. Furthermore, a lack of training can result in management procuring equipment that does not truly meet the agency's needs, is incompatible with other equipment, or is quickly obsolete. For these reasons it is recommended that training take place during the planning stages before equipment is procured.

Training programs for management staff are available from a number of sources. The most readily available are often from vendors, but it is desirable for management to have some APTS knowledge prior to procurement and this might better come from unbiased sources. Training programs for ITS technologies are available from the Institute of Transportation Engineers (ITE), the National Transportation Institute (NTI), and the Federal Transit Administration (FTA). The FTA, for example, offers a Technical Assistance Program for transit managers to assist with long range planning for implementing new technologies and upgrading them once they become obsolete. A few sample course offerings available to management staff are listed in Table 7-1.

Table 7-1. Sample transit ITS management courses available[7]

Course Title	Description
"Project Management for ITS"	Guidance for designing and implementing ITS projects.
"ITS for Transit: Solving real Problems"	Overview of available transit technologies, applications, case studies, and cost-benefit analyses.
"Reinventing Transit: Planning Information Based Transit Services"	Applications of APTS technologies to the transportation planning process, with emphasis to ADA services and requirements.
"Managing Transit Information for Success"	Guidance on how to best use the large amounts of data that can be generated by APTS systems.

7.2. Training for Maintenance Personnel

Even the most reliable APTS technologies will require maintenance. A survey of transit agencies that have deployed APTS technologies found that, unfortunately, personnel skilled at maintaining mechanical systems (engines, transmissions, hydraulic systems) are not necessarily skilled at maintaining electronic systems (Schiavone, 2002). Transit agencies will either need to hire staff that can maintain (or at the very least troubleshoot) these new APTS systems or train existing staff to do it. Key knowledge areas for maintaining APTS technologies include:

- An awareness of the location and function of all system components,
- An understanding of diagnostic tools used to maintain APTS equipment,
- An ability to diagnose malfunctions in individual components, and
- An ability to repair or "send out" components for repair (Schiavone, 2002).

A survey of transit agencies found that having under-trained or poorly trained maintenance personnel can lead to very expensive maintenance practices. Several agencies found that under-trained personnel resort to trial and error maintenance, replacing parts until they eventually fix the problem. This often results in replacing working parts along with the defective ones, significantly increasing overall maintenance costs (Schiavone, 2002). Investing in maintenance training also makes sense in the long term since it is expected that APTS technologies will only become more prevalent in transit operations.

Most transit agencies surveyed used a combination of in-house and outside training programs. Outside equipment vendors, automotive training schools, and local technical colleges can provide training programs. Transit agencies with large maintenance staffs have successfully used "train the trainer" strategies, whereby a few instructors receive training and they in turn train the rest of the staff (Schiavone, 2002).

[7] Additional course information is available at www.its.dot.gov.

The specific areas of training required will depend on the technologies being deployed, but all maintenance staff will likely need to be knowledgeable in the use of computers, not only for diagnostic purposes but also for downloading data collected by onboard systems such as automated passenger counters and equipment monitors.

7.3. Training for Bus Operators

The APTS technologies discussed herein are largely automated, requiring little input from bus drivers, but drivers will need to be trained on how to initialize and operate the equipment when necessary. Drivers can also be helpful to maintenance personnel in spotting and troubleshooting malfunctioning equipment, so training is beneficial in this way as well. Finally, operating equipment while driving can be a distraction. Therefore, operators should be properly trained on regulations and procedures for doing so.

The amount of training required will depend on the types of equipment being deployed. Transit agencies that have deployed APTS technologies have averaged between 5 and 10 hours of operator training per year (Okunieff, 1997). Most operators use the "train the trainer" system described under maintenance training. This approach is all the more necessary given the large number of drivers that would need to be trained. Required knowledge areas for operators with respect to APTS include:

- An understanding location of system components,
- Familiarity with procedures for using on-board equipment,
- An ability and judgment to use covert alarms and other emergency procedures, and
- An understanding of operator-initiated and dispatcher-initiated functions (Schiavone, 2002).

