TCRP SYNTHESIS 48

TRANSIT COOPERATIVE RESEARCH PROGRAM

Sponsored by the Federal Transit Administration

Real-Time Bus Arrival Information Systems

A Synthesis of Transit Practice

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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Real-Time Bus Arrival Information Systems

A Synthesis of Transit Practice

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SUBJECT AREAS

Public Transit

Research Sponsored by the Federal Transit Administration in Cooperation with the Transit Development Corporation

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.

2003

www.TRB.org

TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions*, published in 1987 and based on a study sponsored by the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of vice configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academy of Sciences, acting through the Transportation Research Board (TRB), and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

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TCRP SYNTHESIS 48

Project J-7, Topic SA-14
ISSN 1073-4880
ISBN 0-309-069653
Library of Congress Control No. 2003107942

Price $15.00

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TRANSIT COOPERATIVE RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, D.C. 20001

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Printed in the United States of America

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FOREWORD

By Staff
Transportation
Research Board

Transit administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the transit industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire transit community, the Transit Cooperative Research Program Oversight and Project Selection (TOPS) Committee authorized the Transportation Research Board to undertake a continuing study. This study, TCRP Project J-7, "Synthesis of Information Related to Transit Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute a TCRP report series, *Synthesis of Transit Practice*.

The synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

This synthesis report will be of interest to transit staff concerned with implementing real-time bus arrival information systems at their agencies. Information on relevant technical capabilities, agency experience, cost, and bus rider reactions to these information systems was documented. The report describes the state of the practice, including both U.S. and international experience. It documents survey information, a review of the relevant literature, as well as interviews with key personnel at agencies that have, or are in the process of, implementing these systems.

This report from the Transportation Research Board integrates the information obtained from the literature review and survey responses with the follow-up interviews. Case study information details specifics from agencies that have deployed these systems.

A panel of experts in the subject area guided the work of organizing and evaluating the collected data and reviewed the final synthesis report. A consultant was engaged to collect and synthesize the information and to write the report. Both the consultant and the members of the oversight panel are acknowledged on the title page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

ACKNOWLEDGMENTS

Carol L. Schweiger, Multisystems, Inc., Cambridge, Massachusetts, was responsible for collection of the data and preparation of the report.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Andrew Bata, Senior Director, State Planning, Telecommunications, and Information Services, New York City Transit; Steven Chien, Associate Professor, Department of Civil and Environmental Engineering, Interdisciplinary Program in Transportation, New Jersey Institute of Technology; Brian Cronin, Engineer, Federal Transit Administration, U.S. Department of Transportation; Kang Hu, Transportation Engineer, City of Los Angeles Department of Transportation; Rudolf Kolaja, Traffic Operations Engineer, Intermodal Transportation Division, Traffic Engineering Group, Arizona Department of Transportation; Jerome M. Lutin, Senior Director, Intermodal Planning and Capacity Analysis, New Jersey Transit; Steve Mortensen, Senior Transportation Planner, Mitretek Systems; and Peter L. Shaw, Senior Program Officer, Transportation Research Board.

This study was managed by Donna L. Vlasak, Senior Program Officer, who worked with the consultant, the Topic Panel, and the J-7 project committee in the development and review of the report. Assistance in project scope development was provided by Stephen F. Maher, P.E., and Jon Williams, Managers, Synthesis Studies. Don Tippman was responsible for editing and production. Cheryl Keith assisted in meeting logistics and distribution of the questionnaire and draft reports.

Christopher W. Jenks, Manager, Transit Cooperative Research Program, assisted TCRP staff in project review.

Information on current practice was provided by many transit agencies. Their cooperation and assistance was most helpful.

REAL-TIME BUS ARRIVAL INFORMATION SYSTEMS

SUMMARY

In the late 1980s and 1990s, the deployment of automatic vehicle location (AVL) systems to better monitor and control operations was becoming prevalent throughout the U.S. transit industry. The focus of most of these deployments was to increase operational efficiency, not to provide customer information. As these deployments matured, transit agencies recognized that data from an AVL system could be used to provide customers with real-time predictions of bus arrivals. At the same time, many transit systems in Europe were demonstrating the benefits of providing such real-time information to their customers.

As a result, transit agencies have discovered a growing interest in providing real-time bus arrival information to customers once they have deployed the AVL technology. Transit agencies of various sizes are beginning to invest in real-time information systems, with the realization that they can have a significant and positive impact on their customers. Also, intelligent transportation systems products that specialize in providing real-time transit information exist on the market today and are being procured and deployed by transit agencies of all sizes.

This synthesis describes the state of the practice in real-time bus arrival information systems, including both U.S. and international experience. The panel for this project chose to focus on bus systems, rather than all transit modes, and on the following six key elements of these systems:

- Bus system characteristics;
- Real-time bus arrival information system characteristics, including information about the underlying technology and dissemination media;
- System prediction, accuracy, and reliability;
- System costs;
- Customer and media reactions; and
- Institutional and organizational issues associated with the system.

This report includes a review of the relevant literature, in addition to the results of a survey that was conducted as part of this project. The survey covered items from the six key elements listed previously, including the technical capabilities of the systems, agency experience, cost, and bus rider reactions to these information systems. This synthesis also contains the results of interviews with key personnel at agencies that have implemented or are in the process of implementing these systems.

The literature review revealed that there is not a significant amount of material on this subject in the United States. The number of systems operational in the United States is commensurate with the amount of literature. However, at the time this report was being written, an increasing number of systems were in the process of being deployed across the United States.

In addition, the literature reflects that many of these systems have been deployed throughout Europe. Some of the more prominent European systems, such as the London Buses' Countdown system, began operation in the early 1990s. Two of the key European Commission-funded studies of real-time transit information, INFOPOLIS 1 (conducted in 1996–1997) and INFOPOLIS 2 (conducted in 1998–2000), produced detailed literature describing real-time transit information provided by six types of media. In INFOPOLIS 1, some 53 systems across Europe were described. In INFOPOLIS 2, more than 150 systems providing transit information were identified and surveyed.

The survey conducted as part of this synthesis covered the most fundamental elements of deploying a real-time bus arrival information system: characteristics of the underlying AVL system, type of media distributing the real-time information, how real-time information is predicted, relative costs of the system, customer and media reaction to the system, and institutional and organizational issues associated with the system. Surveys were received from 18 transit agencies from around the world, including 9 from the United States. The U.S. responses represented agencies that carry a total of more than 428 million fixed-route bus passengers annually.

As of 2000, 88 transit agencies in the United States had operational AVL systems and 142 were planning AVL systems. Furthermore, there were 291 operational automated transit information systems in the United States, with 48 planned. This number includes real-time bus arrival information systems, as well as other pretrip, wayside, and in-vehicle systems. The growing deployment of real-time bus arrival information systems is reflected in the large number of agencies deploying AVL and automated transit information systems.

The majority of real-time bus arrival information systems are based on the use of data from Global Positioning System-based AVL systems. Other types of AVL systems, such as signpost and transponder systems, are also being used to generate real-time arrival information. The location data generated from AVL systems are used together with other information, such as current and historical traffic conditions, and real-time operations data (e.g., travel time between specific stops) from the last several buses that passed a particular stop, to predict the arrival time of the next bus at a particular stop.

Most systems are using light-emitting diode signs [also called dynamic message signs (DMSs)] and liquid crystal displays to present bus arrival information at stops. However, other methods of information dissemination are being used as well, including the Internet, mobile telephones, and personal digital assistants.

The most prevalent types of information displayed on DMSs are current time and date, route number and final destination of the vehicle, waiting time (either in countdown format or time range), and service disruptions or other important service and/or security messages. The communications technologies that are used most often to transmit information to DMSs are cellular, such as cellular digital packet data, and conventional telephone lines.

Prediction models being used in real-time bus arrival information systems were reviewed. Although several models in use are proprietary, others have been documented and are fully described in this report. Four specific models are described: (1) Global Positioning System-based bus arrival time estimation algorithms as used in Blacksburg, Virginia; (2) the prediction algorithm developed by the Los Angeles Department of Transportation for the bus rapid transit service, called Metro Rapid; (3) the algorithm developed by the University of Washington to predict the arrival of King County Metro (Seattle) buses; and (4) the algorithm developed to demonstrate a real-time arrival system at Houston Metro.

The input data used by these prediction models and algorithms include current and historical traffic conditions and current and historical bus operations data (e.g., running times between timepoints).

Measuring the accuracy of the prediction models is covered in the report, in addition to descriptions of the methods currently being used. These methods include monitoring AVL and real-time arrival information systems by a dispatcher or software system, plus field visits to compare actual bus arrival times with the times depicted on the DMSs. Surprisingly, several survey respondents do not monitor prediction accuracy, although doing so can result in deciding that predicted data should not be displayed to the customer.

The frequency of monitoring accuracy varies widely among the agencies surveyed. Most agencies thoroughly checked the accuracy during the installation and testing phases of their systems, but less frequently once the system went into regular operation.

In addition to providing information to the customer, data from real-time bus arrival infor-mation systems are used for other purposes, including optimizing service and operations. Several agencies reported that they used the information to perform route and schedule restructuring; to conduct general planning, such as operations and financial planning; and to develop new services.

In terms of costs, data were collected on the capital, operations, and maintenance costs of the underlying technology (AVL system), as well as the costs of providing the real-time arrival information. Capital costs for providing real-time bus arrival information, in addition to the cost of the underlying technology, ranged from $60,000 for one of the smallest deployments [City–University–Energysaver (CUE) in Fairfax, Virginia, with 12 buses and 6 light-emitting diode signs] to $69.75 million for one of the largest deployments (the Countdown system developed by London Buses, with almost 6,000 buses and a total of 4,000 signs to be installed by 2005).

With regard to costs, many agencies are not aware of the expense of operating and maintaining their real-time systems, because communication costs vary widely based on the type of communication and the way the communication is charged (e.g., per packet of data). This issue highlights the need for determining all operations and maintenance costs very early in the deployment process (in the planning stage before procurement), and for providing transit agencies with better information on expected operations and maintenance costs.

For the most part, customer and media reactions to real-time bus arrival information have been positive in those agencies surveyed. However, none of the responding agencies reported a definitive increase in ridership as a result of deploying such a system. Most agencies reported that there may have been an increase in ridership, but that they were not certain that it was a direct result of the system. At a minimum, real-time bus arrival information systems assist in the maintenance of ridership. These systems could potentially contribute to meeting the FTA's objective to increase ridership across the country by 2%.

Benefits realized from deploying real-time bus arrival information systems include improved customer service, increased customer satisfaction and convenience, and improved visibility of transit in the community. One of the perceptions among customers is that bus services have improved, and that people traveling late at night now have the reassurance that the next bus is not far away. Given the accuracy with which real-time arrival estimates are now being calculated, more and more existing and potential transit riders are viewing these systems as a necessary part of their travel experiences. Also, the combination of AVL and real-time arrival information systems results in benefits to transit agency staff, including less time required to monitor and control schedule adherence, improved safety and security for operations personnel and riders, less time required to respond to customer inquiries, improved maintenance management, and improved management effectiveness.

Key lessons learned from the deployment covered procurement, testing and implementation, operations, and maintenance. Overall procurement lessons include financial issues, such as obtaining funds and determining costs; procurement process issues, such as using a negotiated procurement and finding suitable and established vendors; institutional issues, such as obtaining approval for procuring such a system; and technical issues, such as the amount of customization that is necessary for this type of system. Testing and implementation issues included technical issues, such as getting power to the signage, and institutional and organizational issues, such as changes in project scope throughout the project. Operations issues covered a variety of training, financial, and technical issues. Finally, maintenance issues included a discussion of vendor lead times, planning for maintenance funding early on in the project, and updating data on a regular and temporary basis.

CHAPTER ONE

INTRODUCTION

PROJECT BACKGROUND AND OBJECTIVES

Although automatic vehicle location (AVL) systems were initially deployed to increase the efficiency of transit operations, the industry recognized that the data from AVL systems could be used to provide real-time information. Thus, once transit agencies began to realize the operational benefits of AVL technology implementation, their interest in providing real-time bus arrival information to customers increased. Transit agencies of various sizes are beginning to invest in real-time information systems, recognizing that they can have a significant and positive impact on customers. Products from intelligent transportation systems (ITS) that specialize in providing real-time transit information are readily available and are being procured and deployed by transit agencies of all sizes. Also, real-time transit information systems can meet the growing need to disseminate safety and security information (e.g., Amber Alerts) to customers in a security-conscious environment.

At this time, information available to agencies that are considering the deployment of real-time bus arrival information is somewhat lacking. This is because most of the current systems in the United States have not been operational for more than a few years or the existing systems have not yet been evaluated. More information is available on European deployments of these systems. At the time that this report was written, there was one FTA project under way that will produce guidance for agencies interested in deploying such a system. This information is scheduled to be available by summer 2003.

The primary objective of this synthesis is to document the state of the practice in real-time bus arrival information systems, including both U.S. and international experience. A survey was conducted to obtain information on relevant technical capabilities, agency experience, cost, and bus rider reactions to these information systems. This synthesis also includes a review of the relevant literature on current practice in the field. Documented interviews with key personnel at agencies that have implemented these types of systems are an important element of this report.

TECHNICAL APPROACH TO THE PROJECT

This synthesis project was conducted in five major steps. First, a literature review was performed to (1) identify systems in existence or being planned, (2) determine the approaches being used to develop and deploy these systems, and (3) identify the issues associated with operating and maintaining a system.

Second, a survey was conducted to collect information on factors such as system costs, available techniques for predicting real-time arrival times and measuring prediction accuracy, the types of media used to disseminate the real-time information, and the organization and institutional issues. In addition, data on the relevant technical capabilities, agency experience, and bus rider reactions to these information systems were collected through the survey.

Third, the surveys results were analyzed. Fourth, telephone interviews were conducted with key personnel at agencies that have implemented or are in the process of implementing these systems. Lastly, the synthesis presents case studies from selected agencies that have deployed these systems.

SYNTHESIS ORGANIZATION

This synthesis report is organized as follows:

- Chapter two summarizes the literature review.
- Chapter three describes the technical characteristics of real-time bus arrival information systems, including the underlying AVL technology; in-terminal, wayside sign, and monitor technology; prediction algorithms; accuracy of predictions; and use of the information generated by the systems.
- Chapter four presents information about system costs and benefits.
- Chapter five discusses customer and media reactions to real-time bus arrival information systems.
- Chapter six discusses institutional and organization issues.
- Chapter seven presents case studies from selected agencies that have deployed these systems.
- Chapter eight summarizes the results and presents the conclusions of the study, and offers suggestions for future research.
- References are provided for literature that was reviewed, in addition to a bibliography for related material not directly referred to in the text.
- Appendix A contains the survey instrument.
- Appendix B provides a list of the responding agencies.

CHAPTER TWO

LITERATURE REVIEW

The literature review revealed that, to date, a limited amount of information has been written about real-time bus arrival systems, although a wide variety of systems have been discussed. The literature review was conducted as a five-step process beginning with an on-line Transportation Research Information Services (TRIS) search, which yielded 47 documents, many of which were reviewed and used in this report.

The second step in the literature review involved obtaining and reviewing more articles, press releases, and website information received directly from agencies. The third step was to review a white paper written for the FTA Office of Mobility Innovation on real-time transit information systems (*1*). That report cited more than 50 papers and articles obtained from a variety of sources, including the most recent papers from the following:

- TRB annual meetings,
- TRIS,
- Intelligent Transportation Society of America (ITSA) annual meetings,
- Intelligent Transportation Society (ITS) World Congress meetings,
- *ITS Journal,*
- American Public Transportation Association conferences,
- Key project websites from the United States and Europe, and
- FTA documentation.

Most of these documents were reviewed for relevance to this synthesis project. The majority of references cited in the FTA white paper were indeed pertinent, and many are cited in this report.

The fourth step was to identify and review another major reference source—"Traveller Information Systems Research: A Review and Recommendations for Transport Direct" (*2*). This report describes literature and information collected for a major U.K. initiative called Transport Direct. Transport Direct "is an ambitious Programme to provide the U.K. with a travel information service that can present the public with the opportunity to compare travel options across public and private transport modes" (*2,* p. 1).

The fifth step was to identify and review documentation produced as part of the European Commission studies called INFOPOLIS 1 (1996–1997) and INFOPOLIS 2 (1998–2000). The primary goal of INFOPOLIS 1 was "to improve user accessibility to Public Transport information in terms of its presentation as well as its content, and to produce guidelines for European Standards for Human Computer Interface" (*3*). INFOPOLIS 1 produced a significant amount of documentation including a detailed review and analysis of 53 public transport information systems in Europe, which were in operation or being implemented in 1996.

INFOPOLIS 2 was an extension of INFOPOLIS 1, and its primary goal was "to improve user access to electronic intermodal traveler information by developing guidelines for the presentation of information" (*4*). INFOPOLIS 2 also generated many documents, some of which were reviewed as part of the synthesis literature review. More than 150 European public transportation information systems were investigated and almost 100 surveyed. As in INFOPOLIS 1, a detailed review was conducted of the surveyed systems. All documentation reviewed for the synthesis is listed in the bibliography.

The literature yielded several major conclusions about the state of the art and state of the practice of real-time bus arrival information systems. First, over the past several years, an increasing number of agencies have embraced the concept that customer service and "goodwill," and transit's visibility in the community, can be greatly improved by providing real-time bus arrival information. It is obvious from the literature that most agencies focused on implementing AVL systems first, primarily to improve their operational efficiency. The idea of using this information to provide real-time customer information was not embraced until

- The AVL system was fully operational (with virtually no flaws),
- Upper management recognized the potential benefits to providing customers with real-time information, and
- The agency recognized that it would not lose many customers because of the real-time information (e.g., a customer choosing another mode of transportation because of a posted delay).

Second, with the recognition that automobile ownership is increasing and traffic conditions are worsening all over the world, more regions have a vested interest in promoting alternate forms of transportation, particularly public transportation. It is becoming more difficult to promote public transportation in traditional ways (e.g., providing discounted rides). Therefore, agencies are looking for other methods of enticing nonriders to ride and of providing incentives to retain existing riders. Providing real-time information to customers is an effective marketing tool that can help agencies satisfy these objectives.

Finally, from a technical perspective, there are many more hardware, software, and communications tools available to make providing real-time information easier than it was even 10 years ago, and AVL systems provide the backbone technology required to determine real-time bus arrival information. First, AVL systems are now commonly available, more easily deployed than in years past, and somewhat less expensive than they once were. Thus, this greater availability, together with the ability to make arrival predictions using sound AVL data, makes it easier for an agency to consider providing real-time information sooner than it might have thought possible.

Also, there are a variety of methods to make the predictions that constitute real-time information. Even though most vendors provide proprietary algorithms for real-time predictions, these algorithms typically take into account the actual location of transit vehicles, their schedule and timepoints, historical vehicle operations (both immediate history, such as the last several buses on the same route, and recent history, such as vehicle operations over the last 6 months), and sometimes the traffic patterns. Other algorithms that are being used successfully for predictions can incorporate additional conditions such as weather.

Finally, the tools available for disseminating the information are more plentiful and technologically advanced than they were even 5 years ago. Real-time information is not only provided at the bus stop, by means of an electronic display, but it can be provided in a variety of other formats, such as HyperText Markup Language (HTML) and Extensible Markup Language (XML) for Internet applications, and Wireless Markup Language (WML) for Wireless Application Protocol devices [e.g., mobile phones, pagers, two-way radios, and personal digital assistants (PDAs)]. In addition, the software that senses exactly what device is requesting real-time information and provides the resulting information in the correct format already exists. Therefore, if a specific mobile phone using WML 2.0 is requesting real-time information, the processor that provides the real-time information will format the answer in WML 2.0.

CHAPTER THREE

TECHNICAL CHARACTERISTICS OF REAL-TIME BUS ARRIVAL INFORMATION SYSTEMS

UNDERLYING AUTOMATIC VEHICLE LOCATION TECHNOLOGY

The synthesis survey covered several key characteristics of the responding agencies' real-time bus arrival information systems (see Appendix B for a list of the responding agencies). The underlying technology, which is an AVL system, is necessary for determining real-time arrival information. AVL systems provide information on the location of each bus and sometimes other critical information, such as vehicle speed and direction, and schedule adherence.

As of 2000, 88 transit agencies in the United States had operational AVL systems, and 142 were planning such systems, making AVL one of the most deployed ITS systems in the transit industry. Of the 88 deployed systems, 65 are in the 78 largest U.S. metropolitan areas. From 1995 to 2000 there was a 300% increase in agencies with operational systems (*5*). Because of the number of existing and planned deployments in the United States, this underlying technology will make it possible for many agencies to consider deploying real-time bus arrival information systems that may not have considered it before. This possibility is reflected in that in 2000, there were 291 operational automated transit information systems in the United States, with 48 more planned. Real-time bus arrival information systems accounted for some of these automated transit information systems, in addition to other pretrip, wayside, and in-vehicle systems.

Furthermore, "the use of AVL in public transit has been slower in the U.S. than in Canada and Europe. The first demonstration of AVL in Europe was in Hamburg, Germany in 1964" (*6*, p. 4). European countries have deployed a greater number of real-time bus arrival information systems than the United States, and they deployed them earlier.

Table 1 shows, for each responding agency, the number of vehicles equipped with AVL systems. Table 1 also shows that most responding agencies are using either Global Positioning System (GPS)-based AVL technology or differential GPS (DGPS)-based AVL technology, which provides better location accuracy than GPS, as their primary method for determining vehicle location. In addition, two signpost systems are listed in Table 1. These are signpost/beacon systems, in which each bus sends location and/or odometer data to dispatch. Across all respondents, location information on each vehicle is updated—transmitted from each vehicle to a central location—with a frequency of 30 s to 5 min. The frequency of location update is critical to the accuracy of the real-time arrival predictions, which use vehicle location as one of their key inputs.

Besides providing necessary information to real-time bus arrival information systems, AVL systems afford many operational benefits and can be integrated with other ITS systems to provide vital information (e.g., automatic passenger counters) and control vehicle operation (e.g., transit signal priority). These benefits include facilitating the analysis of transit service performance in real time and historically; collecting information needed to perform system planning, such as running times, and scheduling; and providing vehicle locations to emergency management.

REAL-TIME INFORMATION DISTRIBUTION

The most prevalent medium used for the distribution of real-time bus arrival information is the electronic sign, also known as a dynamic message sign (DMS), located at a bus stop. Of those agencies surveyed, there were a total of 98 signs located at bus stops in the United States and 1,981 signs located at bus stops among the non-U.S. respondents. Of all the types of electronic signs available, the light-emitting diode (LED) sign is the most prevalent, with the liquid crystal display (LCD) signs being next most frequently used.

Figure 1 is a photograph of a real-time bus arrival LED sign being used at 11 Portland Tri-Met (Tri-County Metropolitan District of Oregon) bus stops. Figure 2 shows an LED sign being used at Los Angeles County Metropolitan Transportation Authority (LACMTA) Metro Rapid bus stops. Figure 3 shows a Countdown LED sign at a London Buses bus stop near the Hammersmith London Underground stop. Figure 4 shows a bus stop sign in Rome, Italy. This sign not only shows real-time bus arrival information (in English and Italian), but it has a static stick map of the bus route.

Figure 5 shows a unique system used by City Bus in Williamsport, Pennsylvania, which does not actually display real-time bus arrival information, but provides the real-time location (bus bay) of each bus within the transit

TABLE 1
UNDERLYING AUTOMATIC VEHICLE LOCATION (AVL) TECHNOLOGY INFORMATION

Agency	No. of AVL-Equipped Vehicles	Total No. of Vehicles	Type of AVL	Frequency of Location Update (in min)
City Bus (Williamsport, Penn.)	25	25	GPS	5.0
Delaware Transit Corporation (DTC) (Wilmington, Del.)	189	189	GPS	1.0
Fairfax City–University–Energysaver (CUE) (Fairfax, Va.)	12	12	GPS	0.5
Glendale Beeline (Glendale, Calif.)	20	35	GPS	1.5 or every 200 m
King County Metro (Seattle, Wash.)	1,300	1,300	Signpost	1.0 to 3.0
Los Angeles DOT (LADOT)/Los Angeles County Metropolitan Transportation Authority (LACMTA)—Metro Rapid System (Los Angeles, Calif.)	150	150	Transponder to inductive loop system	1.0
Regional Transportation District (RTD) (Denver, Colo.)	1,111	1,111	GPS	2.0
San Francisco Muni (San Francisco, Calif.)	827	827	GPS	1.5
Tri-County Metropolitan Transportation District of Oregon (Tri-Met) (Portland, Ore.)	689	689	GPS	1.33–1.5
ATC Bologna (Bologna, Italy)	450	976	GPS	0.5
Centro (Birmingham, U.K.)	6	NR	GPS	0.5
Dublin Bus (Dublin, Ireland)	156	1,062	GPS	0.5
Kaohsiung (Taiwan)	250	500	GPS	0.5
Taichung (Taiwan)	250	480	GPS	0.5
Taipei (Taiwan)	135	3,808	GPS	0.5
Kent County Council (Kent, U.K.)	141	700	DGPS	0.5
Transport for London—London Bus Services Limited (London Buses) (London, U.K.)	5,700	6,600	Signpost	0.5
YTV (Helsinki Metropolitan Area Council) (Helsinki, Finland)	340	550	DGPS and Signpost	0.5

Notes: GPS = Global Positioning System; DGPS = differential GPS; NR = not reported.

FIGURE 1 Portland, Oregon, Tri-Met Transit tracker sign.

FIGURE 2 Los Angeles Department of Transportation/Los Angeles County Metropolitan Transportation Authority Metro Rapid Bus stop shelter sign.

FIGURE 3 London Buses Countdown sign.

center. This system contains both dynamic signage and audio information that helps transit riders identify the locations of their desired bus routes. Information on the signs and in the audio messages uses data received from mobile data terminals (MDTs), which are installed in all 28 of City Bus' vehicles. When drivers arrive at the transit center, they use the MDT to indicate that they have entered the terminal, as well as their stop and route numbers. These data are then sent to the base control computer in the transit center via a wireless local area network modem. The data are used to build visual and audio messages, and are stored in a database for future analysis. The text messages are displayed on signs inside and outside of the bus, and in corresponding audio messages that are broadcast over the public address system. Drivers have the ability to revise information if an error occurs or if they use a different bus bay than the one originally indicated. Announcements over the public address system include the bus route and the bus stop location, and they are repeated every minute while the bus is in the terminal.

A unique system that is being developed to provide bus operations personnel (not customers) with real-time arrival information uses an electronic toll tag. This project, which was expected to be operationally tested in the spring of 2003, can be described as follows. The Transportation Operations Coordinating Committee, known as TRANSCOM, implemented the System for Managing Incidents and Traffic (TRANSMIT). The committee is a consortium of highway, transit, and public safety agencies in the New York City metropolitan area, including New York, New Jersey, and Connecticut. TRANSMIT uses vehicles equipped with electronic toll tags as anonymous probes to manage traffic and to provide traveler information.

> Transponder readers installed along roadways detect EZ-Pass [electronic toll collection system in New York and New Jersey] tags and scramble tag ID's for privacy. As tags are detected by successive readers, the TRANSMIT system compiles aggregate data on average speeds, travel times, and the number of non-arriving vehicles (expected vehicles not yet detected by the next reader downstream). By comparing this information to historical data, TRANSMIT can detect incidents and alert the member agencies' operations centers for response. TRANSMIT has been implemented on over 100 miles of toll and non-toll roadway in Rockland, Westchester, Bronx, Kings, Queens, Richmond, and New York counties in New York, and Bergen, Hudson, Middlesex, and Union counties in New Jersey (*7*).

An application of TRANSMIT is being developed for New Jersey (NJ) Transit buses that travel to and from the Port Authority Bus Terminal (PABT) in New York City.

FIGURE 4 Bus arrival sign in Rome, Italy.

FIGURE 5 City Bus Transit Centre sign (Williamsport, Pa.).

As currently planned, as NJ Transit buses enter the eastbound approaches to the Lincoln Tunnel and the PABT, TRANSMIT readers over the roadways will read their EZ-Pass tags and compare them with schedule and bus assignment data downloaded from NJ Transit's radio and scheduling systems. The information will then be relayed to NJ Transit personnel at the PABT via wireless PDAs. The personnel will use this information to help expedite afternoon bus departures from the terminal (J.M. Lutin, Intermodal Planning and Capacity Analysis, New Jersey Transit, personal communication, January 2, 2003).

This TRANSMIT application is being evaluated as part of the ITS Program Assessment and Evaluation program by the Federal ITS Joint Program Office (*8*).

One additional method of providing real-time bus information is to display actual vehicle locations on a map of the service area that is available via the Internet and/or kiosks. This method does not provide real-time arrival

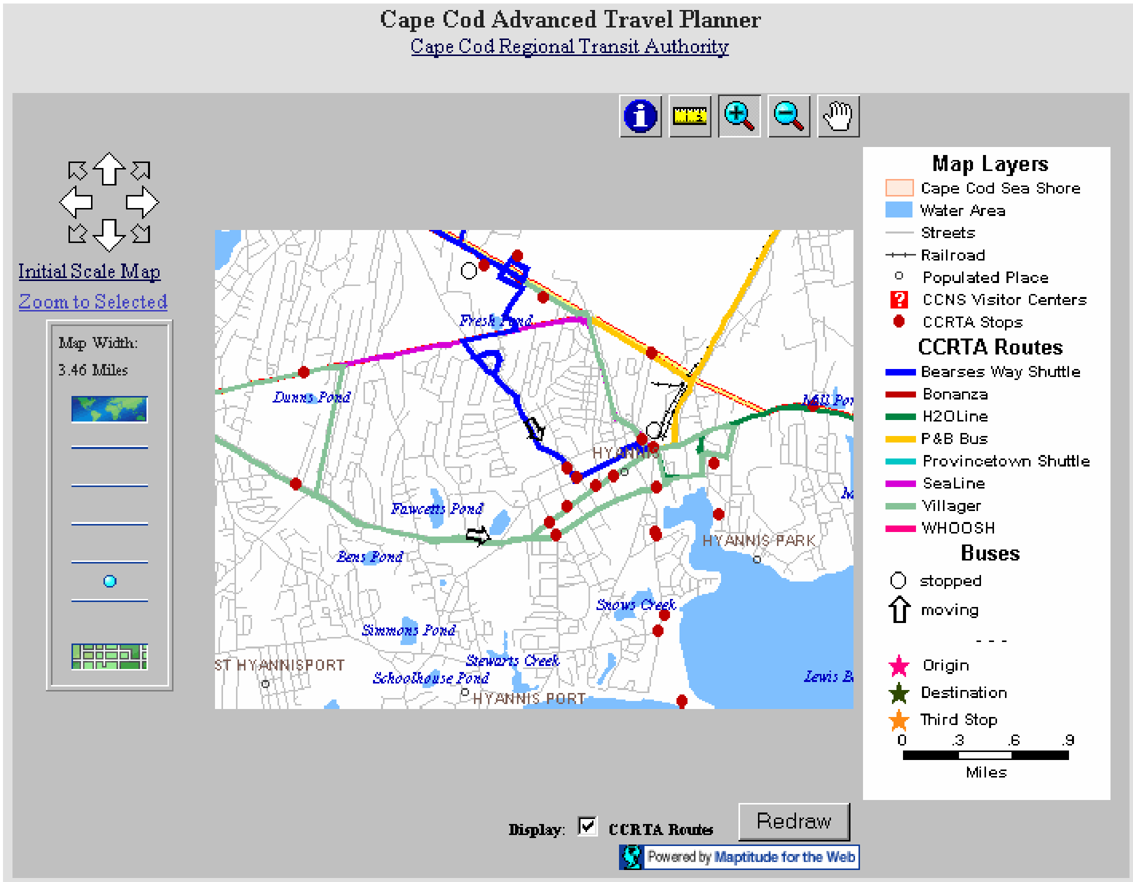

FIGURE 6 Cape Cod Regional Transit Authority (CCRTA) real-time bus location map.

information, but it requires less data and is a visual method to show customers where their vehicles are currently located. One example of this application is available from the Cape Cod Regional Transit Authority via the Internet (http://www.capecodtransit.org), as shown in Figure 6. The current vehicle location and the direction of travel are displayed. Another example combines the real-time vehicle location display with predicted arrival time, as shown in Figure 7. This system, called RideFinder, was deployed by the Central Ohio Transit Authority on kiosks in August 2001. The touch-screen interactive kiosks not only display a map of the hotel airport circulator route with the actual location of the buses and the estimated arrival time of the bus at that stop, but they can be used to access weather information and information on the agency's services and fares. In addition, arrival time is provided in audio format. The visually impaired can simply push a button on the kiosk to hear estimated bus arrival times.

Generally, the following types of information displayed on electronic signs were the most prevalent:

- Current time and date;
- Route number and final destination of vehicle;
- Waiting time, either in countdown format or time range; and
- Service disruptions or other important service messages.

The communications technologies that are used most often to transmit information to electronic signs at bus stops are cellular communications [mostly cellular digital packet data (CDPD)] and conventional telephone lines. Other technologies used less frequently include dedicated short-range communications (e.g., beacons), integrated services digital network lines, and T1 lines (a dedicated telephone connection supporting data rates of 1.544Mbits per second). As mentioned later in this report, having adequate communications coverage in the service area is critical to the success of communicating real-time information to the signs.

Although the survey did not ask respondents specifically about the costs associated with communications and how these costs were funded, the costs are critical and should be included in the budget for operations and maintenance (O&M) once the system is deployed. Furthermore, the use of wireless communication technologies such as CDPD are charged on a monthly basis and are also charged on a "per packet" basis. For example, if an agency uses CDPD to provide communication of real-time arrival information to each DMS, the ongoing communications costs will include charges for each data packet sent to each

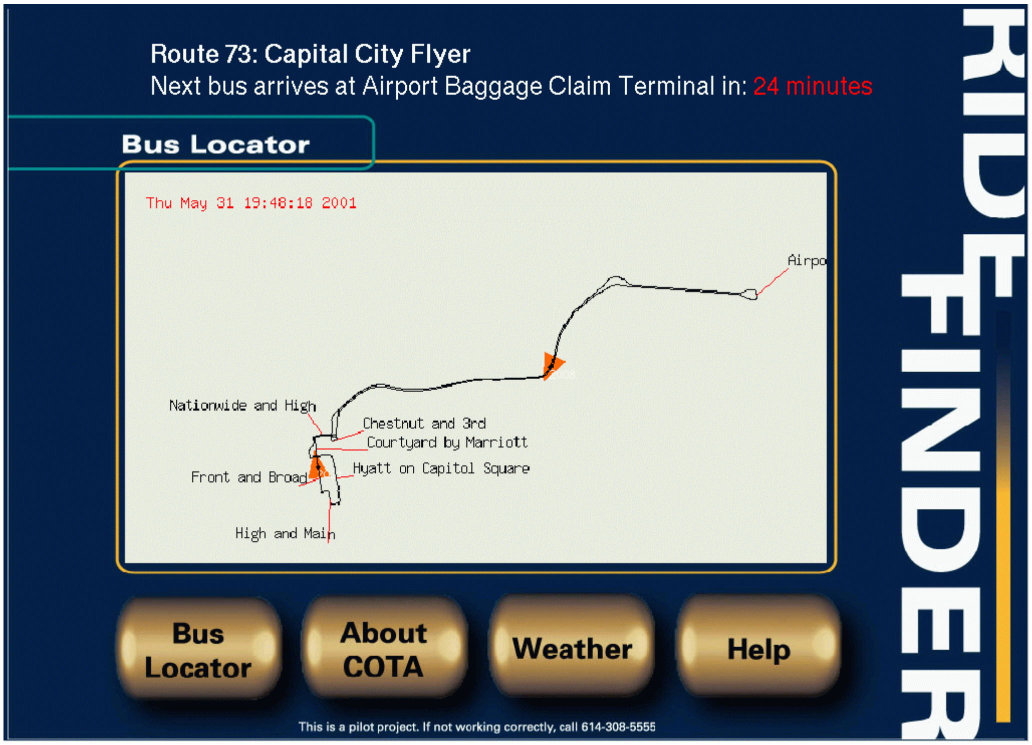

FIGURE 7 RideFinder (Central Ohio Transit Authority) real-time bus location screen.

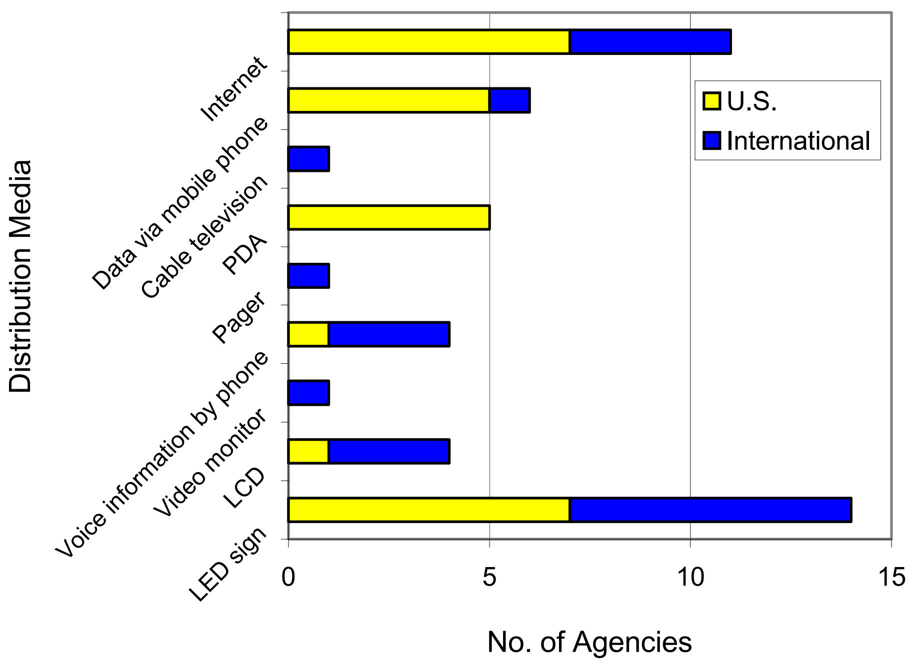

FIGURE 8 Distribution media for real-time bus arrival information.

sign on a monthly basis. If information on each sign is updated at least every minute, the resulting communications charges can be significant.

In addition to electronic signs at bus stops, there are several other types of media being used by the responding agencies to distribute real-time bus arrival information. Seven of the responding U.S. agencies have real-time information available on the Internet, six have real-time information available on PDAs, five on wireless application protocol-enabled mobile telephones, and one using a voice recognition system. Figure 8 provides the distribution media

TABLE 2
INTERNET ADDRESSES FOR REAL-TIME BUS ARRIVAL INFORMATION (as of December 2002)

Agency	Internet Address for Real-Time Bus Arrival Information
DTC (Del.)	http://www.beachbus.com/
Fairfax CUE (Va.)	http://www.ci.fairfax.va.us/Services/CueBus/NextBus.htm
Glendale Beeline (Calif.)	http://www.glendalebeeline.com/
King County Metro (Wash.)	http://www.mybus.org http://busview.its.washington.edu/busview_launch.jsp
RTD (Colo.)	http://www.rtd-denver.com
San Francisco Muni	http://www.sfmuni.com/routes/indxrout.htm
Tri-Met (Oreg.)	http://www.tri-met.org/arrivals/index.htm
Centro (Birmingham, U.K.)	To be announced
Kaohsiung (Taiwan)	http://www.mybus.com.tw
Taichung (Taiwan)	http://www.mybus.com.tw
Taipei (Taiwan)	http://www.apts.com.tw
Kent County Council (U.K.)	Internet planned
London Buses	Internet planned
STIB (Brussels, Belgium)	http://www.stib.irisnet.be/FR/36000F.htm

Notes: DTC = Delaware Transit Corporation; CUE = City–University–Energysaver; RTD = Regional Transportation District; Tri-Met = Tri-County Metropolitan Transportation District of Oregon; STIB = Societe des Transports Intercommunaux de Bruxelles.

for the survey respondents. Table 2 shows the Internet address for each respondent using the Internet as one of the distribution media of real-time information.

Société des Transports Intercommunaux de Bruxelles (STIB) (Brussels, Belgium) did not participate in the synthesis survey, but the agency does provide real-time information on their website, as noted in Table 2. STIB provides real-time bus location and arrival information, as shown in Figures 9 and 10. On the first website screen, the user selects the bus route and destination. Then, STIB displays the position of each vehicle (as a solid box) on a stick map of the route showing all stops. The final destination of the bus is displayed in the upper right-hand corner as a reminder. Next, the user can click on any stop along the route to obtain real-time information about when the next bus on the selected route and direction will arrive. Also, the user can display real-time information for all transit services emanating from the selected stop.

Images from several Internet websites that provide real-time bus arrival information are shown in Figures 11 through 13.