Proper training ensures that equipment is operated properly, that malfunctions are reported promptly, and that safety is not impacted due to additional driver tasks.

It is difficult to estimate how much training will be necessary based on the experiences of other transit agencies because they have been very inconsistent in the amount of training they provide their employees. One survey found that training provided as part of new AVL deployments varied from 8 hours to 10 days for dispatchers, 8 hours to 5 days for management, and anywhere from 2 hours to 48 hours for operators (Okunieff, 1997).

7.4. General Training Issues

Transit agencies should include training in their budgets when planning to procure new equipment. One of the best ways to do so is to include training in the equipment specifications, so that vendors must supply training as part of their overall contract. This ensures that personnel will receive training appropriate to that specific piece of equipment. Furthermore, training should be updated as new functions and features are added, even if the system components themselves are not upgraded.

Section 8
Conclusions and Recommendations

The three proposed scenarios demonstrate that APTS deployment is, in most cases, a continuing process whereby the technologies implemented in early stages become the backbone for new technologies and services offered in later stages. It is important that transit agencies develop a long-term deployment plan and evaluate how technologies implemented in one stage will function with technologies to be deployed at a later date. A prime example lies in the deployment of APC systems. AVL technologies are often installed on buses as part of an APC installation. The location data they provide is then used solely for the purpose of collecting passenger counts on that bus. These systems are effective and can typically be installed at a much lower cost than full function AVL systems, however, this greatly limits their utility for future APTS functions. A fully functional, fleet-wide AVL system will cost more to install, particularly if it is initially used only for passenger counting purposes, but will provide many more opportunities for expanded APTS functions such as real-time transit information, computerized fleet management, transit priority schemes, and computerized dispatching.

The scenarios are presented individually, but in fact they could be easily viewed as a phased implementation. AVL and APC systems installed under Scenario 1 could serve as the backbone for the passenger information services described in Scenario 2. Scenario 3 would then further expand on those services as the transit systems grows.

It is recommended that BJCTA develop a long range plan for APTS implementation. As part of the long range plan, it is recommended that a study be undertaken to explore opportunities to better integrate the services offered by BJCTA and CLASTRAN. As previously mentioned, CLASTRAN currently uses CAD for scheduling and dispatching. It is further recommended that initial deployments use proven technologies. To initiate the deployment of APTS in Birmingham, the following specific recommendations are offered:

1. Consider deploying an AVL/APC system on 10% to 15% of the bus fleet as described under proposed Scenario 1. This is sufficient to automate the collection of ridership data by rotating the buses through the system.

2. Develop a data management plan to ensure that the data collected from the AVL/APC devices are appropriate for NTD reporting as well as system planning purposes.

3. The AVL system deployed under Scenario 1, although initially limited to only a portion of the fleet, <u>must</u> be expandable to a fleet-wide system.

4. It is recommended that BJCTA perform an assessment of the initial AVL/APC deployment to evaluate its impact on planning and operations (cost/benefit, training requirements, equipment reliability, user acceptance, etc.).

5. Upon successful deployment of Scenario 1 (and availability of funding), it is recommended that all BJCTA and CLASTRAN vehicles be equipped and integrated into a fleet-wide AVL system. The fleet-wide AVL systems will then serve as the foundation for deploying Scenarios 2 and 3 or any combination of elements therein. At the time of this deployment, it is recommended that BJCTA seek a consulting firm or other system design input rather than rely solely on equipment vendors and manufacturers for input. At this stage it would also be essential that BJCTA work with ALDOT and the RPCGB to ensure that all APTS deployments are consistent with the regional ITS architecture.

6. As the Regional Transportation Alternatives Analysis concludes, it is strongly recommended that BJCTA consider working with ALDOT to provide transit priority (preemption) at traffic signals along major express bus corridors (e.g., U.S. 280, U.S. 31).

7. Finally, it is recommended that BJCTA work out an arrangement to continue to utilize the GIS resources at RPCGB, or develop and maintain their own, in-house GIS capabilities.

Section 9
References

Ball, W. L. *Economic and Policy Considerations of Advanced Public Transportation Systems (APTS): Assessing the Economic* Feasibility of APTS. Center for Urban Transportation Research (CUTR). Tampa, Florida. October 1994.

Boldt, Roger. Information Technology Update for Transit. Synthesis of Transit Practice 35. Transportation Research Board. Washington, D.C., 2000.

Boyle, Daniel K. Passenger Counting Technologies and Procedures. TCRP Synthesis 29. Transportation Research Board. Washington, D.C., 1998.

Casey, R. F., et al. Advanced Public Transportation Systems: The State of the Art Update 2000. Federal Transit Administration. Washington, D.C., 2000.

Casey, R. F. Advanced Public Transportation Systems Deployment in the United States- Update January 1999. Federal Transit Administration. Washington, D.C., 1999.

Center for Urban Transportation Research. The Use of GIS in Public Transportation. CUTR, Tampa, Florida. 1995.

Dobies, John. Customer Information at Bus Stops. TCRP Synthesis 17. Transportation Research Board. Washington, D.C. 1996.

ECONorthwest and Parsons Brinkerhoff Quade & Douglas, Inc. Estimating the Benefits and Costs of Public Transit Projects. TCRP Report 78, Transportation Research Board. Washington, D.C., 2002.

EG&G Dynatrend, Inc. Review and Assessment of En-Route Transit Information Systems. Federal Transit Administration. Washington, D.C., July 1995.

ESRI. GIS for Public Transit Management. Website. http://www.esri.com/industries/transport/transit.html. Last accessed: May 20, 2002.

Federal Transit Administration (FTA). 2000 National Transit Database. Washington, D.C., 2002. Website: http://www.ntdprogram.com/NTD/ntdhome.nsf. Last accessed: April 2003.

Furth, Peter G. Data Analysis for *Bus Planning and Monitoring.* Synthesis of Transit Practice 34. Transportation Research Board. Washington, D.C., 2000.

Goeddel, D. L. *Benefits Assessment of Advanced Public Transportation System Technologies Update 2000.* Federal Transit Administration. Washington, D.C., November 2000.

Greenfeld, J. "Performance Evaluation of Automated Vehicle Locator and Digital Map Accuracy in Transit Applications." Transportation Research Record No. 1666. Transportation Research Board. Washington, D.C. 1999.

Harman, L. J. and U. Shama. FTA Transit GIS Database. Maintained by the GeoGraphics Laboratory, Moakley Center for Technological Applications, Bridgewater State College. http://www.e-transit.org/. Last accessed: 6/7/02.

Harte, L., R. Shalhoub, A. Shark, and T. Steiner. Public & Private Land Mobile Radio: Technologies, Services, and Economics. Prentice Hall, ISBN: 0136736092. May 2000.

Hatcher, S., B. James, and D. Roberts. "Incorporating Intelligent Transportation Systems into Major Investment Studies: Conceptual Issues and Challenges." Transportation Research Record No. 1651. Transportation research Board. Washington, D.C. 1998.

Institute for Transportation Research and Education (ITRE), KFH Group, and TransCore. Guidebook for Selecting Appropriate Technology Systems for Small Urban and Rural Public Transportation Operators. TCRP Report 76. Transportation Research Board. Washington, D.C., 2002.

ITERIS. Birmingham Area Intelligent Transportation Systems (ITS) Architecture. Norcross, Georgia. June 2002.

Levine, J., Q. Hong, G. E. Hug, and D. Rodriguez. "Impacts of an Advanced Public Transportation System Demonstration Project." University of Michigan. Ann Arbor, Michigan, 1999.