REAL-TIME PREDICTIONS, AND PREDICTION ACCURACY AND RELIABILITY

The key to accurate predictions of real-time bus arrival times is two-fold: the prediction algorithm or model, and the data that are used as input to the algorithm. In many cases, the prediction algorithms are proprietary and not typically disclosed by vendors that provide these types of systems. However, this synthesis revealed a number of models that are not proprietary, several of which are currently in use. Four models will be described briefly here.

As part of an FTA Field Operational Test conducted in Blacksburg, Virginia, entitled the Rural Traveler Information System Operational Test, Lin and Zeng developed four GPS-based bus arrival time estimation algorithms (*9*).

> In addition to GPS-based bus location data, other information [was] used as input data, including bus schedule information, bus delay patterns, and bus stop type information (a time-check stop vs. a regular stop). Whereas all algorithms employ GPS-based bus location data, the level of other information used in each algorithm varies (*9*, p. 13).

Lin and Zeng measured the performance of each algorithm using the following criteria: overall precision, robustness, and stability. They determined that the dwell time at time-check stops is most significant to the performance of each algorithm.

The Los Angeles Department of Transportation (LADOT) developed the Bus Arrival Information System that is being used as part of the LACMTA Metro Rapid bus rapid transit system. This system contains a prediction model that operates generally as follows (*10, 11*):

- Records bus arrival time at every bus detector, an inductive loop placed in the roadway, which serves as an antenna to receive the transponder identification code of the bus;
- Estimates bus travel time using previous bus information; and
- Calculates arrival times for approaching buses to all bus stops.

Specifically, Hu and Wong describe the prediction algorithm as follows.

> This system utilizes the loop-transponder technology as an Automatic Vehicle Locator (AVL) to detect and identify bus

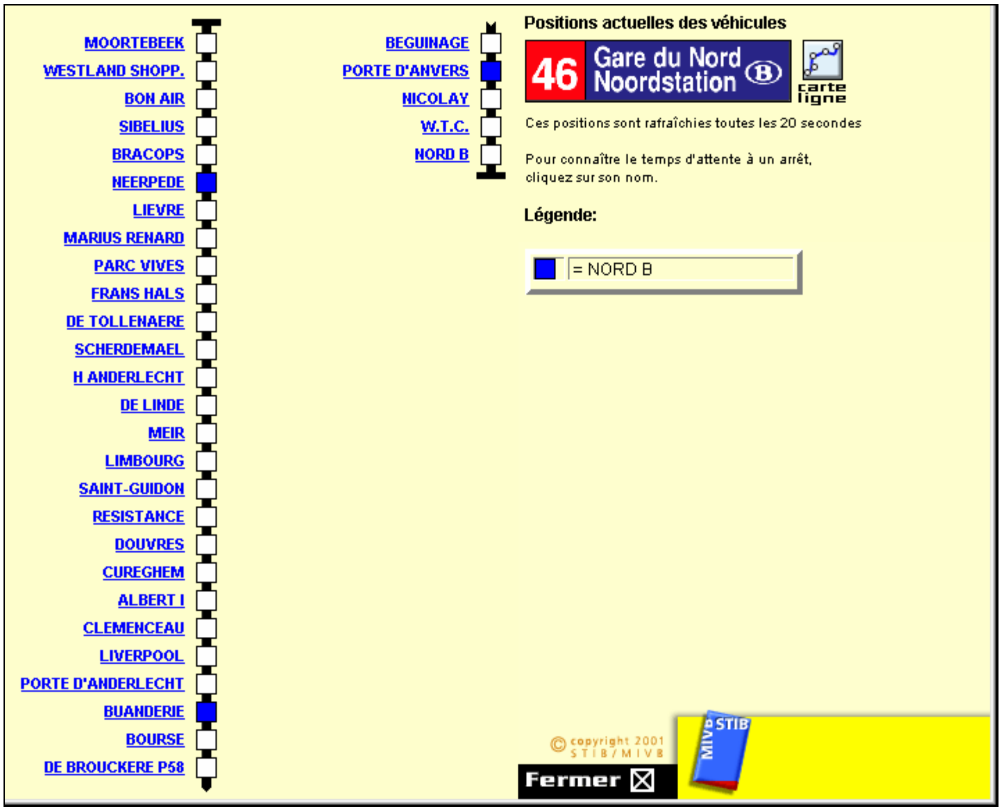

FIGURE 9 Société des Transports Intercommunaux de Bruxelles real-time bus location information (Brussels, Belgium).

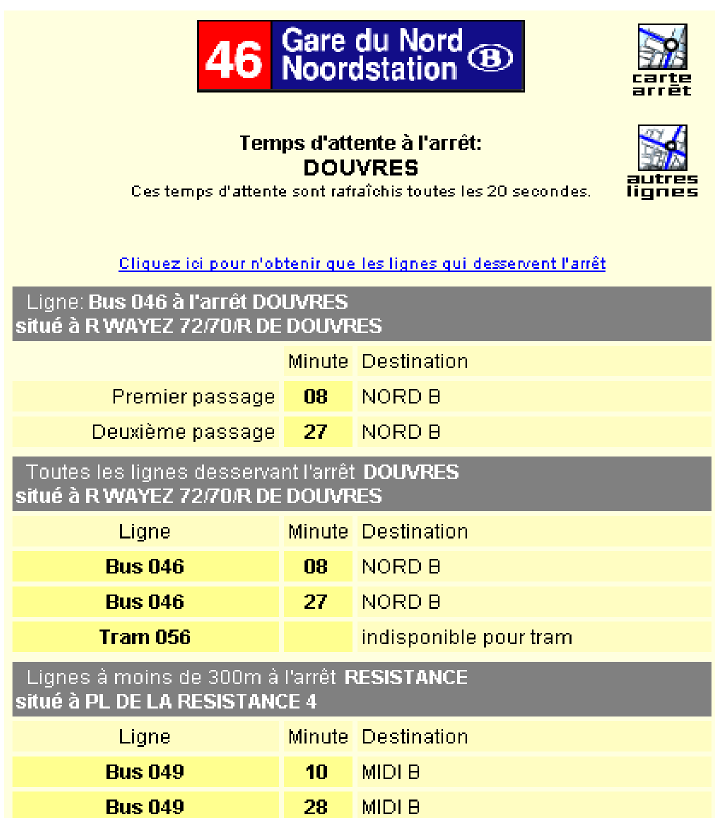

FIGURE 10 Société des Transports Intercommunaux de Bruxelles real-time arrival information at the Douvres stop on Line 46.

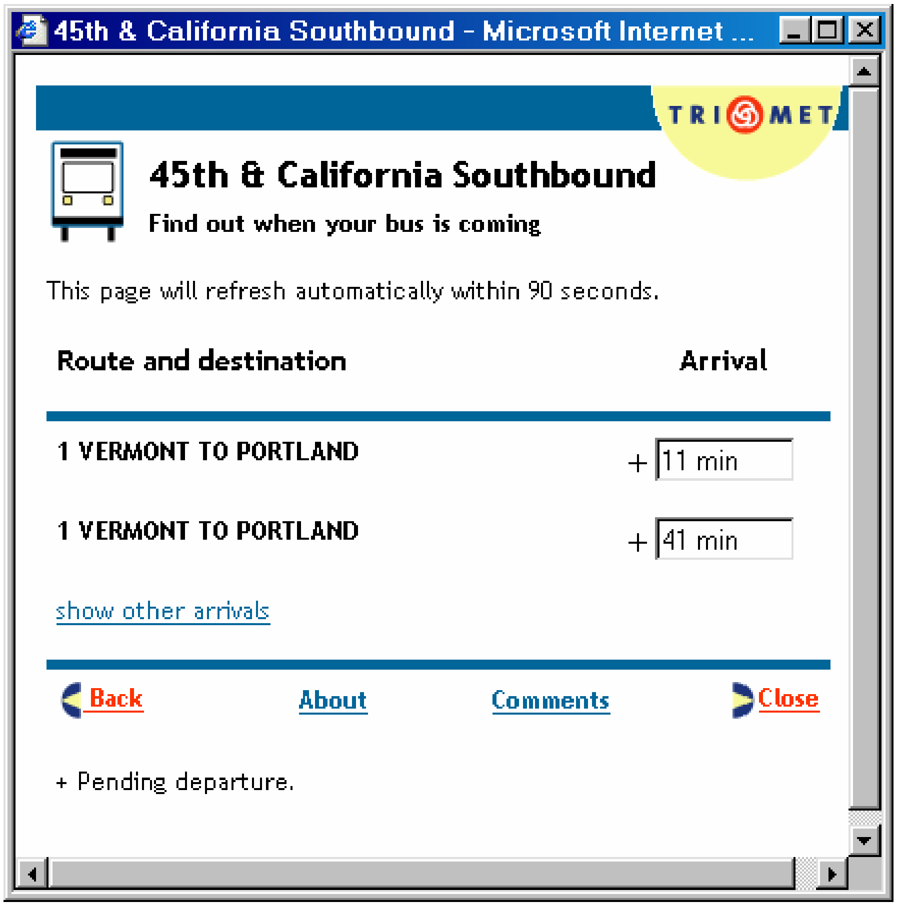

FIGURE 11 Tri-Met Transit Tracker on the Internet.

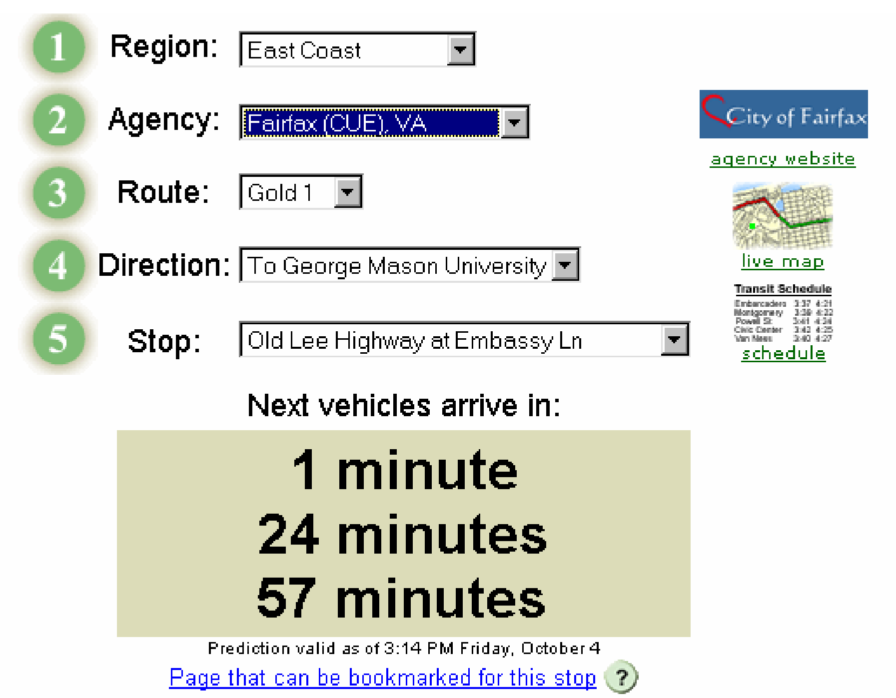

FIGURE 12 Fairfax CUE (City–University–Energysaver) real-time information.

37 AV SW & SW ALASKA ST(farside)

MyBus WAP site: www.mybus.org/wml/
This Metro location is number 6055

Last Updated: Fri Oct 04 11:12:32 PDT 2002

Show Location List   Show Location Map

Route	Destination	Scheduled	Depart Status
22	Downtown Seattle	11:21am	1 Min Delay
22	White Center	11:23am	On Time
51	West Seattle Junctn	11:29am	No Info
54	Downtown Seattle	11:12am	3 Min Delay
54	Downtown Seattle	11:42am	No Info
54	White Center	11:30am	On Time
55	Admiral District	11:15am	9 Min Delay
55	Downtown Seattle	10:57am	No Info
55	Downtown Seattle	11:27am	On Time
570E	INT. DISTRICT STA. (DOWNTOWN SEATTLE)	11:18am	4 Min Delay
570E	SEA-TAC AIRPORT	11:25am	2 Min Delay

Created by ITS-UW, Data from MetroKC, Funding from Sound Transit

FIGURE 13 King County Metro (Washington State) MyBus information.

locations. More than 150 Metro Rapid buses are equipped with system transponders and can be detected when passing through any of the 331 loop detectors throughout the two corridors [Wilshire and Ventura Boulevards]. TPM [Transit Priority Manager] first tracks every data that is generated when a bus traverses through a detector in the system. It consists of two real-time lists—the Hot-List (HL) and the Run-List (RL) objects. The HL tracks movement of every bus operating along a TPM corridor, which contains the bus attributes, position, and running status. The RL stores the detail time-point table and detector attributes, including bus scheduled arrival time-points, and actual arrival time-points.

Bus travel time is a function of distance and prevailing bus speed. TPM employs a Dynamic Bus Schedule Table technique (DBST) using an innovative algorithm approach called the Time Point Propagation (TPP) method, which dynamically builds the Schedule Arrival Time Point table with runtime information from the prior bus arrival time for the same locations plus the active headway value of the current bus.

The actual arrival time-point is also used for the prediction of Estimated Time of Arrival (ETA) of the next bus. ETA is calculated based on the previous bus travel time under the assumption that the current bus would experience the same or similar traffic conditions in the same segment of the corridor. The predicted bus arrival information is then transmitted through Cellular Digital Packet Data (CDPD) services to LED display signs at major bus stations. According to a field survey, the accuracy of the bus arrival information is relatively high (*11*).

Dailey et al. (*12*) created the prediction algorithm that is used by King County Metro to provide real-time bus arrival information via the Internet and mobile telephone, and on LCD displays at the Northgate Transit Center. Also, this algorithm was used to demonstrate the prediction of arrivals for Portland Tri-Met vehicles (*13*). In this algorithm, "the time series, consisting of time and location pairs, is used with historical statistics in an optimal filtering framework [Kalman filter] to predict future arrivals" (*12,* p. 1). According to the authors, seven assumptions drive the algorithm, as follows:

1. Vehicle locations are available irregularly, typically on a one- to five-minute basis;
2. Each scheduled trip is a realization of the stochastic process of the vehicle traveling the route;
3. The stochastic process is represented by the ensemble of realizations;
4. Vehicles are modeled as if moving with constant speed over a limited distance;
5. Starting and stopping motions of the vehicles are included in the variability of the process model;
6. The variability of the process model is normally distributed; and
7. There are known errors in the measurement of the location of the vehicles.

These assumptions allow the problem to be formulated in a statistical framework and fulfill the requirements necessary to use the Kalman filter to make optimal estimates of the predicted time until arrival for individual vehicles (*12*, pp. 1–2).

Welch and Bishop describe the filter this way: "The Kalman filter is a set of mathematical equations that provide an efficient computational (recursive) solution of the least-squares method. The filter is very powerful in several aspects: it supports estimations of past, present, and even future states, and it can do so even when the precise nature of the modeled system is unknown" (*14*).

Puckett and Honkus (*15*) describe a demonstration in Houston, Texas, in which arrival times for one Houston Metro bus route were displayed on a device located at one transit center and were made available on the Internet. Commercial off-the-shelf (COTS) GPS and CDPD devices were used along with a database containing vehicle locations. The location data in the database were then used together with

> stored bus stop information in order to place the vehicle on the appropriate route and update another database with average running times between stops. This second database separated the average running times by day of week and hour of the day. Finally, an Active Server Page was created that generated an automatically updated web page that could be accessed from any machine or device with an Internet connection. The page determined from the running time database, the closest vehicle in either direction and from its current time and location, computed the sum of the average running times to the Transit Center and furnished that information to the page. The update was furnished every minute. The entire computation process was tested over a two-month period. With only minor adjustments in the first few days, the computation and display performed flawlessly (*15*, p. 171).

However, after the conclusion of this demonstration, Houston Metro decided not to fully deploy this system for a variety of reasons, among which were that all Metro buses would have to be equipped with AVL and related communications hardware and software for the system to be effective across the whole Metro system. Furthermore, with the current procurement of its Intelligent Vehicle Operation and Management System, Houston Metro was waiting to examine the cost of using this approach with the hardware and software that would be procured.

As mentioned earlier, several real-time prediction models are proprietary. In addition, one vendor of real-time bus arrival information systems has been issued a patent entitled "Public Transit Vehicle Arrival Information System" that "describes a method for notifying passengers waiting for public transit vehicles of the status of the vehicles, including the arrival times of vehicles at stops" (*16*). In 2001, this patent was the subject of legal actions between the vendor and other providers of real-time bus arrival information systems. All legal actions to date have been settled. However, the situation raises the issue of whether or not the patent holder has an advantage in the industry, and other legal actions may be taken in the future because of the presence of this patent.

Furthermore, another similar patent had previously been issued to an ITS vendor not usually thought of as being in the real-time bus arrival information systems business entitled "Method and Apparatus for Determining Expected Time of Arrival" (*17*). Through 2002, there had been no legal actions related to that patent.

A variety of data is used as input to the aforementioned models. Beyond the typical input, which pertains to vehicle location, other data can be used and may affect the accuracy of the predictions, including

- Current traffic conditions (e.g., real-time traffic speeds);
- Real-time operating data from the last several buses on a particular route that passed a specific stop (e.g., running time between stops);
- Historical traffic conditions (e.g., traffic speeds by day and time of day in the past); and
- Historical bus operations data (e.g., running times between specific timepoints by day and time of day).

Table 3 summarizes the type of input data used by the survey respondents.

TABLE 3
PREDICTION MODELS FOR INPUT DATA

Type of Input Data	No. of U.S. Respondents	No. of International Respondents
Current traffic conditions	4	0
Real-time bus operating data	5	5
Historical traffic conditions	4	1
Historical bus operations	5	3
Schedules corrected by current deviation information	1	

Prediction accuracy is measured in a variety of ways. Some agencies monitor both the AVL and real-time arrival information systems directly (usually from a central location) to determine the accuracy of the predictions. For example, a dispatcher or specially designed software could monitor vehicle locations and predicted arrival times to determine if the predictions are accurate. This monitoring can take place either in real time or historically, using data logs from the signs and/or central system. Other agencies conduct field visits to compare actual bus arrival times with the times depicted on the dissemination media. Several agencies do not monitor prediction accuracy at all. One agency reported that it measures the variation in predicted arrival time for specific prediction times (e.g., when the prediction is that the bus will arrive in 10, 5, and 2 minutes). Furthermore, that agency determines the number of accurate predictions within plus or minus 25% of the displayed predictions.

Monitoring accuracy can be used as a way to determine if any predicted data should be provided to the customer. For example, London Buses reported that if AVL performance drops below 65% (because a driver did not log on to the system or buses were not yet equipped with AVL technology), a route will be removed from the Countdown sign, and a message displayed on the sign will indicate that the route is currently not available. The AVL technology has to perform consistently at 80% before the route is displayed on a sign.

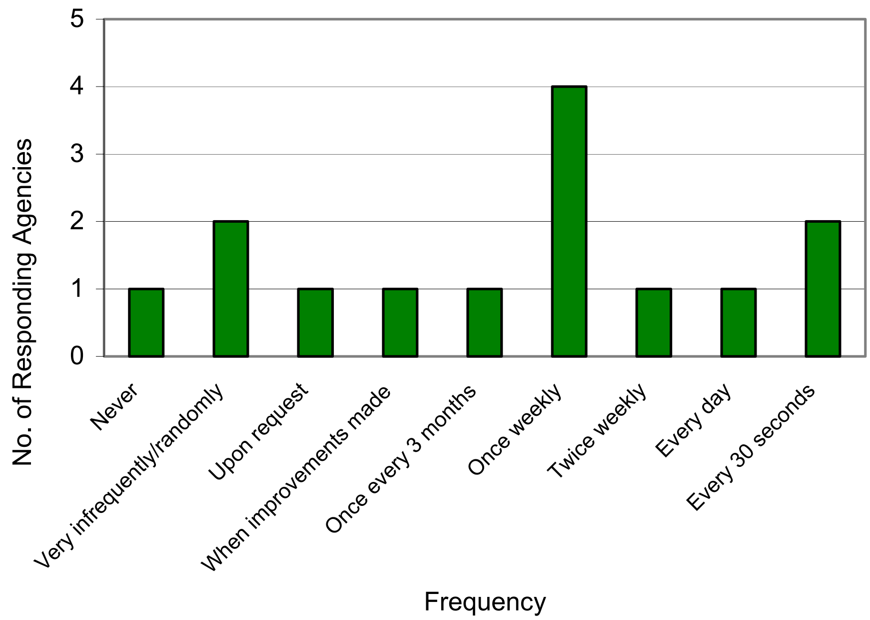

FIGURE 14 Frequency of monitoring information accuracy during regular operation.