Metropolitan Atlanta Rapid Transit Authority (MARTA). Available on the Federal Transit Administration website at http://www.fta.dot.gov/research/fleet/its/efp.htm. Last accessed May 5, 2003

Mitretek. "ITS Benefits and Unit Cost Database". Maintained by Mitretek for the U.S. Department of Transportation. http://www.benefitcost.its.dot.gov/. Last accessed: March 2003.

Metropolitan Transit Authority New York City Transit (MTA-NYCT). Available on the Federal Transit Administration website at http://www.fta.dot.gov/research/fleet/its/efp.htm. Last accessed May 5, 2003

Okunieff, P. "AVL Systems for Bus Transit." *Synthesis of Transit Practice 24.* Transit Cooperative Research Program. Washington D.C. 1997.

Peng, Z. and O. Jan. "Assessing Means of Transit Information Delivery for Advanced Public Transportation Systems." *Transportation Research Record No. 1666.* Transportation Research Board. Washington, D.C. 1999.

RPCGB (Regional Planning Commission of Greater Birmingham). "Strategic Regional Multimodal Mobility Plan – Regional Transit Feasibility Analysis." Regional Planning Commission of Greater Birmingham, December 1999.

RPCGB (Regional Planning Commission of Greater Birmingham). "Birmingham Regional Transportation Alternatives Analysis – System Plan Outline." Regional Planning Commission of Greater Birmingham, March 2003.

RPCGB (Regional Planning Commission of Greater Birmingham). "FY 2000-2004 Transit Development Program" Regional Planning Commission of Greater Birmingham, 2000.

Schiavone, John J. *Understanding and Applying Advanced On-Board Bus Electronics.* TCRP Report 43, Transportation Research Board. Washington, D.C., 1999.

Schiavone, John J. *Training for On-Board Bus Electronics.* TCRP Report 44, Transportation Research Board. Washington, D.C., 2002.

Schweiger, Carol L. "Current Use of Geographic Information Systems in Transit Planning." *Transportation Research Record 1349.* Transportation Research Board. Washington, D.C., 1992.

Shawn, Kelly, C. Winters, and S. Bogren. "Making New Technologies Work for Rural Transportation." RTAP InfoBrief, Number 4. October 2001. http://www.ctaa.org/ntrc/rtap/pubs/ib/newtech.

Stanley, Robert G. Use of Flexible Funds for Transit Under ISTEA TEA-21. TCRP Synthesis 42. Transportation Research Board, Washington, D.C., 2002.

Stern, Richard. Bus Transit Fare Collection Practices. TCRP Synthesis 26. Transportation Research Board. Washington, D.C., 1997.

Strathman, J.G., K. J. Dueker, T. Kimpel, R. Gerhart, K. Turner, P. Taylor, S. Callas, D. Griffin, and J. Hopper. "Automated Bus Dispatching Operations Control and Service Reliability Baseline Analysis." Transportation Research Record No. 1666. Transportation Research Board. Washington, D.C. 1999.

TCRP (Transit Cooperative Research Program). Transit Capacity and Quality of Service Manual. (TCRP) Web Document No. 6, National Research Council, Washington, D.C., 1999. Online: http://www4.nas.edu/trb/crp.nsf/All+Projects/TCRP+A-15

USDOT (U.S. Department of Transportation). *National ITS Architecture: Executive Summary.* Prepared by Iteris, Inc. and Lockheed Martin. Washington, D.C., April 2002.

USDOT (U.S. Department of Transportation). *Automatic Vehicle Location: Successful Transit Applications. A Cross-Cutting Study.* USDOT. Washington, D.C., August 2000.

USDOT (U.S. Department of Transportation). *ITS Deployment Guidance for Transit Systems – Technical Edition.* USDOT. Washington, D.C., April 1997.