The frequency with which prediction accuracy is monitored varies widely among the agencies surveyed, as shown in Figure 14. Most agencies reported that they checked the accuracy exhaustively during the installation and testing phases of their systems, but less frequently during regular operation.

In the synthesis survey, several questions were asked about the reliability of the real-time arrival information. Because several agencies consider accuracy and reliability to be the same, they did not answer those questions about reliability. However, the distinction between accuracy and reliability is an important one: accuracy refers to whether or not the information presented is correct, and reliability refers to whether or not the information is presented consistently (e.g., updated on a regular basis to be timely). Given the perceptions of some survey respondents as to the distinction between these terms, the reliability of real-time bus arrival information systems could be the subject of further study.

USE OF THE INFORMATION GENERATED BY THE SYSTEM

One of the primary concerns about deploying various types of transit technology is being able to effectively use the information that is generated by each technology. For example, some agencies that deploy AVL systems do not fully use all of this information to better plan their services. To better understand how agencies that have deployed real-time bus arrival information systems are using the information generated by the systems—beyond providing the information to the public—the following specific survey question was asked: "How do you use the real-time arrival information?"

In general, it was found that the information is used to optimize the transit service and operations. The use of the information can result in the modification of service frequency, an increase or decrease in the number of buses needed, and/or a better distribution of transit vehicles within the schedule to more closely meet the travel demand.

Of the nine U.S. responses, four agencies reported using the data to perform general transit planning, which can include operations, service, financial, and management planning, and to develop new services; three to change route headways and/or schedules; two to modify route structures; one to increase or decrease the number of buses serving a route; and one to plan new services. Other uses of the data reported by U.S. agencies included monitoring driver behavior, researching customer comments, and monitoring drivers and contractors.

Of the nine international responses, three use the data to perform general planning, three to change route headways and/or schedules, and two to increase or decrease the number of buses serving a route. Other uses of the data reported by responding international agencies include improving bus reliability, expanding the system to other routes, and doing real-time dispatching.

CHAPTER FOUR

SYSTEM COSTS

CAPITAL COSTS

Typically, a real-time bus arrival information system is either added to a base AVL system or it is procured as a separate stand-alone system, even though that would also have an AVL component. Therefore, the synthesis involved collecting information on the costs of the underlying AVL system, if there is one, and the additional costs needed to procure the real-time information system component.

The total capital cost of the underlying AVL systems is shown in Table 4. Table 5 shows the additional capital cost of providing real-time information. Non-U.S. costs were converted to U.S. dollars using the Interbank currency exchange rate for September 19, 2002. Note that the costs shown in these tables were reported by the responding agencies and may not necessarily reflect calculations that could be performed using values from specific columns (e.g., total capital cost divided by the number of equipped vehicles to derive the AVL system cost per vehicle, as in Table 4).

OPERATIONS AND MAINTENANCE COSTS

Of the agencies that responded to the survey, very few actually knew the O&M costs for their AVL and real-time arrival information systems. Tables 6 and 7 show these costs, respectively, if they were known. Note that the costs shown in these tables were reported by the responding agencies and may not necessarily reflect calculations that could be performed using values from specific columns (e.g., total O&M costs divided by the number of equipped vehicles to derive O&M cost per vehicle, as in Table 6).

One item of note in Table 6 is the annual O&M cost per vehicle as reported by London Buses. The reason that this cost is higher than others, as reported in the table, stems from several factors, including the complex operating environment in London. First, all London Buses services are privatized. In 1985, bus services outside London were deregulated, and in the 1990s, within London, bus services were privatized without total deregulation. There are a total of 600 London Buses routes, and every 5 to 7 years, each route is tendered.

TABLE 4
TOTAL CAPITAL COST OF AUTOMATIC VEHICLE LOCATION (AVL) SYSTEMS

Agency	No. of AVL-Equipped Vehicles	Type of AVL	Total Capital Cost of AVL System Reported in Survey (fixed-end and in-vehicle hardware and software)	Reported AVL System Cost per Vehicle
City Bus	25	GPS	$150,000	$3,000
DTC	189	GPS	$12,000,000	NR
Fairfax CUE	12	GPS	$60,000	$5,000
Glendale Beeline	20	GPS	$171,000 (includes the capital cost of two signs)	$8,101
RTD	1,111	GPS	$15,000,000	NR
San Francisco Muni	827	GPS	$9,600,000	NR
Tri-Met	689	GPS	$7,000,000	$4,500
ATC Bologna	450	GPS	$4,891,400	$4,891
Centro	6	GPS	$705,300	NR
Dublin Bus	156	GPS	$660,300	$2,919
Kaohsiung	250	GPS	$187,500	$625
Taichung	250	GPS	$187,500	$625
Taipei	135	GPS	$270,000	$2,000
Kent County Council	141	DGPS	$2,000,000	$5,000
King County Metro	1,300	Signpost	$15,000,000	$7,000
London Buses	5,700	Signpost	$23,251,500–$27,901,800	$3,100–$4,650 (excluding radio)
YTV	340	DGPS and Signpost	$1,400,000	$3,000
LADOT/LACMTA—Metro Rapid System	150	Transponder to inductive loop system	$2,100,000 [Includes cost of traffic signal priority system (signal equipment, roadway sensors, etc.)]	$100

Notes: GPS = Global Positioning System; DGPS = differential GPS; NR = not reported; DTC = Delaware Transit Corporation; CUE = City–University–Energysaver; RTD = Regional Transportation District; Tri-Met = Tri-County Metropolitan Transportation District of Oregon; ATC Bologna = Azienda Trasporti Consorziali Bologna; YTV = Helsinki Metropolitan Area Council; LADOT/LACMTA = Los Angeles DOT/Los Angeles County Metropolitan Transportation Authority.

TABLE 5
ADDITIONAL CAPITAL COST OF PROVIDING REAL-TIME INFORMATION

Agency	Additional Capital Costs for Providing Real-Time Information	No. of Electronic Sign Monitors	Capital Cost per Electronic Sign/Monitor as Reported	Prediction Model Software Cost as Reported
RTD	$1,000,000	0	NR	NR
City Bus	N/A	2 LED	NR	NR
DTC	$500,000	30 LED	NR	NR
Fairfax CUE	Included in AVL cost	6 LED	Included in AVL cost	Included in AVL cost
Glendale Beeline	Included in total AVL cost	2 LED	Included	Included
LADOT/LACMTA—Metro Rapid System	$600,000	44 LED	$5,000	$300,000
San Francisco Muni	Included in AVL cost	5 LED	Included in AVL cost	Included in AVL cost
Tri-Met	$750,000	9 LED	$3,500–$4,000	Included
ATC Bologna	$782,600	130 LED	$1,956,500	Developed with internal resources
Kaohsiung	$187,500	120 LED	$1,500	
Taichung	$187,500	110 LED	$1,500	
Taipei	$300,000	45 LED	$5,000	$20,000
London Buses	$46,503,000 estimated for 4,000 signs	1,473 LED (as of March 2002) (4,000 LED signs to be deployed by 2005)	$3,900 for sign, another $3,900 for data line provision and installation, $7,800 overall	NR
YTV	$1,100,000	11 LED, 10 video monitors	$5,000	$250,000
Centro	NR	30 LED, 10 LCD	NR	NR
King County Metro	$1,000,000 to upgrade on-board hardware plus $250,000 in software	2 LCD	$10,000	$500,000
Dublin Bus	$97,900	20 LCD	$4,900	$81,000
Kent County Council	Included in AVL cost	35 LCD	$10,200	Included in AVL cost

Notes: RTD = Regional Transportation District; NR = not reported; N/A = not available; LED = light-emitting diode; DTC = Delaware Transit Corporation; CUE = City–University–Energysaver; AVL = automatic vehicle location; LADOT/LACMTA = Los Angeles DOT/Los Angeles County Metropolitan Transportation Authority; Tri-Met = Tri-County Metropolitan Transportation District of Oregon; YTV = Helsinki Metropolitan Area Council; ATC Bologna = Azienda Trasporti Consorziali Bologna; LCD = liquid crystal display.

Second, 8,500 buses have actually been equipped with AVL technology, even though only 6,500 were operating as of December 2002. This is because buses are constantly being replaced, and the replacement buses must be equipped with AVL systems when they begin service. In addition, London Buses operates many types of buses, including 600 Routemaster buses (older double-decker buses with the entrance at the back and no door) and low-floor buses.

Finally, the AVL system was integrated with the on-board ticket machine to provide the most effective method for the driver to log on to the system. The AVL system was also integrated with the on-board radio and odometer.

In Tables 6 and 7 there are a significant number of Not Reported responses. Some agencies are not aware of the ongoing O&M costs associated with their AVL and real-time bus arrival systems. This is primarily because of the difficulty in estimating the communication costs, as well as the costs of necessary tangential services, including power, electricity, electronic sign maintenance, software maintenance, and bus shelter procurement and installation. Given the amount of information currently available on the O&M costs of AVL and real-time bus arrival information systems, this topic could be considered for future study.

STAFFING NEEDS

Information was also collected on the possibility of adding full-time staff as a result of deploying a real-time information system. Among the U.S. agencies responding, four indicated that staff had to be added. Overall, personnel were added in the information technology, operations, and customer service areas.

TABLE 6
OPERATIONS AND MAINTENANCE (O&M) COSTS FOR AUTOMATIC VEHICLE LOCATION (AVL) SYSTEMS

Agency	No. of AVL-Equipped Vehicles	Total Annual O&M Cost of AVL System as Reported	Annual O&M Cost per Vehicle as Reported
City Bus	25	NR	NR
DTC	189	$200,000	$1,058 (calculated, not reported)
Fairfax CUE	12	NR	NR
Glendale Beeline	20	Included in AVL cost	Included
King County Metro	1,300	$400,000	$700
LADOT/LACMTA—Metro Rapid System	150	NR	NR
RTD	1,111	NR	NR
San Francisco Muni	827	$1,300,000	$60*
Tri-Met	689	$200,000	$300
ATC Bologna	450	$391,308	$587
Centro	6	$41,233	NR
Dublin Bus	156	$111,816	NR
Kaohsiung	250	$112,500	$375
Taichung	250	$112,500	$375
Taipei	135	$87,750	$650
Kent County Council	141	$60,000	$315
London Buses	5,700	$7,750,500	$1,550
YTV	340	$100,000	$50–100

*Monthly charge per vehicle for cellular digital packet data service.
Notes: NR = not reported; DTC = Delaware Transit Corporation; CUE = City–University–Energysaver; LADOT/LACMTA = Los Angeles DOT/Los Angeles County Metropolitan Transportation Authority; RTD = Regional Transportation District; Tri-Met = Tri-County Metropolitan Transportation District of Oregon; ATC Bologna = Azienda Trasporti Consorziali Bologna; YTV = Helsinki Metropolitan Area Council.

TABLE 7
OPERATIONS AND MAINTENANCE (O&M) COSTS FOR PROVIDING REAL-TIME INFORMATION

Agency	Total Annual O&M Cost for Providing Real-Time Information as Reported	No. of Electronic Signs/Monitors	Annual O&M Cost per Electronic Sign/Monitor as Reported	Annual Maintenance Cost for Prediction Model Software as Reported
RTD	$150,000	0	NR	NR
DTC	$150,000	30 LED	NR	NR
Fairfax CUE	$30,000	6 LED	NR	NR
Glendale Beeline	Included	2 LED	Included	Included
LADOT/LACMTA—Metro Rapid System	N/A	44 LED	$300,000	Negligible
San Francisco Muni	Included in AVL O&M cost	5 LED	$200,000	Included in AVL O&M cost
Tri-Met	$100,000	9 LED	$3,000,000	NR
ATC Bologna	$48,914	130 LED	NR	NR
Kaohsiung	$37,500	120 LED	$3,000,000	NR
Taichung	$37,500	110 LED	$3,000,000	NR
Taipei	$200,000	45 LED	$2,000,000	$30,000
London Buses	Included in cost of real-time system	1,473 LED (as of March 2002) (4,000 LED signs to be deployed by 2005)	NR	NR
YTV	NR	11 LED, 10 video monitors	NR	NR
Centro	$38,753	30 LED 10 LCD	NR	NR
Dublin Bus	$22,363	20 LCD	NR	NR
Kent County Council	Included in AVL cost	35 LCD	$975,000	NR

Notes: RTD = Regional Transportation District; NR = not reported; N/A = not available; LED = light-emitting diode; DTC = Delaware Transit Corporation; CUE = City–University–Energysaver; LADOT/LACMTA = Los Angeles DOT/Los Angeles County Metropolitan Transportation Authority; AVL = automatic vehicle location; Tri-Met = Tri-County Metropolitan Transportation District of Oregon; ATC Bologna = Azienda Trasporti Consorziali Bologna; YTV = Helsinki Metropolitan Area Council; LCD = liquid crystal display.

Among the international respondents, six indicated an addition in staff. Overall, personnel were added in the vehicle maintenance, operations, legal and procurement, customer service, facilities maintenance, vehicle maintenance, and other maintenance areas. ATC (Azienda Trasporti Consorziali) in Bologna, Italy, reported that it decreased staff in the area of operations control, but added staff in vehicle maintenance. London Buses reported the largest increase in staff, with an increase of 40 people, plus additional staff at the contract operating companies.

CHAPTER FIVE

CUSTOMER AND MEDIA REACTIONS TO REAL-TIME BUS ARRIVAL INFORMATION SYSTEMS

CUSTOMER REACTIONS

Three U.S. and five international agencies have measured the public's reaction to real-time arrival information. In a few cases, survey results were obtained directly from responding agencies or were available in papers examined during the literature search and review.

The landmark survey that measured people's reactions to real-time bus arrival information was summarized in a paper written in 1994 for the First World Congress on ITS (*18*). In 1993, London Transport (now called Transport for London) conducted a trial of Passenger Information at Bus Stops on Route 18, which ran between central and west London. Of the 124 bus stops on Route 18, 50 were equipped with LED DMSs showing real-time bus arrival information. These stops covered 7.5 million annual boardings along the route. The following was the timeline:

> Signs for PIBS [Passenger Information at Bus Stops], marketed as "Countdown," were installed in Autumn 1992. System testing and development continued until March 1993, at which time all "testing" signs were removed and the system was considered to be fully operational (*18*, p. 3049).

The surveys and system monitoring covered system reliability and availability, accuracy of the information, reliability of Route 18 service, ergonomics, passenger behavior at stops, passenger perceptions of Countdown, attitudes toward and valuation of Countdown, and ridership and revenue generation. The key findings can be summarized as follows:

- Availability of the system was more than 99%.
- "Accuracy of the information on the signs was within plus or minus one minute 50% of the time; within plus or minus two minutes 75% of the time and within plus or minus five minutes for 96% of the time" (*18*, p. 3051).
- Ninety percent of the riders look at the Countdown signs at least once during their waiting time at the stop.
- Passengers experienced less stress while waiting for the bus when Countdown was present.
- Of passengers interviewed, 65% felt that they waited for a shorter period of time when Countdown was present, with the perceived waiting time dropping from 11.9 to 8.6 min.
- Of passengers interviewed, 64% thought that service reliability had improved since Countdown was introduced, although service reliability had actually decreased since the signs were deployed.
- Passengers valued Countdown at an average of more than 31 cents.

Surveys about the Countdown system continue to be conducted in London. A representative sample of these surveys include these responses derived from London Buses Strategy and Policy Real-Time Information Research Summaries.

- Identify the optimum usage for the bottom line of information on the Countdown display (*19*).
- Assess the potential for providing real-time information about bus services away from the bus stop (*20*).
- Derive principles to determine the best type of information to display at bus stops for which real-time information is not available for all or some routes (*21*).
- Assess whether specific characteristics of different bus stop locations affected customers' perception of Countdown's usefulness (*22*).
- Test the effect of Countdown on perceived and actual wait times at bus stops (*23*).
- Establish customers' satisfaction with on-bus information displays and determine passenger and revenue benefits (*24*).

In 1999, one of the real-time bus information systems, deployed as part of the Federal Metropolitan Model Deployment Initiative (MMDI) in Seattle, called Transit Watch (TW) at the time, was evaluated in terms of customer satisfaction. TW included the installation of video monitors that provide real-time bus information at two key transit centers, Northgate and Bellevue, in the Seattle metropolitan area. (Currently, the video monitors at the Bellevue Transit Center are not operational while that center undergoes renovations. It is expected that three to four monitors will be located there after renovations are completed.) These transit centers were equipped with the monitors several months before a survey of regular and occasional TW users was conducted. The overall results of the survey are as follows (*25*, p. 1):

- TW is both widely used and useful. Real-time bus departure times are the TW feature found most useful by the users;

- Real-time information at locations where key travel decisions are made (e.g., office buildings) would be used and considered useful by a majority of transit passengers. TW users particularly endorsed this suggestion;
- The content, location, accuracy, and presentation of the current TW monitors are satisfactory for most transit riders who use them, although many also offered suggestions for improvements; and
- Although TW and the improved information is perceived as a real benefit by its users, the users did not seem to think that it increased their overall satisfaction with the transit experience. Our analysis indicates that TW in and of itself is unlikely to significantly change aggregate transit trends and perceptions.

In May and June 2002, Portland Tri-Met conducted an intercept survey of passengers to determine customers' perceptions of the Transit Tracker system, which provides real-time arrival information. At the time of this survey, DMSs had been installed at 10 bus shelter locations and 11 MAX (Portland's light-rail system) stations. The purpose of this survey was to assist management in deciding if changes should be made to Transit Tracker to make it more understandable, and if more Transit Tracker DMSs should be installed throughout the service area (*26*, p. 1). A total of 214 passengers were surveyed at four bus shelter locations that had Transit Tracker LED DMSs. Key survey results include the following (*26*, pp. i and ii):

- Of the 214 survey respondents, 65% recognized that the information on the display was real-time.
- Use at one particular bus shelter was the highest, with 100% of the respondents stating that they use Transit Tracker (82% always and 18% sometimes).
- Use at the shelter where Transit Tracker has been installed the longest had the lowest incidence (54%) of those who always use Transit Tracker.
- Twenty-one percent of the respondents suggested adding the label "ETA (Estimated Time of Arrival)" to the countdown column of the display.
- What respondents liked most about the display was that they "know how many minutes until the bus comes" (42%) and think "it is accurate/exact time/real-time" (19%).
- Sixty percent of the respondents could not think of any improvements to make to the Transit Tracker display, and 12% said that they thought more displays should be added.
- The value placed on having Transit Tracker at the bus stop was very high—4.5 on a 5-point scale, with 5 having the highest value and 1 the lowest.

MEDIA REACTIONS

Of the 18 responding agencies, 14 reported that there has been media reaction to the real-time bus arrival information system. In addition to their survey responses, a few agencies provided such media responses in the form of newspaper and magazine articles, video clips, and transcripts of radio and television stories. The video clips provided by Tri-Met were from all of the major television stations and a few of the radio stations in the Portland, Oregon, market. They primarily covered the Tri-Met general manager's introduction of the Transit Tracker real-time bus arrival signs at a specific bus stop in Portland. In a few television reports, bus riders and bus drivers were interviewed on camera for their reactions to the Transit Tracker system.

In addition to television and radio coverage, there were several newspaper articles in the *The Portland Observer*, *The Oregonian*, and *The Portland Tribune*. Additional articles about the system appeared in APTA's *Passenger Transport* and *The Business Journal of Portland*. Overall, media reaction to the Transit Tracker system in Portland has been very positive.

In Denver, news releases about the Talk-n-Ride system were issued by the Regional Transportation District (RTD) and the vendors that provide the voice and mobile applications within the Talk-n-Ride systems (*27, 28*). Many newspapers carried the introduction of Talk-n-Ride, including *The Denver Daily News*, *Boulder Daily Camera*, *Highlands Ranch Herald*, *Brighton Standard–Blade*, *Littleton Independent*, *Englewood Herald*, and *Broomfield Enterprise*. The local Fox television station in Denver, KDVR (Channel 31), ran an interview with a commuter and an RTD control center employee regarding the system. Finally, an article on Talk-n-Ride ran in the January/February 2002 issue of the trade magazine, *ITS International* (*29*).

For the most part, media reactions to these systems have been positive. Furthermore, rider and media reactions have influenced the demand for and the use of real-time bus arrival information systems in the following ways:

- The positive reactions have convinced other transit agencies to install similar systems.
- The use of real-time bus predictions via website, PDAs, and the telephone have significantly increased.
- Positive rider reaction did influence one agency's decision to purchase an AVL system.
- Favorable reactions thus far have encouraged Tri-Met to continue deployment, even though the agency is experiencing financial difficulties. Internet users have made numerous requests for particular bus stops to be included in the Internet application.
- The customer perception is that bus services have improved and that people traveling late at night now have the confidence that a bus is not far away.

CHAPTER SIX

INSTITUTIONAL AND ORGANIZATIONAL ISSUES

REASONS FOR DEPLOYING THE SYSTEM

Although the survey did not exhaustively investigate the reasons for deployment, it did capture the basic reasons why real-time bus arrival information systems are deployed. The major reason is to improve the agencies' level of customer service. Figure 15 shows the relevant survey responses on reasons for deployment.

Current estimates for ridership increases because of the deployment of advanced traveler information systems, of which real-time bus arrival information systems are a subset, range from 1% to 3% (*30*, p. 52). Therefore, it is somewhat surprising that increasing ridership was not the most significant reason for deployment. However, many of the agencies contacted for the synthesis project indicated that it would be very difficult to ascertain if ridership increases did result solely from the real-time bus arrival information. Rather, it is usually a combination of factors that lead to an increase in ridership after such a system has been deployed.

The departments that typically are interested in deploying the real-time bus arrival information system include operations, upper management, marketing, and customer service. Figure 16 shows all of the departments mentioned by survey respondents. As mentioned in the following section, these departments are not always the ones responsible for the deployment.

RESPONSIBILITIES FOR DEPLOYING THE SYSTEM

As expected, the departments that are responsible for deploying these systems are most often operations, planning, and information systems (see Figure 17). Generally, although customer service often has an interest in deployment, it is not necessarily responsible for the deployment. Also, even though the information systems department does not initiate such a project, it is often responsible for the deployment, because of its technical expertise.

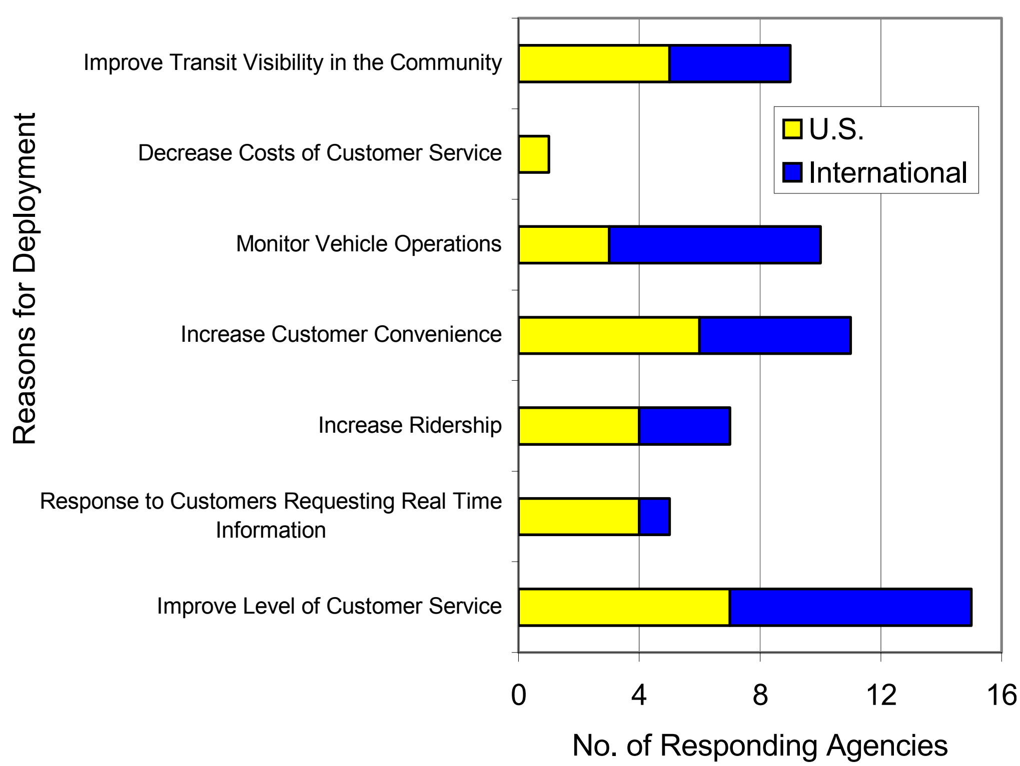

FIGURE 15 Reasons for deploying real-time bus arrival information system.

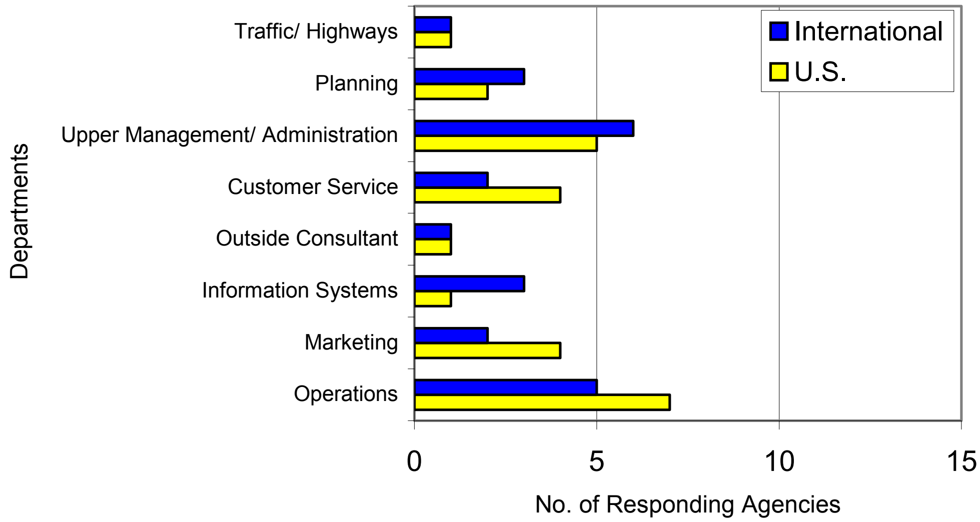

FIGURE 16 Agency departments interested in deployment.

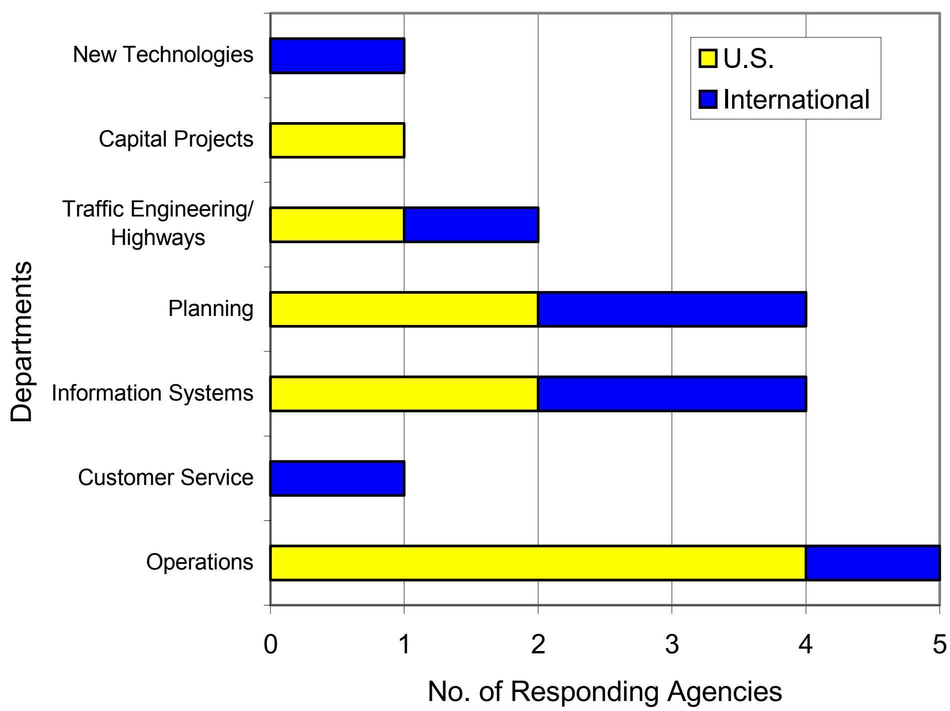

FIGURE 17 Agency departments responsible for deployment.

STAFF REACTIONS TO DEPLOYING THE SYSTEM

Three U.S. agencies, the Delaware Transit Corporation (DTC), RTD, and Tri-Met, have measured the reactions of the agency staff to the real-time bus arrival information system. Of these three, staff reactions were positive in two and mixed in one. Seven international agencies (all respondents except Kent County Council and Transport for London) reported that they have measured staff reactions, with six reporting positive staff reactions. Overall, only two agencies reported that staff had the opinion that the system was "Big Brother," and that more control could be exercised over the bus operators as a result of the system.

BENEFITS REALIZED FROM DEPLOYING THE SYSTEM

Many benefits resulting from the deployment of real-time bus arrival information systems have been reported in numerous articles and customer surveys, as well as by the

TABLE 8
BENEFITS REALIZED FROM DEPLOYING REAL-TIME BUS ARRIVAL INFORMATION

	Benefits								
								Other	
Agency	Improved Customer Service	Increased Customer Satisfaction	Increased Ridership	Increased Customer Convenience	Ability to Monitor Vehicle Operations	Decreased Costs of Customer Service	Improved Visibility of Transit in Community	Improved Ability to React to Service Delays	More Reliable Journey Times
City Bus									
DTC	■	■	■	■			■		
Fairfax CUE	■	■		■	■	■	■		
Glendale Beeline	■	■		■	■		■		
King County Metro	■	■					■		
LADOT/LACMTA	■						■		
RTD	■	■	■	■	■		■		
SF Muni	■	■		■	■			■	
Tri-Met[1]									
ATC Bologna	■	■			■				
Centro	■	■	■	■	■		■		
Dublin Bus	■				■		■		
Kaohsiung	■	■		■	■				
Taichung	■	■		■	■				
Taipei	■	■	■	■	■	■	■		
Kent County Council									■
London Buses	■	■			■		■		
YTV	■			■			■		

Notes: Tri-Met and City Bus did not report benefits. DTC = Delaware Transit Corporation; CUE = City–University–Energysaver; LADOT/LACMTA = Los Angeles DOT/Los Angeles County Metropolitan Transportation Authority; RTD = Regional Transportation District; ATC Bologna = Azienda Trasporti Consorziali Bologna; YTV = Helsinki Metropolitan Area Council.

survey respondents. The literature suggests that the following benefits can be expected from deploying a real-time bus arrival information system (*31*):

- Customers perceive that the waiting time at a bus stop with real-time bus arrival information is reduced and, therefore, waiting is more acceptable.
- Customers are encouraged to use the bus service more often.
- Ridership and revenue can be expected to increase.
- A modal shift toward public transportation could result.

As shown in Table 8, the survey respondents reported that the biggest overall benefit is improved customer service, with increased customer satisfaction as the second greatest benefit. As shown in the two right-hand columns, survey respondents cited additional benefits, including that their ability to react to service delays is greatly improved and that journey times are more reliable.

LESSONS LEARNED

There were six major questions on the survey that covered the critical lessons learned that could help other agencies considering the deployment of real-time bus arrival information systems. Four of these questions asked about the most significant challenges associated with key project phases: procurement, testing and implementation, operations, and maintenance. The fifth question asked respondents to provide additional lessons learned. The final question asked, "If your agency had it to do all over again, would you deploy a real-time bus arrival information system?" A summary of the responses to all of these questions is presented here.

- **Procurement** covered financial, procurement process, institutional, and technical issues.
  - *Financial issues* mentioned by the survey respondents included the lack of availability of funds for the system; the difficulty associated with determining the cost of the system, including O&M costs; and that some agencies are experiencing budget shortages that affect their ability to procure such a system. The primary difficulty associated with determining the cost is that there is a limited amount of documented O&M costs associated with these systems, as was mentioned in chapter four.
  - *Procurement process issues* included the following:
    - ➢ Selecting a negotiated procurement as opposed to an open and competitive procurement. Here it may be more convenient and effective to have the existing AVL technology vendor provide the real-time bus arrival information system. On the other hand, the agency may obtain a better product and service by procuring the system competitively.
    - ➢ There is the difficulty in getting companies to bid and propose on the system because of an inadequate number of suitable or established suppliers and vendors. Although several of the AVL vendors in the United States and abroad provide real-time systems, they typically do not specialize in these systems; they are often an outgrowth of their AVL products, because AVL technology is usually a higher priority system for deployment. Therefore, there are very few vendors that specialize in providing real-time information. Also, if an agency purchases from one of the specialized vendors, it may have to pay for components similar to what it already has in operation (e.g., AVL/computer-aided dispatch components), because the real-time vendor cannot use the system components that are already in place.
    - ➢ There is a lack of mature systems available on the market. As with most technology, this situation is improving over time. However, as mentioned earlier in this report, as of December 2002, many of the deployed systems had not been operational for very many years.
    - ➢ The regulations associated with government procurement can hinder procurement. This comment referred to procurements outside of the United States, although there are regulations (e.g., third-party contracting rules) that govern procurements funded by the federal government that could encumber procurement.
  - *Institutional issues* were diverse. They included getting the approval of a decision-making body to procure the system and the lack of knowledge available among transit agencies as they procure products and services. Obtaining approval can indeed be a challenge, depending on other priorities competing with the procurement of this system. There is the political climate associated with procuring such a system, and the response to the information presented to the decision makers (e.g., cost figures that may appear high). The lack of knowledge within the procuring agency can cause the agency to be unaware of the full potential of the system; to not be able to anticipate potential problems; and to be at odds with the vendor, rather than working with the vendor as a partner. This lack of knowledge has resulted in many changes to contracts (e.g., change orders) and disputes with suppliers and vendors.
  - *Technical issues* included finding an appropriate system that could be tailored to the agency's operational needs and future requirements. Here, there is a trade-off between procuring COTS systems and systems that must be tailored. Most real-time systems must be tailored to the agency at least in terms of basic operating data, such as bus stop locations, route characteristics, and operational rules.
- **Testing and implementation issues** covered technical, as well as institutional and organizational issues.
  - *Technical issues* include the following:
    - ➢ Getting power to the bus shelter for the electronic signs. This activity must involve numerous staff within and outside the transit agency, so it often involves extensive coordination that must be accomplished in a relatively short period of time.
    - ➢ Getting adequate communications coverage in the service area for communicating AVL data and related data to real-time bus arrival signs. This issue can significantly affect the reliability and accuracy of the real-time information.
    - ➢ Reliability and stability of the underlying AVL data, prediction algorithm, system hardware, and control center software.

   - Installation of on-board equipment. This issue involves determining where on-board equipment should be placed, scheduling vehicles for equipment installation, and testing the on-board equipment before a vehicle returns to revenue service.
   - Predicting how the system would function if more buses and signs were added. There are several effects that should be assessed before adding more buses and signs to a real-time system. One major effect will be on the communications system, because more vehicles will need to communicate related data to dispatch (e.g., vehicle location), and more signs will need to receive the real-time arrival information. Also affected will be maintenance. In addition, the performance of the real-time prediction algorithm could be affected.
- *Institutional and organizational issues* were as follows:
   - Changes in project scope owing to a variety of circumstances (e.g., political pressure) can increase costs, extend the project schedule, result in a level of technical complexity that was not originally envisioned, and result in unmet expectations.
   - Moving buses through the installation phase, which was mentioned earlier in the technical issues. This may result in shortages of buses for revenue service, if the appropriate installation planning is not conducted.
   - System customization may involve a substantial amount of unexpected development time. Because most of these real-time information systems have a degree of customization, the specific amount of time devoted to development should be stated by the vendor during the planning phase and monitored closely by the agency.
   - If an agency decides to conduct a pilot test of the real-time system, it should ensure that a large enough sample of equipped buses are provided on a route that is being used to test the system. If not enough equipped vehicles are provided, the reliability and statistical accuracy of the real-time information will be limited. If at all possible, all vehicles on a demonstration route should be equipped.
   - Barriers between departments can cause internal conflicts in fully implementing the system. Often one department recommends the deployment of a real-time system, but another department is actually responsible for the deployment (as discussed earlier in this chapter), and yet another department can become responsible for maintaining the system.

- **Operations issues** covered training, funding, and technical issues.
   - There are four primary *training issues* mentioned by survey respondents.
      - Training bus drivers so that they both master the operation of the system (e.g., are able to log on to the system) and understand how it works;
      - Ensuring that all bus drivers are trained, which requires sound scheduling of training;
      - Ensuring that drivers who do not use the system properly are disciplined and retrained; and
      - Training key agency staff to use the information generated by the system.
   - *Financial issues* included the following:
      - Funding may not be available to continue to operate the system, if either the cost of operating and maintaining the system was underestimated or the cost was not determined during project planning.
      - Operational budget shortages may occur once the system is deployed, meaning that the resources required to operate the real-time system may be competing with other precious and limited agency resources.
      - Communications costs using certain technologies, such as CDPD, can be high. All operating costs should be estimated during the system's planning phase, to anticipate and allocate the resources necessary to operate and maintain the system. However, given the state of the communications industry, the cost of specific technologies can change once the system has been deployed. Therefore, allowing for contingency funds when determining operating costs may be appropriate.
   - *Technical issues* covered a variety of subjects, including
      - Operations-based tools, which are necessary as part of the system (e.g., monitoring schedule adherence);
      - Data "cleanliness" and accuracy, which are often a challenge while maintaining the software;
      - Ensuring that the system is flexible enough to cater to a harsh transit operating environment in which changes can occur unexpectedly;
      - Keeping timetable information maintained and up to date, without requiring excessive manual effort;
      - Automatic detection of system failure, which is necessary for smooth operation; and
      - Providing a mechanism for monitoring driver log-on and making sure it is correct.
- **Maintenance issues** included the following:
   - Vendor lead time to respond to failures and maintenance requests can be slow (e.g., getting the

vendor to send a technician in a timely way to solve a problem). One way of addressing this problem is to require a specific lead time, in the system specifications, for different types of maintenance problems. For example, the agency may specify a 4-h response time for critical system component failures, and a 24-h response time for other problems.
- Planning for maintenance funding is a necessity during the system-planning phase.
- Establishing the appropriate policies and procedures to successfully handle hardware and communications failure is a necessity.
- A long time may be needed for repairing broken components if they have to be sent to the vendor for fixing. The time requirement for fixing components should be included in the system specifications. For example, the specification could state that the vendor must fix a malfunctioning DMS within 2 days.
- Mitigating the possibility of vandalism and handling any instances of vandalism to real-time information equipment at bus stops should be part of the project planning process.
- Updating temporary system changes, such as route changes and exceptional day schedules, should be a capability of the real-time system.

Respondents provided additional lessons learned in a variety of areas. A summary of their responses is provided here.

- A comprehensive needs assessment should be conducted before proceeding with the deployment of a real-time bus arrival information system. In this assessment, the needs of the customer should be analyzed along with the needs of the agency. Also, the needs assessment should examine the impacts on the organizational structure of the agency. Such an assessment can be used to gain the support of higher-level managers, who will be responsible for selling the system to an agency board of directors or other decision-making body [see "Needs Assessment for Transit ITS: A Structured Approach" (*32*)].
- Given that an underlying AVL system is the foundation for a sound real-time information system, the agency should ensure that the AVL data are accurate and reliable. "This is especially critical for real-time systems. Information on delays and arrival times must be correctly calculated and made available within seconds to the central information database. If the criterion of reliability is not respected by those setting up the systems, this will surely be the main reason for the rejection of the systems by customers" (*33*). Furthermore, for fully testing all of the functions of the real-time system, a pilot project (e.g., real-time information for stops on one bus route) should be considered prior to full implementation.
- When conducting research into real-time bus arrival information systems, agencies should contact a vendor's customers, not the vendor directly, to obtain information on the system, how it performs, etc. Furthermore, agencies should contact those customer agencies known to have experience with vendors' products, rather than use a vendor-provided list, to obtain an honest and unbiased assessment of the system.
- There is a difference in opinion among agencies in providing schedule information or no information if the real-time prediction is not accurate. On the one hand, providing schedule information (and informing the customer that it is schedule not real-time information) at least provides the customer with some information. On the other hand, schedule information can be misleading if the system is not operating on schedule.
- Several respondents mentioned communications coverage and cost as key issues when planning and operating a real-time system. Communications coverage needs to be tested before a real-time system is deployed, to ensure that it is adequate to handle the necessary data transfer between the real-time system and electronic signs at bus stops. The cost of communicating data to dynamic message signs (e.g., using CDPD) can be significant, if the cost is based on a "packet-by-packet" basis, because updates to the signs may be provided at a high frequency. This ongoing operational cost must be considered when investigating appropriate communications strategies, and when developing an O&M budget for a real-time system.
- Training those responsible for operating and maintaining the system is also a key element to successful deployment. Training issues, such as those described earlier in this subsection, were mentioned repeatedly throughout the survey responses. One additional issue is ensuring that contract operators are also fully trained on the system, just as agency personnel are trained. This is critical when bus services are operated by contractors and when nonagency personnel are responsible for various aspects of the system (e.g., bus drivers and system maintenance personnel). One way of ensuring that contract operators, particularly bus drivers, use the system properly is to stipulate system use in the contracts with the operators, and to offer incentives and/or levy penalties if the operators do not use or properly use the system.
- Various technical issues that should be addressed during the planning and specifications development phases were mentioned. They included the following:
  - Estimating the number of DMSs that will be deployed in the long-term, to plan for getting power to sign locations;

- Developing sound and reasonable specifications that provide the basis for ensuring that the vendor is performing adequately;
- Having plans to provide alternate power to signs (e.g., solar power, if regular wired power is not possible);
- Ensuring that all user interfaces to the system are easy to use and intuitive;
- Minimizing the need for human intervention in systems operation;
- Ensuring that data used as input to the real-time system can be easily updated, with minimal manual effort required;
- Being realistic about the time required to deploy the system;
- Being prepared from a technical and administrative perspective to accommodate changes to the schedule as the system is being implemented; and
- Ensuring that maintenance, and maintenance resources and costs be considered, and not underestimated, during the planning process.