Appendix – NTD collected by APC/AVL Systems

Adapted from the NTD Data Dictionary:

Form Data Item Description Line/Col. Field Name
406 Service Supplied/Total actual vehicle miles/AM Peak 6b bVMiles
406 Service Supplied/Total actual vehicle miles/Midday 6c cVMiles
406 Service Supplied/Total actual vehicle miles/PM Peak 6d dVMiles
406 Service Supplied/Total actual vehicle miles/Other 6e eVMiles
406 Service Supplied/Total actual vehicle miles/Avg. Weekday Total 6f fVMiles
406 Service Supplied/Total actual vehicle miles/Avg. Saturday Total 6g gVMiles
406 Service Supplied/Total actual vehicle miles/Avg. Sunday Total 6h hVMiles
406 Service Supplied/Total actual vehicle miles/Annual Total 6i iVMiles
406 Service Supplied/Total actual vehicle hours/AM Peak 7b bVHours
406 Service Supplied/Total actual vehicle hours/Midday 7c cVHours
406 Service Supplied/Total actual vehicle hours/PM Peak 7d dVHours
406 Service Supplied/Total actual vehicle hours/Other 7e eVHours
406 Service Supplied/Total actual vehicle hours/Avg. Weekday Total 7f fVHours
406 Service Supplied/Total actual vehicle hours/Avg. Saturday Total 7g gVHours
406 Service Supplied/Total actual vehicle hours/Avg. Sunday Total 7h hVHours
406 Service Supplied/Total actual vehicle hours/Annual Total 7i iVHours
406 Service Supplied/Total actual vehicle revenue miles/AM Peak 8b bVRevMls
406 Service Supplied/Total actual vehicle revenue miles/Midday 8c cVRevMls
406 Service Supplied/Total actual vehicle revenue miles/PM Peak 8d dVRevMls
406 Service Supplied/Total actual vehicle revenue miles/Other 8e eVRevMls
406 Service Supplied/Total actual vehicle revenue miles/Avg. Weekday Total 8f fVRevMls
406 Service Supplied/Total actual vehicle revenue miles/Avg. Saturday Total 8g gVRevMls
406 Service Supplied/Total actual vehicle revenue miles/Avg. Sunday Total 8h hVRevMls
406 Service Supplied/Total actual vehicle revenue miles/Annual Total 8i iVRevMls
406 Service Supplied/Total actual vehicle revenue hours/AM Peak 9b bVRevHrs
406 Service Supplied/Total actual vehicle revenue hours/Midday 9c cVRevHrs
406 Service Supplied/Total actual vehicle revenue hours/PM Peak 9d dVRevHrs
406 Service Supplied/Total actual vehicle revenue hours/Other 9e eVRevHrs
406 Service Supplied/Total actual vehicle revenue hours/Avg. Weekday Total 9f fVRevHrs
406 Service Supplied/Total actual vehicle revenue hours/Avg. Saturday Total 9g gVRevHrs
406 Service Supplied/Total actual vehicle revenue hours/Avg. Sunday Total 9h hVRevHrs
406 Service Supplied/Total actual vehicle revenue hours/Annual Total 9i iVRevHrs
406 Service Supplied/Total scheduled vehicle revenue miles/AM Peak 10b bVSchMls
406 Service Supplied/Total scheduled vehicle revenue miles/Midday 10c cVSchMls
406 Service Supplied/Total scheduled vehicle revenue miles/PM Peak 10d dVSchMls
406 Service Supplied/Total scheduled vehicle revenue miles/Other 10e eVSchMls
406 Service Supplied/Total scheduled vehicle revenue miles/Avg. Weekday Total 10f fVSchMls
406 Service Supplied/Total scheduled vehicle revenue miles/Avg. Saturday Total 10g gVSchMls
406 Service Supplied/Total scheduled vehicle revenue miles/Avg. Sunday Total 10h hVSchMls
406 Service Supplied/Total scheduled vehicle revenue miles/Annual Total 10i iVSchMls
406 Service Supplied/Charter service hours/Annual Total 11i iChHours
406 Service Supplied/School bus hours/Annual Total 12i iSchHours