- One specific lesson learned from the institutional and organizational perspective was that an agency should plan for the organizational change that will be required and that will inevitably occur as a result of deploying a real-time bus arrival information system. This lesson has been expressed not only by those agencies involved in deploying these systems, but also by agencies that have deployed any type of technology system.
- Using the system to monitor service performance is crucial to getting the most out of the system. Many agencies view such a system as only providing real-time information to customers and potential customers; however, it can be used to monitor and ensure service quality and development.
- The relationship between the agency and the vendor is critical to successful deployment. Adversarial relationships often hinder project schedules and can lead to finger pointing about the assignment of responsibilities for problems. An open relationship between the vendor and agency, in which the vendor and agency support their respective responsibilities, leads to a more successful deployment.
- A survey respondent from a metropolitan region that has multiple transit systems in operation suggested that close coordination is needed so that all real-time systems are compatible, particularly if the same underlying system will eventually be used for transit signal priority.
- Finally, U.S. Transit agencies could learn from their European counterparts. U.K. agencies and operators created a forum, the Real Time Information Group, which developed "A National Strategy for Real Time Information" (*34*) that addresses the requirements of the system.

When asked, "if your agency had to do it all over again, would you deploy a real-time bus arrival information system?" all respondents answered "yes." Then, the final question on lessons learned was: If "yes," what would you do differently this time? The following summaries of survey responses represent several major themes.

- Several survey respondents emphasized the importance of training for all levels of transit agency staff, including drivers, and administrative, management, and O&M staff.
- Several respondents mentioned using a pilot to comprehensively test the system prior to full deployment. Given that these systems have wide customer exposure and can result in an individual's decision on whether or not to ride transit, significant testing should occur before the customer is exposed to the information. Using a pilot project will not only facilitate the testing process, but it can also provide a way to receive customer input as the system is being finalized, before it is fully deployed. This kind of market research is invaluable, because it provides information on customer needs, maximizes ridership exposure to the system, results in goodwill between the agency and customers, and provides the opportunity for early buy-in of the system by customers.
- Data management was raised as a key issue in real-time bus arrival system deployment. First, data from other systems are necessary as input to the real-time system. For example, schedules are often used as input to these systems. Because schedules change periodically throughout the year, schedule updates must be communicated to the real-time system in a timely way. This should be an automatic process rather than a manual one. Second, the number of vehicles, bus stops, bus routes, and signs should not be limited in the system, or the limitations should be known during project planning. Third, reports, including statistics and archived information, should be easily generated by the system.
- From a planning perspective, the issue of conducting an adequate needs analysis was raised. As mentioned earlier, this is a critical step in determining the need for the system, as well as beginning the assessment of the scope and cost of such a system. Another planning issue was ensuring that there was a contractual mechanism that requires contractor operators to use the system. In several instances (e.g., London Buses), operators are not under a contractual obligation to use the system, so there is no way to enforce their use of the system. Also, if operators do not use the system (e.g., logging on to the system), it could significantly affect the real-time information being generated.
- Marketing was discussed as an important aspect of the acceptance and use of the system. Often agencies

assume that the presence of real-time arrival signs will market the system adequately. However, to win customer acceptance and customer "delight," it is necessary to develop a marketing campaign to name the system, introduce it, and explain how it works. One example of a targeted marketing campaign is that of ATC in Bologna, Italy. Its program, called "hellobus," provides real-time bus arrival information via a Global System for Mobile communication (GSM) mobile telephone. GSM is a digital mobile telephone system that is widely used in Europe and other parts of the world. A significant amount of marketing was done by the GSM mobile telephone provider and ATC to introduce the service and inform the public (see http://www.comunicazionevodafoneomnitel.it/iniziative/cittadini/hellobus/hellobus.asp).

- Several respondents mentioned specific technical aspects of real-time information systems that should be considered, including "Use CDPD units with higher gain, low profile antennae"; ensure that display units can scroll the appropriate number of lines of information; and use a specially trained and experienced staff team to perform on-board equipment installation, rather than using regular, untrained staff.

CHAPTER SEVEN

CASE STUDIES

Several of the U.S. transit agencies that responded to the synthesis survey were interviewed by telephone to obtain more detailed information on their real-time bus arrival information systems. In addition, a visit was paid to London Bus Services Limited, a division of Transport for London, to obtain detailed information about one of the most visible and successful real-time bus arrival systems in the world. Also, information was obtained about two other systems. The results of the interviews, the site visit to London Buses, and additional information on agency systems are presented here.

REGIONAL TRANSPORTATION DISTRICT, DENVER

RTD was one of the first public transportation agencies to deploy a GPS-based AVL system. The decision to purchase the AVL system was made in 1992, with final system acceptance in 1996. In 1999, RTD began looking at using the AVL data to provide real-time information to customers. In December 2001, RTD introduced Talk-n-Ride, a telephone service that provides real-time bus (and light-rail) arrival information. RTD already provided and continues to provide real-time bus arrival information (called Bus Locator) through its website at http://www.RTD-Denver.com (see Figure 18) before the introduction of Talk-n-Ride.

Customers using Talk-n-Ride can provide the key information, route number, direction and stop name to the system by voice to obtain the ETA for the next three buses at a particular stop. The ETA calculations are done based on data from RTD's AVL system. RTD does not report an ETA for anything less than 5 min, and it only reports a delay only when a bus is 5 min or more late.

RTD provides PDA and web-enabled mobile telephone access to real-time information using the same customer inputs as Talk-n-Ride. The same server and software are used to provide ETAs by means of a PDA and mobile telephone as used for Talk-n-Ride and Internet applications. An interpreter program determines the type of device that is requesting ETA information and the operating system being used by that device. Once the system determines the device type and related operating system, the ETA prediction

FIGURE 18 RTD schedule page with bus locator option.

is calculated and provided to the requesting device in the correct code (determined by the operating system of the device). For example, data are returned in WML 2.0 if the mobile telephone requesting the ETA information is running WML 2.0. A total of 440 devices and multiple versions of XML, WML, and HTML are supported.

RTD built the software applications to provide ETA information in-house, but it partnered with several vendors to provide the mobile and voice applications. Two full-time staff members were added to the information technology department to handle the provision of real-time information. One person writes applications to maintain the Oracle database used by the applications. Another full-time person is needed to manage the work being done by consultants, to maintain the system, and to address other system-related issues.

One issue that is currently being addressed by RTD staff is when a bus interlines. Currently, ETA information is not accurate for this situation. For example, if a bus interlines from an airport route and a northeast suburb, the last timepoint may be at the airport. Then, the bus has a layover and it interlines to a new route. Currently, ETA information for the first stop on the new route is not correct. "Dummy" timepoints are required for the first stop to have accurate ETA information. Pullouts cause a problem similar to interlining. RTD is currently addressing both of these issues.

RTD also has 60 kiosks located in and around the Denver metropolitan area (see Figure 19). Because these kiosks provide RTD's Internet site, real-time information can be obtained from them.

RTD will be testing a vendor-supplied, real-time bus arrival information system. This system, which will consist of 20 electronic signs on three bus routes, is expected to be operational by the end of 2002. The vendor's system will use RTD's location data, generated by the existing AVL system, with the vendor's own algorithm to predict arrival times.

FIGURE 19 RTD kiosk.

KING COUNTY METRO, SEATTLE

King County Metro (KC Metro), the only U.S. survey respondent with a signpost-based AVL system, has been providing real-time information to its customers through the systems BusView and MyBus. These applications were developed by the University of Washington as part of the Seattle MMDI, called Smart Trek. [Information collected by Multisystems, Inc., for this subsection became the basis for part of Chapter 3.1 in Casey et al. (*35*), which deals with the state of the art of such systems.]

BusView provides bus riders with real-time bus location information via the Internet (see Figure 20). In mid-1998, the service became available to the public via the Smart Trek web page. The software application that supports BusView geographically represents the location of 1,300 KC Metro buses traveling on 250 routes throughout its large service area. Development of the BusView application cost approximately $230,000. The raw bus location information is supplied by KC Metro's AVL system, which was upgraded for the real-time information with approximately $1.2 million of MMDI funding. On-board hardware and system software were upgraded to accommodate real-time information.

The University of Washington's ITS Research Program, part of the Washington State Transportation Center, developed the software algorithms needed to achieve the necessary time and location accuracy for BusView displays. The center's staff also created the web interface for BusView, which is based on an advanced Java software application. The importance of the Java application is that the information service can run seamlessly on most computer workstations using one of the industry's standard web browsers. This means that users of PCs, Macintosh, UNIX, or other standard computer platforms can all use the service.

BusView allows transit riders to see exactly where any bus on any route is currently located on a scaled map.

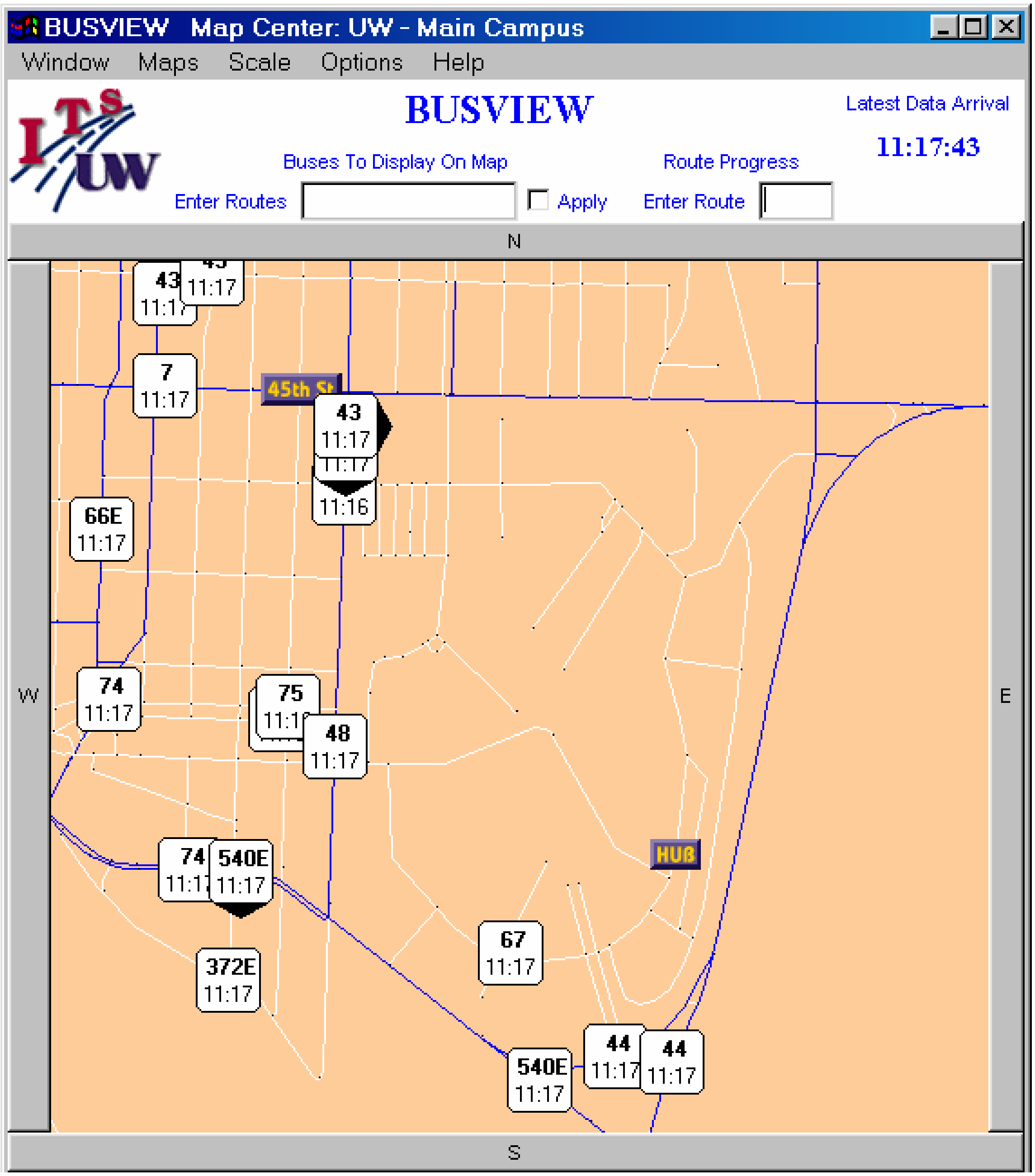

FIGURE 20 BusView main window.

Transit riders can quickly select geographical subareas of interest using a typical drop-down menu to focus on, for example, a region surrounding their homes or workplaces. If the default area is not appropriate for a user's needs, they can easily scroll the map in any direction to display the exact area they want to view.

BusView offers a substantial array of features and customization options. Key features are described here.

On the initial BusView screen, the bus icons show the route number of a bus, direction of travel, and approximate location at its last location report time. Maps are not labeled with streets names, to prevent visual clutter. However, to orient themselves according to a map, users can simply hold the cursor over any designated intersection to display a label of the cross streets. A user can enter specific route numbers into a special "Visual Route Filtering" input box to filter out all other routes in which they are not interested. A "Route Selection" input box enables the user to launch another pop-up box that presents detailed text information about a single route. A user may view two different areas simultaneously by launching a new BusView window and navigating to the second area.

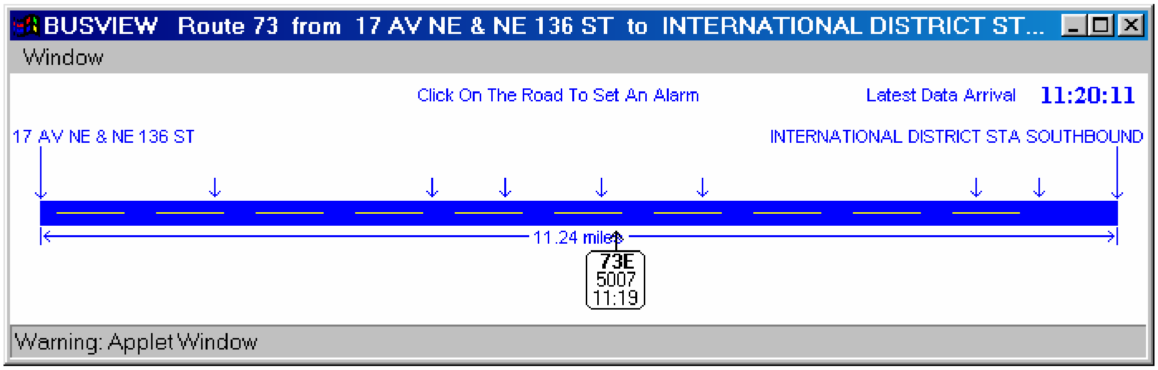

FIGURE 21 BusView progress window.

Clicking on an icon in the main screen allows the user to push it behind or bring it on top of overlapping icons, a feature that is important where the number of routes and combined headways can result in numerous bus icons being placed on top of one another. Clicking on an icon also allows the user to jump to the published timetable or launch a new bus progress screen.

The bus progress window shows a linear representation of an entire bus route (Figure 21). It shows buses for a single direction of travel, based on which direction the bus was moving when the user selected it in the main window. Arrow icons along the route indicate the locations of timepoints in the published bus schedule. By holding the cursor over an arrow icon, the user can view either the timepoint's intersection or the name of a major landmark if the timepoint is a location such as a shopping mall.

By clicking anywhere on the route in the bus progress window, a user can add an alarm clock icon that will produce a visual and audio notification that indicates when the next bus passes that particular point. Using this feature, a rider can, for example, be notified when the next bus is several blocks away from home or work, allowing the user to time his or her arrival at the bus stop.

The BusView applet was designed to allow individual users to customize it for their own travel preferences. The first time the service is used, a selection of preloaded maps appears in the menu list of the main screen. If a user's Web browser supports and accepts cookies, then each time a new map is selected, it is added to a list of maps stored in the cookie file. During subsequent use of this service, the map drop-down menu described earlier is updated to include maps chosen previously by an individual user.

In the upper right corner, each BusView window displays the time when data were last received by the system. New data are put into the BusView system approximately every second. Although each data update does not include new location information for every bus, new data are available for each bus approximately every minute. A user can determine roughly how current the time information is on his or her bus by comparing the bus icon time with the window time. The greater the disparity between the two, the less reliable the current bus icon position.

The MyBus system is a pretrip service available via the Internet (see Figure 13), PDA, and mobile telephone. The cost for developing MyBus was included in the $500,000 budget for another Smart Trek project called TransitWatch, as mentioned previously in chapter five. MyBus now provides information previously provided by Transit Watch via the Internet. MyBus provides real-time information for each bus stop and route in the KC Metro system.

TRI-COUNTY METROPOLITAN TRANSPORTATION DISTRICT OF OREGON, PORTLAND

Tri-Met has a three-pronged approach to providing real-time bus arrival information. First, it is beginning to provide real-time bus arrival information on LED signs at bus stops. As of September 2002, 11 signs have been deployed at 10 bus stops (and 28 signs at 11 light-rail stops). The plan is for 50 LED signs to be deployed at an additional 50 sites by the end of fiscal year 2003 (June 30, 2003), dependent upon the availability of power at those sites. Ultimately, Tri-Met would like to outfit a total of 250 sites with LED signs displaying real-time bus arrival information. The arrival sign system was developed by the AVL vendor.

The second part of the approach is to provide real-time information via the Internet to those customers who have Internet access at work or at home. Since September 2002, Tri-Met has provided real-time bus arrival information for every route and most bus stops in the system on the Internet (see Figure 11). Given that Portland has one of the highest Internet penetration rates in the United States, this approach has been highly successful in the short time it has been operational. This Internet service was developed in-house.

The third part of the approach is to provide real-time information on portable (wireless) devices, such PDAs and mobile telephones. This application, being developed in-house, was expected to be available to customers by the beginning of 2003.

The number of signs deployed at bus stops, as part of the first step in the approach, will depend on the success of the Internet and wireless applications. For example, signs will not be deployed in areas of low ridership, which might be better served by the Internet and wireless applications.

Tri-Met does not use a prediction algorithm per se to calculate the real-time arrival information that is displayed on the LED signs. Information that is sent to each bus driver via an MDT about their arrival time at the next stop is sent to the signs. Each sign has the schedule loaded in it, and the sign processor applies the information about arrival time to the schedule, to determine the offset from the schedule. This is a distributed, decentralized system, because information that will be used to determine arrival times is sent to the sign for processing.

In contrast to the way that processing is done at each sign, the Internet and wireless applications determine real-time bus arrival times centrally. The prediction algorithm is centralized. The same logic as used at each sign is used for the centralized prediction process.

Tri-Met believes that providing real-time bus arrival information is a way of improving the customer's perception of the bus service. Although Tri-Met has only recently begun to measure customer satisfaction with the real-time information, it appears that customers perceive that their waiting times are shorter and that the service is more frequent. At one of the key LED sign locations, an intercept survey of 200 people was recently conducted, as described in chapter five. In that survey, customer response was very positive, with the value placed on having Transit Tracker at the bus stop very high—4.5 on a 5-point scale, with 5 having the highest value and 1 having the lowest value.

SAN LUIS OBISPO TRANSIT

San Luis Obispo (SLO) Transit in San Luis Obispo, California, has deployed a unique real-time bus arrival information system, which was developed by California Polytechnic State University at San Luis Obispo (Cal Poly). This system, part of the Efficient Development of Advanced Public Transportation Systems (EDAPTS), was developed and designed by Cal Poly using COTS hardware, plus software developed by the researchers. A functioning model of the system was developed in 1994 and 1995, and the system's concept was fully developed in 1997. Cal Poly began the conceptual stage of EDAPTS by performing a detailed needs assessment of transit ITS in this area of California, and it prepared a Concept of Operations (*36*). Full deployment of the system occurred in 2001.

This system is unique because it was developed with the small transit agency in mind. Using COTS hardware and an existing radio system, this system costs less than traditional systems currently available. The primary goal of EDAPTS is to build a system, including real-time bus arrival information, using COTS technology. Other system objectives include providing passenger information; developing an open source, public domain system that is accessible to small- and medium-size transit agencies; deploying the system incrementally; and providing an affordable, but comprehensive system.

The primary components of EDAPTS are a GPS-based AVL system, on-board MDTs, Smart Transit Signs, and use of the existing analog voice radio system. The real-time bus arrival information displayed on the solar-powered Smart Transit Signs, as shown in Figure 22, is determined as follows. When a bus leaves a stop, the bus in effect knows how it is doing against the schedule. This information on schedule adherence is used together with information about where the bus is on the route, the trip and pattern that the bus is on, and the number of the stop that the bus just stopped at. This information is then sent to the Smart Transit Sign, which maintains a timetable and vehicle assignments for the whole SLO transit system. Then, the software resident in the sign uses the real-time data, timetable, and vehicle assignments to calculate when the bus will arrive at the next stop and subsequent stops.

FIGURE 22 Smart Transit Sign, San Luis Obispo (Calif.) Transit.

Another unique feature of EDAPTS is the use of the existing radio system to provide the communications backbone for the system. "Rather than move the information over specialized data links, the EDAPTS team chose to 'piggyback' the digital data on the standard analog voice radio system" (*37*).

Expansion of EDAPTS is continuing, with a graphical interface, interactive kiosks, an Internet application, and automated announcements being planned.

TRANSPORT FOR LONDON—LONDON BUS SERVICES LIMITED

London was one of the first cities in the world to deploy LED signs at bus stops that indicate the arrival times of the next buses at each equipped stop. This system, called Countdown, was piloted in 1992 by London Buses on bus Route 18. The results of surveys conducted during the pilot indicated that Countdown was highly popular with customers. In 1993 and 1994, Countdown was tested along several bus corridors. In 1996, a London-wide rollout of the AVL and Countdown programs was approved. In 2001, the AVL program was 80% complete, and the Countdown program was 25% complete. As of March 2002, 1,473 Countdown signs had been installed and were operational. The current plan is to have a total of 2,400 signs installed by March 2003 and 4,000 signs by 2005. The 4,000 signs would cover 25% of all stops and will benefit 60% of all passenger journeys. Expenditures for the AVL and Countdown programs total $69.75 million (£45 million).

The London Countdown system is based on the agency's beacon (also known as signpost) AVL system. An on-board AVL unit receives the identity of a roadside beacon as the bus passes the beacon. Because each beacon has a unique identifier, the bus can then determine its location, and the location information is forwarded directly from the vehicle to a central system by means of the on-board radio. Currently, there are 5,000 beacons deployed in the London Buses service area. Figure 23 shows how the AVL and Countdown systems function.

The central system sends information to bus stop signs. There is a modem in the sign that receives the arrival information from the central system, and there is a processor in the sign that determines on the sign the order of bus arrivals. The predicted time to arrival is displayed on the sign, along with the bus route number and final destination (see Figure 3). This time is "counted down" until the bus arrives at the stop.

London Buses continues to conduct an extensive amount of market research to determine customer satisfaction with Countdown and the interest in future enhancements, such as providing real-time information away from the bus stop and siting Countdown signs. Recent market research yielded several key findings.

- Results of 1,125 interviews with passengers waiting at 16 bus stops in North West London included the following (*22*):

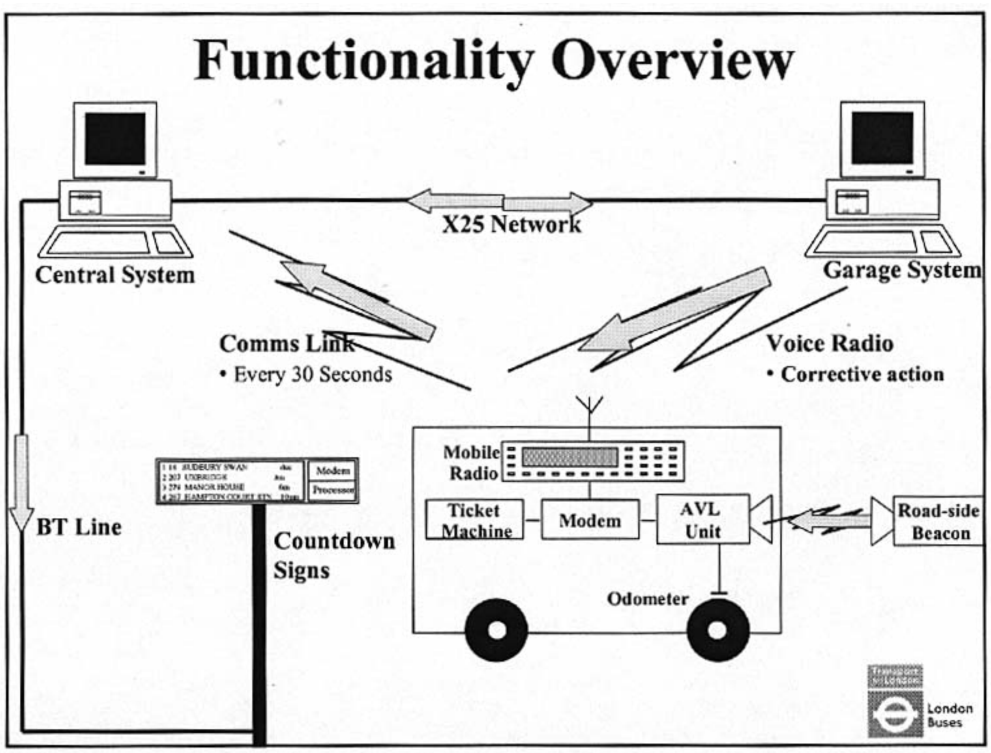

FIGURE 23 London Buses automatic vehicle location and Countdown systems.

- On a scale of 0 to 10, Countdown achieved an overall usefulness rating of 7.1.
- High-frequency stops achieved the best overall rating for usefulness at 7.5.
- Countdown was rated the least useful at low-frequency stops at 6.8.
- Those respondents who had seen Countdown previously were more inclined to value its usefulness, suggesting a learning process.
- The main reasons that Countdown was considered useful were that it gives arrival time information and it allows passengers to take alternative action.

• Results of seven group discussions in Shepherds Bush, Islington, and Bromley with regular, infrequent, and very infrequent bus users, included the following (*20*):

- Current bus users considered that it was most important to have off-system information available in their homes.
- Also important was information on points of interchange with other means of transport and off-system information in supermarkets.
- There was more interest in the availability of journey-planning information than in information relating to familiar or regular journeys. More interest was generated in static information than in real-time information.
- Current bus users thought telephone and Teletext were the most readily acceptable means of communicating off-system bus information.
- Customers would be prepared to pay a small fee for using any new application, but this fee should be kept to a minimum.

Within London Buses, the Monitoring Analysis Route Quality Information System (MARQUIS) was developed to provide "widespread access to route performance information and reports via PCs" (as indicated in a March 2002 handout "About the MARQUIS Project," distributed by London Buses). Ultimately, the primary purpose of MARQUIS is to improve bus service and to understand actual bus operations. Other objectives of the project are

- Allow service providers access to data that will be used to calculate performance,
- Facilitate service provider's evaluation of their own performance,
- Better plan bus services, and
- Reduce paperwork.

MARQUIS, as shown in Figure 24, consists of archived AVL data that is stored on each bus and later downloaded into the system when the bus enters the garage, plus related information about routes and schedules. It has dedicated servers and a report-generation function that can be accessed via the Internet by bus operators and Transport for London staff, and by means of the Intranet for London Buses staff.

The following reports can be generated by using MARQUIS:

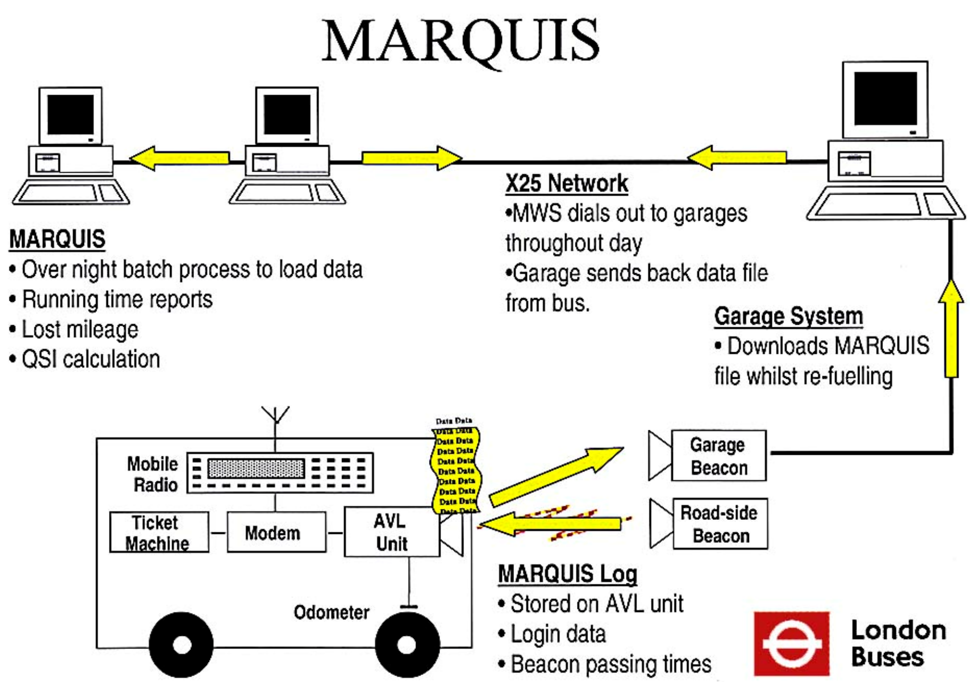

FIGURE 24 London Buses Monitoring Analysis Route Quality Information System (MARQUIS).

- Running time analysis,
- Headway analysis,
- Bunching report,
- Terminal behavior,
- Loaded trip data, and
- Matched trip data.

As of March 2002, 33 garages were outfitted with the MARQUIS software, which included the capability to download the AVL data stored on-board each vehicle.

Overall, London Buses has experienced many of the same challenges that have been prevalent in the U.S. deployment of real-time bus arrival systems. First, there is the challenge of receiving adequate support from outside companies that provide key aspects of the system. These include power, telephone, and shelter companies. Lack of support from these outside firms has resulted in Countdown signs being inoperable and incurring a long lead-time for sign installation—that is 3 months for the shelter, 4 months for the telephone service, 1 month for checking the shelter modifications for the signs, and 1 month for completing the installation.

Second, requiring operators to use the system is a challenge because all service is operated by contractors. As mentioned earlier in the report, operators in London are not under a contractual obligation to use the system. This is an issue for several agencies in the United States as well. As of December 2002, London Buses is in the process of implementing a training program that will ensure that all service controllers and new drivers are adequately trained on the AVL system.

Finally, responding to the needs of the community has also been a challenge. Many London citizens have requested Countdown signs at their neighborhood stops, and there has been political pressure to deploy Countdown in areas where AVL technology has not yet been fully implemented. Similar situations have occurred in several locations in the United States.

ACADIA NATIONAL PARK—ISLAND EXPLORER BUS SYSTEM

The TRACKER system was introduced to support the operations management and passenger information requirements of the Island Explorer (IE) transit system. IE serves Acadia National Park (ANP) and nearby areas in northeastern Maine. The TRACKER initiative was funded through the support of the FHWA, the Maine Department of Transportation (DOT), the U.S. Department of the Interior, and a variety of local interests. TRACKER is only one aspect of a broader Field Operational Test involving several different types of ITS for the ANP area.

IE transit service connects various destinations in ANP with one another, as well as with area hotels, inns, and campgrounds, and with local communities. It has become very effective in providing a viable alternative to automobile use in and around ANP. Downeast Transportation, Inc., currently operates IE from mid-June through Labor Day each year, using 17 propane-powered vehicles. This fare-free service is supported by the National Park Service, the U.S.DOT, Maine DOT, area towns, local businesses, and the Friends of Acadia, a nonprofit organization.

Each bus is equipped with a GPS receiver, which uses information from GPS satellites to continuously determine the vehicle's position. Each GPS receiver is integrated into a mobile data computer (MDC). The MDC also receives a GPS correction via radio to increase the accuracy of the computed vehicle location. Passenger counts and schedule adherence data are sent to dispatch, using the mobile data communication system, when the vehicle passes a "triggerbox" location as it departs each stop. Triggerboxes are locations stored in the MDC that trigger an event when the vehicle has exited or entered a stop. Vehicle location data are sent with these stop reports. Whenever it has been more than 2 min since the last location report, an additional location report is sent. This information is sent to the dispatch center operated by Downeast Transportation.

Selected major stops are equipped with DMSs that display text, including the expected departure time of the next bus. The specific equipped stops are located at the Village Green in Bar Harbor, the ANP Visitors Center in Hull's Cove, Jordan Pond House in ANP, and Sand Beach in ANP. Implementation for the Sand Beach sign was not expected until early 2003, in conjunction with construction of a new pavilion structure. For the Visitors Center, Jordan Pond, and Sand Beach signs, the stop serves only a single route, and the sign reports on the next buses inbound and outbound. For the Village Green, the major transfer point, a larger sign has been provided with enough text lines to report on the estimated departure time for the next outbound bus on all routes.

The method for predicting the expected departure time for the sign-equipped stops is based on the current schedule adherence status of the incoming bus. When a bus departs from a stop, its schedule adherence is reported to the dispatcher and used to update the downstream next departure displays. If a bus is running early, it is expected that the driver will wait at the next stop to restore schedule adherence. Thus, the next departure sign is still based on the schedule. However, if a bus is running behind schedule, the time displayed on the sign is estimated using an algorithm that calculates if the bus is expected to recover any of the delay. Such makeup time is based on the portion of scheduled layovers that can be used for schedule recovery and any preplanned capacity to recover time enroute.

In the first season of operation, summer 2002, the AVL and real-time bus arrival information systems were very successful. Several riders commented on the DMSs as part of a survey that was conducted on August 7 and 9, 2002, to measure rider satisfaction with the IE service [http://www.exploreacadia.com/surv02_1.pdf (as of December 2002)].

CHAPTER EIGHT

CONCLUSIONS

The literature review, survey, telephone interviews, and site visit yielded the following results.

- Global Positioning System-based automatic vehicle location (AVL) systems are the most prevalent underlying systems that provide the basis for real-time bus arrival information systems. However, agencies that have made significant investments in signpost technology (e.g., London Buses and King County Metro) are using that method to provide the basis for their real-time systems.
- Light-emitting diode (LED) dynamic message signs (DMSs) are the most prevalent media for providing real-time bus arrival information. Most of these signs provide similar real-time information, including the following for the arriving vehicle: route number, final destination, and estimated time of arrival. Estimated time of arrival can be counted down or provided in 5-min intervals. Several of the LED DMS deployments also include a line at the bottom of the sign that can provide additional information about major delays, rescheduling, and security announcements; basic transit information; and other regional information. Other types of dissemination media are being used, including the Internet, telephone, and wireless devices.
- Many of the vendor-supplied real-time information systems use proprietary prediction models to determine the real-time bus arrival information that is provided to the public. However, several systems have developed and use their own algorithms to make real-time arrival predictions. These models vary in complexity, with the simplest using loop–transponder technology along with runtime information and the actual headway. Perhaps the most complex nonproprietary model uses a Kalman filter technique to perform predictions. Accuracy of predictions is measured in two distinct ways: (1) using information available at a central location (e.g., central dispatch) to monitor the information provided by the real-time bus arrival information system against the actual vehicles arrivals and (2) monitoring the accuracy of the prediction information physically at the bus stop (e.g., checking the DMS display and the actual bus arrival time).
- The cost of the underlying AVL technology varies from $100 per vehicle (for transponder technology) to more than $7,000 per vehicle. The cost of providing the real-time information in addition to AVL technology ranges from under $100,000 for a 156-bus system to $46.5 million for a system with 5,700 buses and 4,000 LED DMS displays. Operating and maintenance (O&M) costs vary widely among systems, with the highest costs being noted for those systems that use cellular digital packet data communications technology to transmit the information to DMS displays. In addition, many agencies reported an increase in staff due to the deployment of a real-time information system, mostly in the information systems, operations, and customer service areas.
- Reactions from transit customers and agency staff have generally been positive, although few agencies have formally measured rider and/or staff reactions. However, the positive reactions have indeed influenced the use of real-time bus arrival information systems. Among customer perceptions are that bus services have improved, and that individuals traveling late at night have the confidence that a bus is not far away.
- There are many institutional and organizational issues associated with the deployment of these systems. The biggest reason for deploying a system is improving customer service. Operations and upper management most often were interested in the deployment of the system, with information systems, operations, and planning departments responsible for the deployment. The benefits realized from these systems are most often improved customer service, improved customer satisfaction, ability to monitor vehicle operations, and improved visibility of transit in the community.
- There are many lessons that can be learned from the deployment of real-time bus arrival information systems. These cover financial, technical, institutional, and organizational issues. Overall lessons learned included conducting a feasibility study before considering a real-time information system, having a sound foundation (e.g., AVL system) before deploying real-time information, and not underestimating O&M costs. It was also acknowledged that making the system a success would require significant training and cultural change.

Several conclusions can be drawn from the results of this synthesis.

- Needs assessment—It is important for an agency considering the deployment of real-time information to conduct a needs assessment to determine if real-time information is needed. Needs can be developed for all user groups, including agency staff, existing riders, potential riders, and vehicle operators. A systematic approach for conducting a needs assessment should be followed. Once the need is determined, the deployment of functions necessary for an AVL system should be implemented and operating flawlessly well in advance of deploying the real-time information system, unless the real-time information system is an integral part of the AVL system.

- Additional capabilities—When the real-time information system is part of the AVL system, it is important for agencies to understand if additional capabilities are available through this integrated system. This is a procurement issue, necessitating that the understanding be developed very early in the procurement process. Included are the capability for the dispatch center(s) to monitor vehicles, for additional ITS systems to be added to the system (e.g., automated annunciation and automatic passenger counting systems), and for computer-aided dispatch capabilities (such as determining schedule and route adherence). Some stand-alone real-time bus arrival information systems do not provide these capabilities. Consequently, add-ons or separate systems may have to be deployed to gain these functions, if needed.
- Distribution of media—Selection of the distribution media often is based on the number of passengers that can be affected by the real-time information. For example, whereas many agencies have selected LED DMSs at bus stops, others have determined that greater numbers of passengers would benefit more from the information being disseminated by means of telephone, Internet, or wireless devices. The technology necessary to distribute the real-time information is advanced enough that distribution to almost any device, wired or wireless, is possible.
- ADA concerns—Little seems to be done to accommodate persons with disabilities when deploying real-time bus arrival information. Given that the majority of these systems have DMSs at bus stops, it is crucial that information is provided to those who are visually impaired. Also, information provided on the Internet or on wireless devices should be accessible to everyone.
- Prediction model and inputs—Knowing the actual prediction model is not as important as knowing the inputs to the model and how they are used. For example, it is important to know if the model uses the performance of the last three buses at the stop or if traffic conditions are being used as input to the prediction model. Because several of the vendor-supplied models are proprietary should not preclude agencies from understanding what the inputs are and how they are used to produce real-time predictions.
- Costs—Not enough is yet known about the O&M costs of real-time information systems. Several of the survey respondents did not know how much it would cost to operate and maintain their systems.
- Passenger and staff reactions—It is important to formally survey passenger and staff reactions. The use of surveys can help to ensure that the agency fully understands the impact that a real-time information system has on its customers and agency staff. In addition, a formal system and project evaluation should be performed whenever possible to determine if, among other factors, the system has increased ridership, improved customers' perceptions of the overall system, and improved the perception of transit in the community.
- Training—Training staff at all levels is critical to fully utilizing the capabilities of the real-time information system. In addition, because deploying such a system represents a new way of providing customer service, training agency staff in how best to use the information and handle customer questions about the information is crucial.
- Reliability—Reliability of the information is crucial. A lack of reliability may be a major reason for customers to reject the system.
- Marketing—Another key element of customer acceptance and use is based on how the system is marketed. Several agencies have not marketed their systems at all, allowing for the spread of information about the system by word of mouth. However, other agencies have launched specific campaigns that inform the public about the system, how it works, and what they can expect from it. Depending on the specific market that is being targeted for the real-time information, a tailored marketing campaign could be developed and launched.
- Readiness—A few survey respondents explained that there was significant political pressure to deploy a real-time bus arrival information system either before the supporting technology was in place or before the supporting technology operation was stable. If the system is not based on a stable AVL system and if it has not been fully tested, such pressure can ultimately cause an agency's customers to mistrust the information being presented.

Based on the survey results, it was determined that there are six areas where future study could be done to better inform transit agencies about real-time bus arrival information systems.

- The determination of whether or not an agency needs a system to better service its customers could be examined more closely. Because transit intelligent transportation systems needs assessments are often not done or are greatly abbreviated, identifying which factors would point out the need for a real-time bus arrival information system could be useful to the transit industry. One approach to addressing this recommendation is to develop a business model that would assist in determining whether or not deploying real-time information is a good business decision; for example, does it stabilize and/or maintain ridership?

- A real-time bus arrival information system, together with its underlying technology (e.g., AVL), can provide a very powerful operations management tool. Understanding the uses and benefits of AVL technology, automatic passenger counting, real-time arrival information, and other related technologies as integrated management tools is crucial to being able to optimize transit services at the lowest possible cost. The transit industry could benefit from updated information about the deployment and use of these management tools, from a practical perspective.
- Further information is required about the costs of operating and maintaining a system. Now that more agencies are operating these systems, research into O&M costs conducted over the next few years should yield more data than what is currently available.
- Although the U.S. transit market is quite different from the European and Asian markets, U.S. transit agencies could learn from the deployments of these systems in other parts of the world. For example, a forum composed of representatives of U.K. transit agencies and operators was established specifically to address the issue of providing real-time information. A similar group could be formed in the United States.
- In survey results, several agencies considered accuracy and reliability to be the same. Given these perceptions, the reliability of real-time bus arrival systems could be a topic of future study.
- The results of other current projects that are examining real-time transit information systems could be examined, together with the results of this synthesis to produce a "how to" guidebook for transit agencies that are contemplating the deployment of these systems. Two projects in particular, an FTA study entitled "Real Time Transit Information Assessment," and TCRP Project A-20(A), "Strategies for Improved Traveler Information," will provide important information for the transit industry. The FTA project will produce a Guidance Report that contains practical information and advice for transit agencies on implementing and operating useful and successful real-time transit information systems. TCRP Project A-20(A) will produce a summary of practice in the area of improved traveler information that would be useful to the transit industry and that will be published as *TCRP Report 92* in mid-2003. A combination of these project outputs could be developed into a training course for transit agencies seeking more information and guidance on deploying real-time transit information systems.

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ABBREVIATIONS AND ACRONYMS

ANP	Acadia National Park
APTA	American Public Transportation Association
AVL	automatic vehicle location
CCRTA	Cape Cod Regional Transit Authority
CDPD	cellular digital packet data
COTA	Central Ohio Transit Authority
COTS	commercial off-the-shelf
CUE	City–University–Energysaver (Fairfax, Va.)
DGPS	Differential Global Positioning System
DMS	dynamic message sign
DTC	Delaware Transit Corporation
EDAPTS	Efficient Development of Advanced Public Transportation Systems
ETA	estimated time of arrival
GPS	Global Positioning System
GSM	Global System for Mobile communication
HTML	HyperText Markup Language
IE	Island Explorer
ITS	intelligent transportation systems
KC Metro	King County Metro (Washington State)
LACMTA	Los Angeles County Metropolitan Transportation Authority
LADOT	Los Angeles Department of Transportation
LCD	liquid crystal display
LED	light-emitting diode
MARQUIS	Monitoring Analysis Route Quality Information System
MDC	mobile data computer
MDT	mobile data terminal
MMDI	Metropolitan Model Deployment Initiative
PDA	personal digital assistant
RTD	Regional Transportation District (Denver, Colo.)
SLO	San Luis Obispo (Calif.) Transit
STIB	Société des Transports Intercommunaux de Bruxelles
TRANSCOM	Transportation Operations Coordinating Committee
TRANSMIT	TRANSCOM System for Managing Incidents and Traffic
Tri-Met	Tri-County Metropolitan Transportation District of Oregon
TRIS	Transportation Research Information Services
WML	Wireless Markup Language
XML	Extensible Markup Language

APPENDIX A

Survey Questionnaire

TRANSIT COOPERATIVE RESEARCH PROGRAM

(TCRP) Synthesis Topic SA-14

Questionnaire About Real-Time Bus Arrival Information Systems

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Date: ____

Name and Title of Respondent: ____

Transit Agency Name: ____

Address: ____

Phone Number: ____________________ Fax Number: ____________________

Respondent's E-mail Address: ____

Purpose of this Survey: More and more transit agencies are providing real-time arrival information for buses. With the growth in use of automatic vehicle location systems at transit agencies, even more agencies are experimenting with or planning to provide this real-time information. The objective of this survey is to collect information on the state of the practice in real-time bus arrival information systems. The survey contains questions about relevant technical capabilities, agency experience, cost, and bus rider reactions to these information systems. Once the survey results are reviewed, key agencies that have implemented, or are in the process of implementing, these systems will be selected for telephone interviews to gather more in-depth information. All survey responses will be confidential. The final results of the survey will be synthesized into a report that will be published by the Transportation Research Board (TRB). **Thank you for taking the time to complete this survey!**

Bus System Characteristics:

1. How many fixed-route buses does your agency operate? ______________________________
2. How many bus stops does your system have? ______________________________
3. How many fixed bus routes do you operate? ______________________________
4. What is the total mileage covered by all of your fixed routes? ______________________________
5. How many bus garages/depots do you have for your fixed-route bus fleet? ______________________________
6. How many passengers do you carry annually on your fixed-route bus service? ______________________________

Real-Time Bus Arrival Information System Characteristics:

7. How many of your fixed-route buses are equipped with automatic vehicle location (AVL) technology? ___________
8. What type of AVL system are you operating? (Please check all that apply)

☐ Global positioning system (GPS)	☐ Signpost/beacon system in which bus sends location and/or odometer data to dispatch
☐ Differential GPS	☐ Signpost/beacon system in which signpost/ beacon sends location and/or odometer data to dispatch
☐ Dead reckoning/odometer	☐ Global Navigation Satellite System (GLONASS)
☐ Ground-based radio [e.g., Long-Range Aid to Navigation (LORAN-C)]	☐ Other (please specify) ____________________ ________________________________ ________________________________

9. Does your AVL system have a central dispatch function that allows bus monitoring of all equipped buses from a central location(s)? ☐ YES ☐ NO

10. Is the bus schedule loaded on each bus or at a central location?
    ☐ Loaded on each bus ☐ Loaded at a central location

11. How often is location information updated for each vehicle? ______________________________

12. Does the AVL system include a passenger counting capability? ☐ YES ☐ NO

13. How many bus stops are equipped with electronic real-time arrival signs? ______________________________

14. How many of each type of electronic sign do you have installed at bus stops? (Please provide the total number of signs in each category.)

___ Light-emitting diode (LED) signs	___ Video monitor
___ Liquid crystal display (LCD)	___ Flat panel display
___ Other (please specify)	___ Other (please specify)

15. What information is displayed on each type of sign? (Please check all that apply)

☐ **LED Sign:**	
☐ Current time	☐ Date
☐ Route number	☐ Final destination of arriving bus
☐ Waiting time (countdown)	☐ Waiting time [time range (e.g., 5–10 minutes)]
☐ Service disruptions	☐ Current location of arriving bus
☐ General system information	☐ Tourist information
☐ Weather information	☐ Advertising
☐ Other (please specify) ____________________	☐ Other (please specify) ____________________
☐ **Video Monitor:**	
☐ Current time	☐ Date
☐ Route number	☐ Final destination of arriving bus
☐ Waiting time (countdown)	☐ Waiting time [time range (e.g., 5–10 minutes)]
☐ Service disruptions	☐ Current location of arriving bus
☐ General system information	☐ Tourist information
☐ Weather information	☐ Advertising
☐ Other (please specify) ____________________	☐ Other (please specify) ____________________
☐ **LCD Display:**	
☐ Current time	☐ Date
☐ Route number	☐ Final destination of arriving bus
☐ Waiting time (countdown)	☐ Waiting time [time range (e.g., 5–10 minutes)]
☐ Service disruptions	☐ Current location of arriving bus
☐ General system information	☐ Tourist information
☐ Weather information	☐ Advertising
☐ Other (please specify) ____________________	☐ Other (please specify) ____________________
☐ **Flat Panel Display:**	
☐ Current time	☐ Date
☐ Route number	☐ Final destination of arriving bus
☐ Waiting time (countdown)	☐ Waiting time [time range (e.g., 5–10 minutes)]
☐ Service disruptions	☐ Current location of arriving bus
☐ General system information	☐ Tourist information
☐ Weather information	☐ Advertising
☐ Other (please specify) ____________________	☐ Other (please specify) ____________________
☐ **Other (please specify):** ______________________________	
☐ Current time	☐ Date
☐ Route number	☐ Final destination of arriving bus
☐ Waiting time (countdown)	☐ Waiting time [time range (e.g., 5–10 minutes)]
☐ Service disruptions	☐ Current location of arriving bus
☐ General system information	☐ Tourist information
☐ Weather information	☐ Advertising
☐ Other (please specify) ____________________	☐ Other (please specify) ____________________

16. How often is the real-time information updated on the displays? ______________________________

17. Information about how many arriving buses is being displayed on each type of sign at once?

___ Light-emitting diode (LED) signs
___ Video monitor
___ Liquid crystal display (LCD)
___ Flat panel display
___ Other (please specify)
___ Other (please specify)

18. What types of problems have you had with signs/monitors? (Please check all that apply)

☐ Vandalism
☐ Display failure
☐ Graffiti
☐ Moisture/dirt infiltration
☐ Electrical problems
☐ Mounting problems
☐ Casing problems
☐ Other (please specify) ______________
____
____

19. What communications technologies are used to send messages to the signs? (Please check all that apply)

☐ **LED Sign:**	
☐ Conventional telephone line	☐ Radio
☐ Dedicated short-range communication	☐ Cellular communication (e.g., cellular digital packet data)
☐ T1 line	☐ Digital subscriber line (DSL)
☐ Other (please specify) ___________________	
☐ **Video Monitor:**	
☐ Conventional telephone line	☐ Radio
☐ Dedicated short-range communication	☐ Cellular communication (e.g., cellular digital packet data)
☐ T1 line	☐ Digital subscriber line (DSL)
☐ Other (please specify) ___________________	
☐ **LCD Display:**	
☐ Conventional telephone line	☐ Radio
☐ Dedicated short-range communication	☐ Cellular communication (e.g., cellular digital packet data)
☐ T1 line	☐ Digital subscriber line (DSL)
☐ Other (please specify) ___________________	
☐ **Flat Panel Display:**	
☐ Conventional telephone line	☐ Radio
☐ Dedicated short-range communication	☐ Cellular communication (e.g., cellular digital packet data)
☐ T1 line	☐ Digital subscriber line (DSL)
☐ Other (please specify) ___________________	
☐ **Other (please specify):** ____	
☐ Conventional telephone line	☐ Radio
☐ Dedicated short-range communication	☐ Cellular communication (e.g., cellular digital packet data)
☐ T1 line	☐ Digital subscriber line (DSL)
☐ Other (please specify) ___________________	

20. Is real-time arrival information available via any other media? (Please check all that apply)

☐ Mobile telephones (voice information)	☐ Mobile telephones (data display)
☐ Personal digital assistants (PDAs) (e.g., Palm Pilot)	☐ Internet. Please specify web address: ______________________________
☐ Cable television	☐ Other (please specify) ______________ ______________________________

Real-Time Bus Arrival Information System Prediction, Accuracy, and Reliability:

21. Does the prediction model/algorithm used to determine real-time arrivals use any of the following information? (Please check all that apply)

☐ Current traffic conditions	☐ Historical traffic conditions
☐ Real-time operating data from the last several buses on that route that passed that stop	☐ Historical real-time operating data
☐ Other (please specify) ____________________	

22. Please describe the prediction model/algorithm, including the inputs and outputs.

____

____

____

23. How do you measure the accuracy of the predictions? Please describe.

____

____

24. How often do you monitor the accuracy of predictions? ____________________

25. What is the accuracy on a daily basis (or other time frame if not measured daily)?

____

26. If the accuracy falls below a certain threshold, what information do you display to the public? Please specify the threshold as a percentage: __________%

☐ Scheduled arrival time	☐ "No information available"
☐ Other (please specify) ____________________	

27. Is there a seasonal impact on prediction accuracy and reliability?

☐ YES ☐ NO

If yes, what is the impact? ____________________

____

28. How do you measure the reliability of the real-time arrival information displayed at bus stops? Please describe.

____

____

29. How often do you measure the reliability? ____________________

30. What is the reliability on a daily basis (or other time frame if not measured daily)?

____

31. How often do you check the functioning of the displays at bus stops? ____________________

32. How do you check the functioning of the displays at bus stops?

____

____

33. How do you use the real-time arrival information? (Please check all that apply)

☐ Modify route structures	☐ Change route headways/schedules
☐ Increase or decrease the number of buses serving a route	☐ General transit planning
☐ Planning new services	☐ Other (please specify) ____________________

Real-Time Bus Arrival Information System Costs:

34. What was the total capital cost of the AVL system? $____________________

If available, what was the capital cost per bus? $_____________________
If available, what was the capital cost of the fixed-end part of the system? $_____________________

35. What was the additional capital cost for providing real-time arrival information? $____________________

If available, what was the capital cost per electronic sign/monitor? $____________________
If available, what was the cost for the prediction model software? $____________________

36. What is the total annual operations and maintenance cost for the AVL system? $____________________

If available, what is the annual operations and maintenance cost per bus? $_____________________
If available, what is the annual operations and maintenance cost for the fixed-end part of the system? $___________

37. What is the total annual operations and maintenance cost for providing real-time arrival information? $___________

If available, what is the annual operations and maintenance cost per electronic sign/monitor? $__________________
If available, what is the annual maintenance cost for the prediction model software? $__________________

38. Did staff need to be added as a result of deploying the real-time bus arrival information system? ☐ YES ☐ NO

If yes, how many full-time equivalents (FTEs) had to be added? _____________
In which departments did you add FTEs? (Please check all that apply)

☐ Operations	☐ Customer service
☐ Marketing	☐ Facilities maintenance
☐ Outside contract staff	☐ Vehicle maintenance
☐ Planning/scheduling	☐ Other maintenance (e.g., electrical)
☐ Legal/procurement	☐ Other (please specify) ________________________

Customer and Media Reaction to Real-Time Bus Arrival Information System:

39. Have you measured the public's reaction to the real-time arrival information?
☐ YES ☐ NO

If yes, are the results of the measurements (e.g., surveys, survey/market research reports) available to us for review?

☐ YES (see attached, or contact ____________________) ☐ NO

40. Did the deployment of the real-time bus information system result in an increase in bus ridership? ☐ YES ☐ NO

If yes, how much did ridership increase as a result of deploying the system? _____%

41. Have the media reacted to the real-time bus arrival information system?
☐ YES ☐ NO

If yes, can we obtain copies of their reactions to the system (e.g., newspaper and magazine articles, Internet articles, video clips of televised reactions)?

☐ YES (see attached, or contact ____________________) ☐ NO

42. Have you issued any press releases about the real-time bus arrival information system?
☐ YES ☐ NO

If yes, can we obtain copies of the press releases?
☐ YES (see attached, or contact ____________________) ☐ NO

43. To what extent have rider/media reactions influenced the demand for and the use of real-time bus arrival information systems?
____
____
____

Institutional/Organizational Issues Associated with the Real-Time Bus Arrival Information System:

44. What were the reasons for deploying a real-time bus arrival information system? (Please check all that apply)

☐ To improve the level of customer service	☐ To monitor vehicle operations
☐ To respond to customers requesting real-time information	☐ To save on the costs of customer service
☐ To increase ridership	☐ Improve transit visibility in the community
☐ To increase customer convenience	☐ Other ________________________

45. Which department(s) was interested in deploying the real-time bus arrival information system? (Please check all that apply)

☐ Operations	☐ Customer service
☐ Marketing	☐ Upper management/administration
☐ Information systems	☐ Planning
☐ Recommended by an outside consultant	☐ Other (please specify) ____________

46. Which department was primarily responsible for deploying the real-time bus arrival information system? (Please select only one)

☐ Operations	☐ Customer service
☐ Marketing	☐ Information systems
☐ Outside contract staff	☐ Planning
☐ Legal/procurement	☐ Other (please specify) ___________

47. Did you measure the reactions of your agency's staff to the real-time bus arrival information system?
☐ YES ☐ NO

If so, what were the reactions? ☐ Positive ☐ Negative ☐ Mixed

If negative or mixed, what were the reasons for the negative reactions?

48. Have staff reactions influenced the extent to which you utilize real-time bus arrival information? ☐ YES ☐ NO

49. What benefits have you realized from deploying the real-time bus arrival information system?

☐ Improved customer service	☐ Ability to monitor vehicle operations
☐ Increased customer satisfaction	☐ Decreased costs of customer service
☐ Increased ridership	☐ Improvement in transit visibility in the community
☐ Increased customer convenience	☐ Other ________________________________

50. What was the one biggest problem associated with procuring the system?

51. What was the one biggest problem associated with implementing and testing the system?

52. What is the one biggest problem associated with operating the system?

53. What is the one biggest problem associated with maintaining the system?

54. Please describe any additional “lessons learned” that would benefit transit agencies that are considering deployment of real-time bus arrival information systems.

55. If your agency had to do it all over again, would you deploy a real-time bus arrival information system?
☐ YES ☐ NO

If yes, what would you do differently this time?

If no, why not?

Please return the completed questionnaire by May 9, 2002 to:

Ms. Carol L. Schweiger
Principal
Multisystems, Inc.
10 Fawcett St.
Cambridge, MA 02138-1110 U.S.A.
Telephone: 617-864-5810
Fax: 617-864-3521
E-mail address: cschweiger@multisystems.com

We encourage you to return your completed survey to Ms. Schweiger via fax at 617-864-3521 (01 617-864-3521 for non-U.S. respondents). If you have any questions on the survey or the project, please do not hesitate to call Ms. Schweiger. Thank you very much for your participation in this important project.

APPENDIX B

List of Agencies Responding to the Survey

U.S. Transit Agencies

Planner
Delaware Transit Corporation
400 S. Madison Street
Wilmington, DE 19801

Transportation Director
Fairfax CUE
10455 Armstrong Street
Fairfax, VA 22030

Transportation and Parking Services Supervisor
Glendale Beeline
City of Glendale
10455 Armstrong Street
633 East Broadway, Room 300
Glendale, CA 91206

King County Metro
201 S. Jackson
KSC-TR-0333
Seattle, WA 98104

Programmer/Analyst
Regional Transportation District
1600 Blake Street
Denver, CO 80202

Senior Operations Manager
San Francisco Muni
700 Pennsylvania
San Francisco, CA 94107

Planner/Analyst
Tri-Met
4012 SE 17th Avenue
M.S. HPD2
Portland, OR 97202-3993

Operations Manager
Williamsport Bureau of Transportation
1500 West Third Street
Williamsport, PA 17701

Transportation Engineer
Los Angeles Department of Transportation
(survey filled out for Los Angeles County Metropolitan Transportation Authority)
200 N. Main Street
ATSAC Center—CHE P4, MS 759
Los Angeles, CA 90012

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International Transit Agencies

General Manager
ATC Bologna
Via Saliceto 3
Bologna, Italy 40128

Dublin Bus
59/60 O'Connell Street
Dublin, Ireland

Engineer
Institute of Transportation
6F, 240, Tun-Hwa North Road
Taipei 105 Taiwan, ROC

Real Time Information Project Manager
Centro
Centro House, 16 Summer Lane
Birmingham, West Midlands, UK B19 3SD

Chief of Transportation Operations and Management Division
Institute of Transportation, Ministry of Transportation and Communications
8F, 240, Tun-Hwa North Road
Taipei 105 Taiwan, ROC

Kent County Council
Invicta House, Count Hall
Maidstone, Kent, UK ME14 1XX

AVL Manager
Transport for London—London Bus Services Limited
172 Buckingham Palace Road
London, UK SW1W

Team Manager/Information Systems
YTV (Helsinki Metropolitan Area Council)
PO Box 521
Helsinki, Finland FI 00521

Abbreviations used without definition in TRB Publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation