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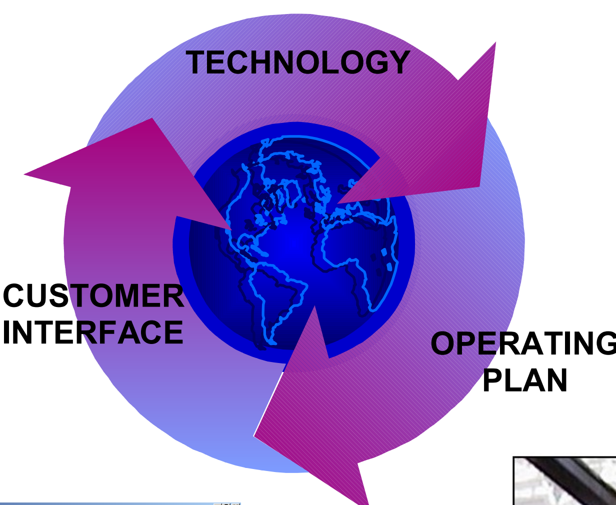
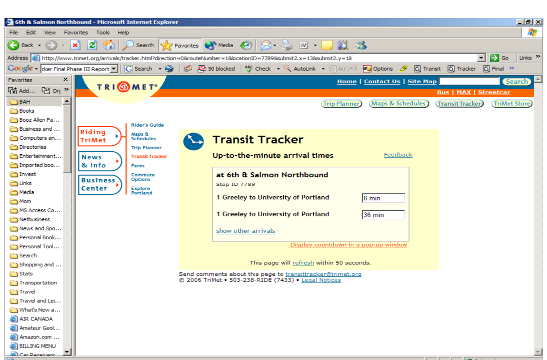
Real-time Bus Arrival Information Systems Return-on-Investment Study

Final Report





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13. ABSTRACT (Maximum 200 words)
This reference document was prepared for the Office of Research, Demonstration and Innovation of the Federal Transit Administration (FTA). The objectives of the study include developing a methodology for determining the return on investment of real-time information systems for bus services, examining the relevant technologies, system boundaries, unit costs and benefits of such systems, and then presenting them within a benefit-cost evaluation structure. This study includes the input of an Expert Panel Workshop to refine the individual cost and benefit elements, and to obtain information from transit agency representatives on how transit agencies measure or would measure a return on investment of these systems. Two approaches are examined for calculating the costs—direct costs, which would only give a model useful for incremental cost calculations, and a fully-allocated approach, which would be more useful for modeling larger deployments. This evaluation also applies the return-on-investment study on an operational system using the evaluation elements and methodology developed for the project. This application of the benefit-cost methodology served as the initial validation of the methodology and its elements. The demonstration concludes with an outline of the types of information required to conduct a benefit-cost analysis of a real-time information system.

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Preface

The information developed and presented in this document was prepared for the Federal Transit Administration (FTA) by a project team from Booz Allen Hamilton. The project team included Donald Schneck, Rick Laver, Georges Darido, Laura Cham and David Jackson. The project was contracted through the Architecture and Engineering Contract with the Office of Research, Demonstration and Innovation.

The project was managed through the FTA Office of Research, Demonstration and Innovation, and its Office of Mobility Innovation. The FTA project manager was Charlene Wilder. Overall guidance was provided by Walt Kulyk, Director of the Office of Mobility Innovation. In addition, an FTA technical oversight panel included Paul Marx of the Office of Policy and Budget, Eric Pihl of the Office of Planning and Environment, and Brian Cronin, Aletha Goodine and Sebastien Renaud of the Office of Research, Demonstration and Innovation. The panel offered guidance in the development of the methodology, the conduct of the expert panel workshop and comments on the results. These contributions were important to the direction and pertinence of the results, and the project team would like to thank the FTA staff and panel for their assistance.

The project team would also like to thank Tri-County Metropolitan Transportation District of Oregon (TriMet). TriMet kindly offered their support and information to the application of the benefit-cost methodology developed as part of this study. David Crout of TriMet staff provided detailed cost and benefit data to support the application of the benefit-cost methodology. TriMet's success with the implementation of their real-time bus arrival, passenger information system, among other intelligent information systems, provided the actual data and experience to demonstrate the methodology on an operational system.

The project team would also like to thank the expert panel members who contributed insight and guidance to the development of the methodology. These members included:

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EXECUTIVE SUMMARY

This study was developed to help transit agencies with the development and implementation of Intelligent Transportation Systems (ITS), in general, and Real-time Passenger Information Systems in particular. The focus of the study effort is the return on investment (ROI) in these passenger information systems and the methodology used to apply this evaluation approach.

Real-time Bus Arrival Information Systems

Intelligent Transportation Systems (ITS) have been the focus of efforts to improve the effectiveness of transportation services and allow them to become more customer friendly. Real-time Bus Arrival Information Systems are one aspect of these ITS systems that focus upon real-time bus operations information and distributes that information to the public in an effort to reduce passenger wait times.

These real-time bus information systems have been implemented to facilitate transit usage through both perceived and actual reductions in passenger waiting time. Access to this information before beginning the trip can help to reduce the wait time. Information available to the traveler underway can help to reduce the perceived wait time.

Study Objectives

The objectives of the study were oriented toward the development of a methodology for determining the return on investment of real-time information systems for bus services. This includes examining the relevant technologies, system boundaries, unit costs and benefits of such systems, and then presenting them within a benefit-cost evaluation structure. The study objectives included the following:

- Develop a generic methodology for determining the return on investment of real-time bus arrival information systems
- Investigate and collect unit costs, impacts, and return-on-investment information
- Present the proposed methodology to an expert panel
- Perform a return-on-investment study using the methodology developed
- Test the methodology on an expansion of an existing system in a potential future phase of the project

Expert Panel

The project team organized and conducted the Expert Panel Workshop to refine the individual cost and benefit elements, and to provide feedback on the proposed methodology for performing the return-on-investment studies of real-time bus arrival information systems. The purpose of the expert panel was to obtain information from transit agency representatives on how transit agencies measure or would measure a return on investment of these systems. Comparable input was also garnered from automatic vehicle location (AVL)/real-time transit information system vendors. The role of the expert panel was to:

- Validate the boundaries of the relevant systems and technologies
- Provide input on the proposed benefit-cost analysis methodology
- Identify and help quantify all relevant costs and benefits
- Identify additional data sources
- Provide insight on barriers to implementation

To facilitate and provide structure for the workshop, the project team identified and presented draft return-on-investment study elements and a draft methodology. The expert panel discussed the draft elements and methodology proposed by the Booz Allen project team and suggested revisions to the process to emphasize the benefit-cost approach. The panel reached a consensus on the benefit-cost elements and the methodology.

Return-on-Investment Methodology

The heart of the return-on-investment evaluation was a detailed benefit-cost analysis. When used to evaluate new technologies, traditional benefit-cost analyses compare the discounted streams of costs and benefits associated with the proposed technology—including costs and benefits to individual riders and operating agencies, and to society in general. Implementation of the new technology is viewed as desirable—either to the individuals or to society as a whole—when the benefits of implementation exceed the costs (i.e., the ratio of discounted benefits over discounted costs exceeds one). While traditional benefit-cost analyses are generally limited to costs and benefits that are quantifiable in monetary (dollar) terms, practitioners have developed several techniques to include both and qualitative and non-monetary quantitative factors as well.

Two approaches were examined for calculating the costs—direct costs only and both direct and indirect costs associated with the real-time information systems. Using the direct costs only would give a model useful for incremental cost calculations. Using the fully-allocated model would be more useful for modeling larger deployments. It was agreed that the fully-allocated cost model was the preferred approach and that it would be best to show both methods as appropriate.

Application of the Proposed Methodology

With concurrence from the Federal Transit Administration (FTA) and the results from the Expert Panel Workshop, the project team contacted selected transit agencies to apply the benefit-cost methodology to a particular real-time bus arrival system investment decision. The request focused on availability of unit costs, benefits, impacts, and return-on-investment information on real-time bus arrival information systems. This information and the recent system implementation were found available at TriMet in Portland, Oregon. The project team worked with representatives of this agency to apply the return-on-investment study on an operational system using the evaluation elements and methodology developed for the project. This application of the benefit-cost methodology served as the initial validation of the methodology and its elements.

This brief demonstration has outlined the types of information required to conduct a benefit-cost analysis of a real-time information system, using TriMet's Transit Tracker system as a test case. In addition to highlighting the information needs associated with this type of analysis, this demonstration has also outlined the circumstances required to attain a positive net benefit for the Transit Tracker system. Using fairly conservative assumptions regarding informed trip volumes, reductions in wait time and reduction in the cost of wait-time uncertainty, it was shown that Transit Tracker very likely achieves strong, positive net (social) benefits. The completion of a more conclusive assessment of Transit Tracker or any other real-time information system in the future will require the collection of specific use data as required to replace these assumptions with robust parameter estimates (e.g., estimates of the number of trips for which a real-time information system is used, the average time savings for each use, etc.)

Future Applications and Enhancements

The results from this development of the return-on-investment approach for real-time bus arrival passenger information systems may be applied in a potential, future field test and return-on-investment study. As existing systems become more widely implemented and accepted by the transit rider, the benefits of these systems can be more clearly demonstrated. Options include those transit systems with existing passenger information systems such as:

- TriMet
- Los Angeles County MTA
- King County Metro
- San Francisco Muni
- Pace (suburban Chicago)
- Denver RTD
- Fairfax CUE
- Cape Cod Regional Transit Authority
- AC Transit (Oakland, CA)
- Portland Streetcar

This process can also be applied with other system investments within the overall Intelligent Transportation Systems (ITS) realm. The FTA will determine if the subsequent field test and return-on-investment study are needed.

1.0 INTRODUCTION

This research study was guided by the Federal Transit Administration (FTA) Office of Research, Demonstration and Innovation. Funding was provided through the Joint Program Office of the Federal Highway Administration (FHWA). This study was developed to help transit agencies with the development and implementation of Intelligent Transportation Systems in general, and Real-time Passenger Information Systems in particular. The focus of the study effort is the return on investment (ROI) in these passenger information systems.

1.1 Study Objectives

The objectives of the study were oriented toward the development of a methodology for determining the return on investment of real-time information systems for bus services. This includes examining the relevant technologies, system boundaries, unit costs and benefits of such systems, and then presenting them within a benefit-cost evaluation structure. The study objectives included the following:

- Develop a generic methodology for determining the return on investment of real-time bus arrival information systems
- Investigate and collect unit costs, impacts, and return-on-investment information
- Present the proposed methodology to an expert panel
- Perform a return-on-investment study using the methodology developed
- Test the methodology on an expansion of an existing system in a potential future phase of the project

1.2 Report Organization

In accordance with the proposed framework outlined in the project work plan, this study is organized into the following sections:

1.0 Introduction
2.0 Background
3.0 Project Approach
4.0 Expert Panel
5.0 Return on Investment Methodology
6.0 Sample Application

This presentation of the study results reflects the process undertaken in the study, the approach required in its implementation and the results outlined for each deliverable.

2.0 BACKGROUND

Intelligent Transportation Systems (ITS) have been the focus of efforts to improve the effectiveness of transportation services and allow them to become more customer friendly. Real-time Bus Arrival Information Systems are one aspect of these ITS systems that focus upon real-time bus operations information and distributes that information to the public in an effort to reduce passenger wait times.

These real-time bus information systems have been implemented to facilitate transit usage through both perceived and actual reductions in passenger waiting time. Access to this information before beginning the trip can help to reduce the wait time. Information available to the traveler underway can help to reduce the perceived wait time. This Return-on-Investment (ROI) Study has been developed in accordance with the strategic goals of the Federal Transit Administration (FTA) for measuring cost-effectiveness and improving financial performance of transit investments. It provides an improved understanding of the costs and benefits of these systems and the means to estimate these impacts within the decision-making process of the investment question.

2.1 Project Overview

One such ITS investment that is becoming more widely implemented is real-time bus arrival information system. The development of real-time bus arrival systems has been accomplished through several alternative technologies and differing technical approaches. Some of these interact directly with the vehicle location systems and utilize similar satellite-based communications networks to determine bus arrival times. Others utilize cellular-based communication to identify vehicle location and from that estimate the bus arrival times to upcoming destinations. Both of these technologies have been demonstrated successfully. State of the practice in these systems has been well documented, and the alternative approaches are well understood.

The critical technical issues in real-time bus arrival systems are the collection, communication, display, and then dissemination of the real-time bus arrival information. This implementation process has been examined in recent research and has been achieved successfully at several agencies. However, the hypothesis has been posed that system deployments around the country still fail, are under-utilized, or do not achieve the desired outcome because of ineffective planning or lack of information to support the investment decisions for these systems.

Although technical issues are critical to the implementation and utilization of a real-time bus arrival system, the most important issues at the decision point in their deployment are the justification of the system and then the implementation of the system in a way that achieves maximum customer benefits from its use. Dissemination of traveler and vehicle information through a mechanism that is useful to current and potential bus riders is essential in order to reap the benefits from the capital investment and ongoing maintenance costs for the system. This return-on-investment approach to the development, evaluation and implementation of real-time passenger information systems is the focus of this research study.

The motivation for this study is based on the extensive deployments that occurred previously and the significant slowing of the deployments in more recent years.

- Deployment of real-time bus arrival information systems in the United States during the 1990s grew significantly. As of 2000:
  - 88 transit agencies had operational AVL systems
  - 142 were planning AVL systems
  - 291 had operational automated transit information
  - 48 were planning automated transit information
- Future deployment of these systems may be hindered by:
  - Uncertainties in the utilization and return of such investments
  - Lack of a consistent benefit-cost methodology for investment decision

This project was developed to help answer this question of future deployments.

Continued development and implementation of real-time bus arrival systems may be hindered by lack of a clear justification of the benefits. Additionally, there is no systematic utilization of the real-time bus arrival information to achieve the objectives of increased customer satisfaction, and improved service and transit visibility. The highest benefits, however, may be achieved from increased transit ridership. This includes more frequent travel by current riders and the additional travel of new riders.

The FTA has noted that real-time transit information systems have many perceived benefits, including the following:

- Maintenance of or increase in transit ridership
- Improvement of customer service
- Increase in customer satisfaction and convenience
- Improvement of transit visibility
- Provision of critical information during emergencies

These benefits and their measurement are the focus of the benefit-cost approach. The quantitative measurement of these benefits and the values of those benefits are critical to the success of this process and the demonstration of the real-time bus arrival information systems.

2.2 Understanding of the Problem

There are issues critical to the implementation of real-time bus arrival systems and there are issues critical to its utilization, but the most important issues are the justification of the system(s) and then the implementation of the system to achieve the customer benefits from its use. Dissemination of the resulting traveler and vehicle information in a useful mechanism to current and potential bus riders is essential in reaping the benefits from the system capital investment and ongoing maintenance.

One potential issue that may stand in the way of continued development and implementation of these real-time bus arrival systems is the clear quantitative measurement of the costs and benefits and justification of these systems investments. The systematic utilization of the information to achieve the objectives of increased customer satisfaction, ridership increases, travel time savings and service and transit visibility are the keys to their successful implementation. However, the highest benefits are likely achieved from travel time savings and potential increases in transit ridership from more reliable service and greater passenger visibility into this real-time bus arrival information. The challenge lies in collecting data that provide a reliable measure of each of these benefits.

2.3 Business Case for Systems Investments

The heart of any business case is the benefit-cost analysis. When used to evaluate new technologies, traditional benefit-cost analyses compares the discounted streams of costs and benefits associated with the proposed technology — including costs and benefits to individual riders and operating agencies, and to society in general. Implementation of the new technology is viewed as desirable — either to the individuals or to society as a whole — when the benefits of implementation exceed the costs (i.e., the ratio of discounted benefits over discounted costs exceeds one). While traditional benefit-cost analyses are generally limited to costs and benefits that are quantifiable in monetary (dollar) terms, practitioners have developed several techniques to include both qualitative and non-monetary quantitative factors, as well as the more traditional monetary quantitative measures. This process considers both types.

Completion of a comprehensive benefit-cost analysis requires the identification of all direct and indirect costs and benefits associated with the proposed real-time bus arrival system investment. In general, the full range of costs and benefits to include in the analysis will expand as the number of stakeholders considered in the analysis increases. For example, a benefit-cost analysis for an individual agency may not consider costs and benefits to other regional beneficiaries such as the riders and other users of the bus arrival information. Similarly, an industry level benefit-cost analysis may not consider broader benefits to society as a whole (e.g., vehicle emissions from the former drivers). Hence, it is important to consider all stakeholders at the start to insure the more comprehensive identification of costs and benefits. Finally, while it is critical that the listing of costs and benefits be comprehensive, it is equally important to avoid double counting (counting the same cost or benefit twice) and transfers (where a benefit to one stakeholder becomes a cost to another stakeholder, with no net benefit to society). The proposed benefit-cost approach fulfills the Federal Office of Management and Budget Circular A-4 requirements for measuring benefits and costs, and supports the wider implementation of these systems in the future.

The deployment of real-time traveler information systems for transit is becoming more prevalent. The advent of automatic vehicle location (AVL) systems not only has provided the transit industry with tools to monitor and control operations, but the opportunity to provide customers with real-time information. Real-time traveler information systems for transit, also referred to as real-time transit information systems, display information in different ways using a variety of dissemination devices. Many applications use a countdown to arrival of the next transit vehicle (e.g., next bus in 5 minutes). Some systems provide the estimated time of day (e.g., 3:45 PM) for the arrival of the next transit vehicle. Other systems provide the geographic location of vehicles on a route map. Dissemination media include dynamic message signs (DMS), video monitors, and kiosks at transit stops and stations, the Internet, telephones, and personal digital assistant (PDA) devices.

2.4 Real-time Bus Arrival Information Systems Studies

Transit agencies have implemented a significant number of real-time transit information systems, although, prior to 2002, only a limited amount of information about them was available. In 2002, two research studies were conducted to obtain useful information on these systems. Reports from these studies include the following:

- *Guidance for Developing and Deploying Real-time Traveler Information for Transit*, developed by Battelle for the Federal Transit Administration (FTA) and United States Department of Transportation (U.S. DOT) Intelligent Transportation Systems (ITS) Joint Program Office (JPO), April 30, 2003, U.S. DOT # FTA-OH-26-7017-2003.1
- *TCRP Synthesis 48: Real-time Bus Arrival Information Systems*, Transit Cooperative Research Program (TCRP), Transportation Research Board (TRB), 2003

The first document identifies the issues and challenges of planning, implementing, operating, and maintaining real-time transit information systems, and identifies recommended practices. The second document is a synthesis of the state of the practice in real-time bus arrival systems.

Few evaluations of these systems have occurred or have been documented publicly. However, Tri-County Metropolitan Transportation District of Oregon (TriMet) performed a small in-house assessment of its Transit Tracker system. This assessment was followed by a national evaluation sponsored by the U.S. DOT ITS Joint Program Office as a part of the National Evaluation Program. In both of these evaluations, a quantitative analysis of user perceptions was conducted based on survey data. The evaluations provide quantitative results of the system's operational performance and impacts based on the analysis of subjective data. The evaluations do not provide quantitative results of the system's operational performance and impacts based on an analysis of objective data, such as ridership numbers.

The justification by most transit agencies for implementing real-time transit information systems is to improve customer satisfaction. Information on the general qualitative impacts of these systems is available; however, the quantitative impacts of these systems are lacking. Therefore, a need existed to develop a quantitative structure to estimate the benefits and costs of these systems, to assess the value of these benefits and costs, and to determine the return on investment.

3.0 PROJECT APPROACH

The purpose of this project was to conduct a return-on-investment study of bus real-time traveler information systems, also referred to as real-time bus arrival information systems. The study was limited to real-time traveler information systems for buses (as opposed to bus and passenger rail) to establish the process within a manageable scope and project size. This section describes the study approach applied to develop this quantitative approach to the benefit-cost structure.

A major goal of the Federal Transit Administration (FTA) has been to increase transit ridership by two percent annually. It is hypothesized that real-time bus arrival information systems may help transit agencies increase ridership. This project technical approach measured the impacts of these systems, including the impacts on transit ridership.

3.1 Overview of the Study Process

The overall goal of the project was to develop generic benefit-cost elements and a generic methodology (set of criteria) for evaluating the return on investment (ROI) of real-time bus arrival information systems, and to demonstrate a benefit-cost analysis (calculate the return on investment of an operational real-time bus arrival information systems). Successful implementation of this project was intended to assist transit agencies in assessing the return on investment of real-time bus arrival information systems, shed light on the benefits versus the costs of these systems, and provide objective justification for implementing real-time transit information systems or for spending funds on other higher priority capital projects. Since the process application results were favorable (i.e., benefits exceed costs), the project results and the methodology may lead to a more widespread deployment of these systems.

The project was initiated with the development of an outreach effort. This involved the conduct of an expert panel to identify return-on-investment evaluation elements and suggest a methodology for the benefit-cost analysis. The project team convened an expert panel representing transit agencies that have operating real-time bus arrival information systems and automatic vehicle location (AVL)/real-time transit information systems, as well as vendors of these systems. The panel session was organized to provide feedback to the study team on the proposed process, and to refine the process to reflect investment planning and implementation operational conditions.

Evaluation process elements included items such as:

- Benefits
- Costs
- Measures of effectiveness
- Data elements
- Data sources.

Together the project team and the expert panel determined the preferred approach to conduct a return-on-investment study of real-time bus arrival information systems. This approach is based on the perspective of and input from transit agencies and AVL/real-time transit information system vendors.

A survey was conducted with these selected transit agencies with operational systems and vendors to investigate the unit costs of these systems and to identify any studies that the transit agencies may have performed on these systems where system impacts or the return on investment was measured. Data availability was provided through the survey, but it was limited because virtually all of the systems had not completed a benefit-cost analysis of the system investment. The benefit-cost methodology developed for the study was applied and tested on the investment in real-time bus arrival systems at TriMet in Portland, Oregon. This application of the benefit-cost process served as the demonstration of the study methodology and its elements.

3.2 Return on Investment

The heart of the return-on-investment evaluation was a detailed benefit-cost analysis. When used to evaluate new technologies, traditional benefit-cost analyses compare the discounted streams of costs and benefits associated with the proposed technology—including costs and benefits to individual riders and operating agencies, and to society in general. Implementation of the new technology is viewed as desirable—either to the individuals or to society as a whole—when the benefits of implementation exceed the costs (i.e., the ratio of discounted benefits over discounted costs exceeds one). While traditional benefit-cost analyses are generally limited to costs and benefits that are quantifiable in monetary (dollar) terms, practitioners have developed several techniques to include both and qualitative and non-monetary quantitative factors as well.

Two approaches were examined for calculating the costs—direct costs only and both direct and indirect costs associated with the real-time information systems. Using the direct costs only would give a model useful for incremental cost calculations. Using the fully-allocated model would be more useful for modeling larger deployments. It was agreed that the fully-allocated cost model was the preferred approach and that it would be best to show both methods as appropriate.

The most appropriate methodology for quantifying the benefits was also examined. Based on OMB Circular A-4, all of the traditional transit benefits of increased ridership and reduced dwell time apply to this evaluation, with the exception of increased fare revenue, which is a transfer. On page 45 of the Circular, it recommends that benefits be reported in three categories:

I. Monetized
II. Quantifiable, but not monetized
III. Qualitative, but not quantifiable

The quantification process and the monetization of the costs and benefits were guided by the methodology description included in the following chapter. For example, using the list of potential benefits included there, the following may be considered in the ROI in category I:

- New Riders:
  - Transit Travel time savings
  - Reduced auto costs
- Existing Riders:
  - In-vehicle transit travel time savings
  - Out-of-vehicle transit travel time savings
- Highway Users:
  - Reduced congestion/delay from increased transit ridership
- Agency/Operator Benefits:
  - Reduced O&M costs
- Social Benefits:
  - Reduced highway maintenance/administration costs (may be negligible)

There are also potential benefits that are difficult to monetize (category II) and may be very small:

- Improved mobility for new riders

- Reduced emissions - air
- Reduced emissions - noise
- Reduced accident rate

Finally, there are category III benefits that are difficult to quantify, such as improved customer satisfaction through an increased sense of security. The best way to gauge these benefits is through passenger satisfaction or preference surveys.

3.3 Kickoff Meeting

The project team attended an initial kickoff meeting with FTA officials at the U.S. DOT headquarters in Washington, DC, to discuss the project goals and expectations. The meeting focused on the project approach, staffing levels, schedule, budget, tasks, deliverables, and travel. The project manager and key staff assigned to the project attended the kickoff meeting. The project team took notes and prepared meeting minutes of the key points discussed. A clear understanding was gained of the project challenges and the expectations for the results.

3.4 Expert Panel Workshop

With direction and assistance from the FTA, the Booz Allen project team established an expert panel of representatives from transit agencies that have operating real-time bus arrival information systems, and representatives from major AVL/real-time transit information system vendors. The panel reflected a diverse set of transit agencies, considering factors such as transit agency size and geographic location. Also, the mix of transit agencies included those that have developed systems in-house, developed systems with an AVL vendor, or have purchased complete systems from a vendor.

The project team organized and conducted the Expert Panel Workshop to refine the individual cost and benefit elements and to provide feedback on the proposed methodology for performing the return-on-investment studies of real-time bus arrival information systems. The purpose of the expert panel was to obtain information from transit agency representatives on how transit agencies measure or would measure a return on investment of these systems. Comparable input was also garnered from AVL/real-time transit information system vendors. To facilitate and provide structure for the workshop, the project team identified and presented draft return-on-investment study elements and a draft methodology. The expert panel discussed the draft elements and methodology proposed by the Booz Allen project team and suggested revisions to the process to emphasize the benefit-cost approach. The panel reached a consensus on the benefit-cost elements and the methodology.

The project team also distributed a survey with the expert panel to identify transit agencies that may have:

- Unit cost information on real-time bus arrival information systems

- Documented studies on real-time bus arrival information systems where system impacts or the return on investment was measured
- Data available for the contractor to perform a return-on-investment study using the evaluation elements and methodology developed by the expert panel and contractor.

The results of the survey and the panel workshop are included within the report.

3.5 Benefit-cost Methodology and Application

With direction from the FTA and the results from the expert panel workshop, the project team contacted selected transit agencies to apply the benefit-cost methodology to a particular real-time bus arrival system investment decision. The request focused on availability of unit costs, benefits, impacts, and return-on-investment information on real-time bus arrival information systems. This information was found available at TriMet in Portland, Oregon. The project team worked with representatives of this agency to apply the return-on-investment study on an operational system using the evaluation elements and methodology developed for the project. This application of the benefit-cost methodology served as the initial validation of the methodology and its elements.

The following chapters of this final report present the results of the expert panel meeting, the summary of the survey results, the benefit-cost methodology and the application of that methodology on the operational passenger information system at TriMet in Portland, Oregon. Candidate sites for future field test and return-on-investment study of real-time bus arrival information systems are also presented.

4.0 EXPERT PANEL WORKSHOP

The first sections of this chapter include an introduction followed by a synopsis of the major points, issues, and results of the workshop. The next section is a summary of the survey responses and data received. The concluding section is a brief discussion of the next steps and the approach to refine the benefit-cost methodology.

4.1 Introduction

A proposed methodology was presented to an expert panel consisting of invited representatives from 11 transit agencies from across the country with implementation experience, 4 system suppliers, the American Public Transportation Association, Federal Highway Administration, Federal Transit Administration and its consultant on this task, Booz Allen Hamilton. The one-day workshop was held on August 9, 2005 at Montgomery County's Public Safety Communications Center in Gaithersburg, Maryland. The role of the expert panel was to:

- Validate the boundaries of the relevant systems and technologies
- Provide input on the proposed benefit-cost analysis methodology
- Identify and help quantify all relevant costs and benefits
- Identify additional data sources
- Provide insight on barriers to implementation

Members of the expert panel were also asked to complete and return a survey to document the individual real-time information system implementation experiences.

4.2 Workshop Synopsis

This section presents a synopsis of the key issues identified during the Expert Panel Workshop. The tentative agenda for the meeting and the complete list of attendees is included in **Appendices A** and **B** of this report. The meeting attendees discussed the key issues related to the delivery of real-time traveler information, which can be grouped into five major topics:

- Enabling technologies and customer-facing passenger information systems
- Quantitative and qualitative benefits of these technologies
- Implementation decisions and barriers

- Data quality
- Return-on-investment analysis

4.3 Technologies Utilized

The expert panel recognized the essential contribution of a number of vehicle location and network communications technologies that enable the implementation of real-time passenger information. Current enabling technologies include voice and data radios, Global Positioning Systems (GPS), Galileo (new satellite location technology), loop-inductors, signposts, repeaters and radio frequency identification devices (RFID). These enabling technologies are complemented by supporting technologies, such as software integration and servers. Customer-facing or passenger information technologies include customer service centers, websites, traveler information line (511 support), dynamic message signs (DMS), information kiosks and voice annunciation systems. These passenger information technologies were recognized as independent options to provide different channels for each customer market segment, trip purpose, income level, age and origin and destination locations.

Other issues related to the technologies involved the canyon effects of GPS-based location determination equipment, polling rates, the importance of open architecture, and the decision between dedicated and public bandwidth, fiber optic and wireless computer networks, and commercial or private technologies, which affect the quality, availability and application of real-time information.

4.4 Benefits

There was recognition by the expert panel of the importance to consider both quantitative and qualitative benefits, including service operations and customer satisfaction. While panel members felt there were clear benefits to real-time information technologies, there was not general agreement on what these benefits are and how they are quantified. Benefits were also identified that result from enabling technologies and customer facing information systems. There is also an overlap of the two that makes it difficult to isolate the incremental benefits of real-time information systems layered on enabling technologies. These are summarized in **Table 4-1**.

Table 4-1
Key Benefits of Real-Time Bus Arrival Information

Supporting Technologies	Overlapping	Real-Time Information
• Improved on-time performance and schedule planning • Improved incident management and response times	• Reduced passenger wait times and better service reliability also resulting in reduced safety/security risks • Increased customer satisfaction	• Use of passenger information system to disseminate safety and security messages, and next-bus arrival information

Supporting technologies can improve on-time performance and schedule planning through real-time operations management and development of realistic schedules. The resulting, more reliable transportation can help increase ridership by assisting passengers in keeping their work and personal schedules. Real-time operations management also improves failure management and incident response times, which helps restore a system back to normal. These systems also provide litigation support for accident investigations and customer complaint claims.

Passenger wait times are reduced by way of more reliable service and passenger choices. Pre-trip information sources, such as customer service centers, websites, traveler information line (e.g., 511 support), have a direct impact upon reduced passenger wait times and help to increase choice travel. Although stop signage with next-arrival information does not directly reduce wait times, since passengers have to be at the stop to know this information, it reduces anxiety and may provide a perceived benefit of less safety and security risk. Real-time vehicle information helps operations management maintain buses on schedule, which reduces service variability and increases passengers' perception of performance. Real-time information is most valuable to passengers in departure time decisions, i.e., what time to depart to a stop, which requires access to pre-trip information. By knowing next-bus arrival information, passengers may be able to make better use of their time or seek alternate modes of transportation (e.g., if the wait time is too long).

There is also the benefit of using passenger information systems for public advisories, street closures, accidents or re-routing. Communication systems, such as Transit Television Network (TTN), were being used to disseminate safety and security messages to the riding public.

Overall, there is improved fleet management and incident response times, which helps restore the system back to normal. This may reduce the delay incurred by the passengers, and increases customer satisfaction by way of better service reliability, convenient traveler information and improved customer services.

4.5 Implementation

Several key issues in system implementation were identified by transit agencies, which are summarized into four categories.

4.5.1 Customer-Driven Vs. Budget-Driven

The decision and level of implementation of real-time passenger information systems can be driven by customer demand (or public pressure) and quality of service improvements or by the available budget. One transit agency stated that the decision to invest in real-time system process was driven by the directive of senior staff, board members and political stakeholders as a means of improving the quality of customer service. Several additional panel members agreed that this influence drove investment decisions more than internal service improvement initiatives. This theme was agreed by virtually all of the panel members, emphasizing top-down initiatives to invest in these passenger information systems. As a consequence, the directive of agency management to pursue real-time investments as an agency goal often obviated the need for agency staff to perform their own, internal return-on-investment studies for these investments. It was also noted that implementation can be driven by customer expectations if similar passenger information system exists on a different mode.

4.5.2 Barriers to Implementation

Barriers to implementation of the system and organizational changes necessary for implementation identified by the panel included:

- Security concerns with regards to the vulnerability of attacks knowing information about where the bus is and when it is arriving
- Department and staff coordination, especially for regional agencies with multiple transit providers
- Fleet maintenance and management, especially if only a subset of buses are equipped

- Organizational changes in internal staff and management processes including the use of the new data and hiring new staff or training existing staff with the skills needed to coordinate integration and maintain the data.

4.5.3 Incremental or System-Wide Implementation

On the question of the scale of implementation, one transit agency preferred the flexibility of phased/incremental implementation of system components. Another agency emphasized the difficulties in incremental installation based on the difficulties to maintain the fleet along the same route. For another agency, the experience of implementation was somewhere between, phasing system components on a garage-level basis. Also discussed was the level of cooperation between the agency and the supplier during implementation.

4.5.4 Marketing

To make riders aware of the new information sources, a number of agencies mentioned the use of online resources (such as their website) and other media to promote the new systems. Other agencies did no customer outreach or marketing after implementation. It was suggested that marketing of the passenger information system should be included within the implementation plans for these systems.

4.6 Data Quality

The agencies represented agreed that reliability and data accuracy are very important. The public needs to feel confident that the information is accurate and up-to-date to accrue the most benefit from these systems. The information needs to be kept current and delivered reliably over time because public use and expectation increases as more passengers get familiarized with the system. On that regard, the management of the system data often requires business process re-engineering and change management to take place within the agency with the goal of ensuring that system data are maintained and delivered in a timely and accurate fashion. The use of the information within the ongoing management and operations performance reporting was a key consideration for the system.

The participating agencies also stated that good system integration is important. One important condition to the use and success of passenger information is an accurate, geo-coded bus stop inventory to each side of street.

4.7 Return on Investment Analysis

With regards to a ROI analysis of passenger information systems, the agencies agreed that the process should identify the enabling technologies first, and then focus on incremental passenger information (customer-facing) technologies. They also pointed out that passenger safety and security should be included in the return-on-investment analysis. They then emphasized the benefit-cost type of approach for the return-on-investment methodology.

An unanticipated result of the expert panel workshop was the realization that these agencies are generally not using formal return-on-investment analyses for their decision making process for these information systems. None of the participants indicated having performed a formal ROI analysis for either the real-time info systems or enabling technologies. In some cases, analytical techniques were used in the evaluation of alternatives, but not necessarily for the investment decision. Therefore, the implementing agencies did not have a clear, objective handle on the value of these investments versus the cost of implementation.

The largest challenge to developing a formal methodology appears to be an absence of clear benefits measurements or measures of effectiveness and significant data quality issues. The agencies and vendors also emphasized that cost allocation and evaluation of benefits of individual system components were difficult to address on a segregated level. Separation of the enabling technologies from the individual systems was emphasized as a critical issue for the methodology to the project team.

4.8 Summary of Surveys

The purpose of the survey was to document implementation, current deployment and rider use of real-time bus information systems at panel member agencies. Specifically, the objectives of the survey were to:

- Identify the real-time information systems deployed by panel member agencies and determine the level of deployment (e.g., percent of AVL equipped vehicles)
- Identify all supporting technologies (e.g., AVL/Computer-Aided Dispatch (CAD), communications network)
- Estimate the cost ranges for these systems
- Determine the number of boardings where passengers used real-time information prior to (or during) their trip and the potential passenger time savings or other end-user benefits

A description of the survey is included in **Appendix C**. Survey data were used to help determine the technologies in use and the level of deployment, and to better understand customer utilization in order to help measure and aggregate benefits from real-time information. The following subsections summarize the survey responses received by technology. The survey was distributed to the 11 participating expert panel agencies; the total number of respondents was 7:

- Ride-on (Montgomery County)
- TriMet (Portland)
- Arlington County Transit
- Long Beach Transit
- Los Angeles County MTA
- Pace (suburban Chicago)
- King County Metro

4.8.1 Communications Network

Most respondents indicated that they have radio communications and global positioning satellite (GPS) location determination technologies. One participant responded that they have both cellular and computer wide area networks along with GPS receivers. The capital cost of communications networks varied, with a range of approximately $2,000-$3,000 per vehicle. Two agencies reported two separate cost values, one for replacement and another for upgrade of software and hardware. Maintenance costs had a higher range of cost values, varying from $145 to more than $650 per vehicle per year. One agency stated their system was still under warranty and no recurring cost information was available.

4.8.2 Automatic Vehicle Location (AVL)

GPS and computer aided dispatch (CAD) systems were the most popular technologies in AVL systems. Two agencies reported having signpost positioning devices and, of these, one also indicated having web-service, telephone and an interactive voice response system as part of their AVL system.

An estimate of average capital cost per vehicle was difficult to determine because most of the costs reported were part of a packaged procurement, which included the tracking/communications systems, real-time information and other systems. **Table 4-2** summarizes the cost values reported by four of the agencies.

Table 4-2
Automatic Vehicle Location Systems Costs

Scale of Deployment	Capital	Operational	Maintenance
240 / 353	**$6,000,000**	**$25,000/yr**	$65,000/yr *
~800 vehicles	**$6,300,000 ***	**Not reported**	$50,000/yr for maintenance contract
30	**$136,000**	**$20,000/yr**	$12,550/yr
~1300	$9,000,000 **	Not reported	Not reported

* Reported as including the CAD system; ** Initial cost plus upgrade

4.8.3 Real-Time Information

Four agencies stated having software and server technologies in the area of real-time information systems. One of the software packages reported was developed by a local university. The reported capital, operational and maintenance costs of three of these systems are summarized in **Table 4-3**. The cost of the real-time system for one of these four agencies was included in their AVL costs and cannot be separated out. Therefore, the information is not included in the table.

Table 4-3
Real-time Information Systems Costs

Scale of Deployment	Capital	Operational	Maintenance
13 wayside signs	**~$10,000/unit**	**Included in overall agency communications cost**	0.5 Full-Time Employee (FTE)
4 units	**$32,000 plus $35,000 for software**	**$5,000/yr**	$4,000/yr
Real-time predictions at three transit centers and web	$500,000 for Location View (predicted times at location) $232,000 for Map view (location of buses)	$10,000/yr	$10,000/yr

4.8.4 Passenger Information

Only three of the seven agencies reported detailed cost information about passenger information systems. These agencies reported the use of servers and landline internet as the enabling technologies. The reported capital, operational and maintenance costs of the other three systems are summarized in **Table 4-4**.

Table 4-4
Passenger Information Systems Costs

System	Capital	Operational	Maintenance
Servers and Landline Internet	**640 programmer hours / year**		
Servers	**$35,000 / yr**	**$5,000/yr**	$4,000/yr
Real-time predictions at three transit centers and web.		~ $35,000 / yr	

4.8.5 Phone-Based Information

Again, only three of the seven agencies recorded responses about phone-based information (the same three that provided Passenger Information survey data). All three reported having a customer service line, with only one of these having a 511 phone system. The third agency reported had the oldest and largest deployment of these systems, installed in 1991, with upgrades in 1993, 1996 and 1999, is currently being replaced. This phone-based information service for this agency provides scheduled times only, not predicted arrival times. The reported capital, operational and maintenance costs of the other three systems are summarized in **Table 4-5**.

Table 4-5
Phone-Based Information Costs

Technology Utilized	Scale of Deployment	Capital	Operational	Maintenance
Customer Service Line	**All buses and rail**	**Included in web-based development**		
Customer Service Line	**All revenue hours**	**$54,000**		$4,000/yr
Customer Service Line, Schedule Information, 511	Potential for 95%, not currently fully-utilized	~ $100,000 in 1999	One Full-time Employee	~ $5,000/yr

4.8.6 Wayside Activity

Four agencies identified some type of wayside or in-vehicle information technology, such as Dynamic Message Sign (DMS) and Automatic Voice Annunciation (AVA), implemented on their bus system. The results of the wayside activity part of the survey are summarized in the **Table 4-6**.

Table 4-6
Wayside Activity Characteristics

Scale of Deployment	Cost	Date of Deployment
19 DMS	**$12,000**	2001-2004
13 wayside signs, with 4 having voice annunciation	• **Capital: Approx. $10,000 per unit** • **Operational: approaching zero.** • **Maintenance: 0.5 FTE**	January 2001
4 VMS, 9 Kiosks at points of interest. AVA on all fixed routes.	**Not reported**	July 2002
Flat panel monitors (2) at 3 transit centers, LED signs (8) on one route.	• Cost of computer systems: ~$5,000. Discontinued LED cost about $3,000 per sign. • DSL connection cost $80/month/location • For LED sign demo, cost of $70/month for cell connection • $1,000/yr for maintenance.	Two locations in late 1990's, one in 2004. LED sign demo available 2004-June 2005.

5.0 RETURN ON INVESTMENT: THEORY AND APPLICATION

This chapter describes the proposed approach for evaluating the return on investment (ROI) from future real-time information system investments. The chapter begins by considering a range of alternate ROI measures that may be used for such analysis and the traditional benefit-cost analysis as the preferred approach for this investment type. Specifically, the benefit-cost analysis provides the best means of capturing the large potential benefits that accrue to the users of real-time information systems, benefits not considered by traditional ROI measures. The chapter then goes on to consider how to apply the benefit-cost analysis to real-time information system investments. Here, two options are provided: (1) comparisons of gross investment benefits to gross investment costs and (2) the use of normalized, cost effectiveness measures (similar to the cost per new passenger measure used by Federal Transit Administration's New Starts evaluation process). Finally, this chapter concludes with the identification of the specific types of investment benefits that should be included in the evaluation of real-time information systems, as well as the challenges inherent in obtaining these cost and benefit data.

5.1 ROI Measures and Public Transit Investments

The objective of return-on-investment measures is to determine how effective a particular investment has been in generating investment benefits. Many of these measures have their origin in the private sector, where for-profit business enterprises continually seek new ways to reduce unit costs or increase revenues as a means of increasing both profits and shareholder value. Given these business objectives, many traditional ROI measures are focused on evaluating investment cost savings that accrue to the entity (e.g., firm) making the investment, but place no emphasis on the benefits (or costs) to the investing entity's customers or to society in general.

Examples of two traditional measures are found in **Table 5-1**, including the accounting rate of return (ARR) and the payback method. ARR compares the magnitude of the annual cost savings that result form making the investment (e.g., cost savings from an improved production process) with the total cost of that investment. Here, a higher ARR ratio denotes higher annual investment cost savings as a percent of the project's investment cost and hence a higher return. Similarly, the "payback" method relates the initial investment cost to the annual benefits of that investment [1]. This provides a crude measure of the time (in years) required to "pay back" the initial investment cost via cost savings. A project with a shorter payback period has a higher return.

Both of these traditional measures suffer from two critical problems. First, neither method takes into consideration either the "value of time" (i.e., the fact that a dollar today does not have the same value as a dollar next year) or the timing of investment costs and benefits over time. Investment costs (including those for real-time information systems) are typically greatest in one initial period, whereas investment benefits (e.g., time savings to riders) may accrue to the project for many years into the future, a flow of costs and benefits over time that is not well captured by either of the ARR or payback methods.

Table 5-1
Evaluation of Return-on-Investment Standard Methods

Method	Approach	Calculation
Accounting Rate of Return (ARR)	**Annual cost savings as a percent of initial investment cost**	ARR = $\frac{\text{Reduction in annual costs}}{\text{Initial investment cost}}$
Payback Method	**Time taken to recoup initial investment cost**	Payback = $\frac{\text{Initial investment cost}}{\text{Annual investment benefits}}$
Benefit-Cost Analysis using Net Present Value (NPV) *Preferred method*	**Benefit-cost analysis determines if discounted investment benefits exceed discounted costs**	Determine if: $\sum(\text{Benefits}_t)/(1+i)^t > \sum(\text{Costs}_t)/(1+i)^t$ *Where i is the investor's cost of capital and t is the year in which costs and benefits accrue.*
Internal Rate of Return (IRR)	Determine discount rate at which discounted benefits equal discounted costs	Find *i* such that: $\sum(\text{Benefits}_t)/(1+i)^t = \sum(\text{Costs}_t)/(1+i)^t$

Second, the ARR and payback measures only measure those investment benefits that accrue to the entity making the investment (i.e., a profit oriented business). In other words, these measures do not consider the value of investment benefits accruing to other potential stakeholders, including either the firm's customers or to society. This problem becomes critical when evaluating the investment benefits from real-time

[1] *Note that if the benefits included in the payback method are limited to only the annual cost savings resulting from the investment, then the payback method is merely the inverse of the ARR method (i.e., Payback = 1/ARR)*

information systems. In particular, the benefits of real-time information systems accrue primarily to those transit riders using the information generated by these systems, with few if any benefits accruing to the transit agency making the investment. Given this consideration, and the problems cited above, the ARR and payback methods are considered inappropriate to the problem of evaluating the effectiveness of investments in real-time information systems.

In contrast to the ARR and payback methods, Table 5-1 provides two alternative investment return measures better suited to the evaluation of real-time information system investments. These include net present value (NPV) based benefit-cost analysis and a related measure, internal rate of return (IRR). The goal of benefit-cost analysis is to compare the discounted stream of investment benefits with the discounted stream of investment costs. The investment is considered to be effective if the discounted benefits are greater than or equal to the costs. It is important to note here that benefit-cost analysis offers the following benefits over the simpler ROI ratios discussed above.

Advantages of Benefit-Cost Analysis:

- Evaluates the timing of costs and benefits over the full life of the project
- Accounts for the "time value of money"
- Captures *all* investment costs (capital and operating)
- Captures the benefits accruing to *all* stakeholders including:
  - the investing entity (e.g., a transit agency),
  - other users of the investment (e.g., transit riders) and
  - society (e.g., from potential reductions in auto use)
- The ratio of discounted projected benefits to discounted project costs (benefit-cost or B/C ratio) provides an accurate measure of investment return. Specifically, investments with a B/C ratio > 1 represent positive investment returns. The magnitude of the ratio denotes the extent to which benefits exceed costs. Alternatively, benefit-cost analysis is used to calculate a net investment benefits, equal to the project's total discounted benefits less the total discounted costs.

Inspection of the calculations in Figure 5-1 above reveals that the internal rate of return method (IRR) represents a modified application of the benefit-cost model. Specifically, this method determines the exact interest rate at which a project's discounted benefits equal its discounted costs. This rate is then referred to as the IRR. While offering many of the same benefits of benefit-cost analysis, IRR offers the additional benefit of determining those interest rate conditions under which the project has a positive return (i.e., any interest rate *less* than the IRR). However, by not focusing on the actual cost of capital, IRR does not measure the actual magnitude of the investment benefits (i.e., how much bigger are investment benefits as compared to investment costs?). Also, under some circumstances IRR can generate *two* interest rate solutions, leaving the analyst to determine which solution is the correct answer.

Given these issues, it is recommended that discounted benefit-cost analysis be utilized to evaluate the effectiveness of investments in real-time information systems.

5.2 Application of Benefit-Cost Analysis to Real-Time Information Systems

Effective application of benefit-cost analysis to the assessment of a real-time information system investment requires the identification and collection of all benefit and cost data associated with that specific investment. A comprehensive discussion of the benefits and costs associated with real-time information system investments is provided below. Once collected, these data must then be incorporated into a benefit-cost model for that investment. A proposed model for the analysis of real-time information systems is provided in **Equation 5-1** as a benefit-cost ratio, and in **Equation 5-2** as a net benefits calculation.

$$Benefit-Cost\ Ratio = \left\{ \frac{\sum_{t=1}^{n} \left\{ \left(\left(Users,\ Agency\ \&\ Social\,Benefits_t \right) * \left(1 + Rider\,Growth \right)^t \right) / \left(1+i \right)^t \right\}}{\sum_{t=1}^{n} \left\{ \left(Investment\ \ Cost_t + O\,\&\,M\,Costs_t \right) / \left(1+i \right)^t \right\}} \right\} \qquad (5\text{-}1)$$

$$Net\,Benefits = \sum_{t=1}^{n} \left\{ \left(\left(Users,\ Agency\ \&\ Social\,Benefits_t \right) * \left(1 + Rider\,Growth \right)^t \right) / \left(1+i \right)^t \right\} - \sum_{t=1}^{n} \left\{ \left(Investment\ Cost_t + O\,\&\,M\,Costs_t \right) / \left(1+i \right)^t \right\}$$

(5-2)

For equations 5-1 and 5-2, i is the discount rate, n is the life of the project or investment, and t is the project year (from 1 through n).

The numerator of this equation identifies the total benefits accruing to all investment stakeholders including real-time information system users (i.e., riders that access the information system), the agency that owns and operates the system and finally any benefits accruing to society in general (e.g., if the investment induces increased ridership, society may benefit from reduced auto travel). Assuming the magnitude of these benefits are related to the number of riders accessing real-time travel information, the benefits may then need to be scaled over the life of the investment (*n)* to capture projected ridership growth.

The denominator of this equation considers the investment's initial capital cost as well as the ongoing costs to operate and maintain the real-time information system over the life of the investment. It may prove necessary to scale these costs to reflect the influences of increasing operating and maintenance cost with system age as well as any costs associated with system "modernization" (e.g., web site updates).

5.3 Cost Effectiveness Measures

The net-benefits measure shown in equation 5-2 compares a project's *total* investment benefits with its *total* investment costs. For many investments, this "total" net-benefits measure can be difficult to compare across projects and sometimes difficult to interpret within any given project. For example, consider the benefit-cost analysis of the two hypothetical project examples in **Table 5-2**. Both projects have B/C ratios greater than one and positive net benefits. Hence, both projects have good investment returns. Note, however, that while project A has the better return per dollar invested, project B provides larger net benefits (implying that project B is the more expensive). Two questions arise. First, which of these two projects is the more desirable? Second, given that the net benefits for a real-time information system come from a range of sources (potentially including agency cost reductions, time savings to riders and perhaps local reductions in auto use), what does it mean to have "$20 million" in net benefits?

Table 5-2
Hypothetical Project Comparisons Using Benefit-Cost Measures

Project	B/C Ratio	Net Benefits (B-C)	Net Benefits per Informed Trip
A	**1.2**	**$20 million**	$1.11
B	1.1	$25 million	$1.85

One means of addressing these issues is to normalize each project's net benefits to a common basis. In the case of real-time information system investments, the logical choice is to evaluate the net benefits of each investment on a "per informed trip" basis. This calculation is outlined in **Equation 5-3**.

$$Net\ Benefits\ Per\ Informed\ Trip = \left\{ \frac{Annual\ Benefits - Annual\ O\ \&\ M\ Costs - \sum_x Annualized\ Capital\ Costs_x}{Informed\ Trips\ Per\ Year} \right\} \quad (5\text{-}3)$$

Here, the numerator compares the annual benefits of the real-time information system with its annualized capital and operating costs. The annual benefits are the sum of all benefits to the agency, the information system users (i.e., information using riders) and any benefits to society. The annual operating and maintenance (O&M) costs include all costs to operate and maintain the real-time information system. Finally, calculation of the annualized capital costs for component *x* for the investment are provided in **Equation 5-4**, where *i* is the discount rate. Specifically, this equation shows how to calculate this value for a specific investment component (e.g., electronic information sign). This calculation takes into consideration the expected useful life of a given component and the agency's cost of capital to determine the component's expected annualized capital cost. These annualized capital costs must then be summed across all capital components to determine the total annualized capital cost for the investment (see Equation 5-3).

$$Annualized\ Capital\ Cost_{Component\ x} = \left\{ \frac{i}{1-(1+i)^{-(Useful\ Life)}} \right\} * Capital\ Cost_{Component\ x} \quad (5\text{-}4)$$

The net annual benefits in the numerator of equation (5-3) are next divided by the denominator, which is the annual number of trips on which real-time information is used. This calculation yields a measure of the net benefits per informed trip. The hypothetical examples on Table 5-2 suggests that project B yields significantly higher benefits per informed trip, and hence likely represents the better project (on the assumption that real-time information systems should primarily benefit agency riders). The example benefit-cost analysis of Portland TriMet's Transit Tracker information system presented in the next chapter relies heavily on the approach presented in equation 5-3. FTA also uses a similar approach with its cost effectiveness measure (cost per new rider) for New Starts projects.

It is recommended that this approach be considered for future evaluations of real-time information system investments. In practice, it may prove difficult to obtain reasonable estimates of annual benefits, operating and maintenance costs, and/or real-time information system costs that are representative of the entire life of the project, which may make use of this approach problematic.

5.4 Identification of Investment Costs and Benefits

Effective application of benefit-cost equations 5-1, 5-2 and 5-3, require the identification all potential costs and benefits of real-time bus information systems to all relevant stakeholder groups. The analyst then needs to collect these data through agency interviews, passenger surveys and related sources. When identifying and collecting these data, it is important to consider both qualitative, as well as quantitative impacts (i.e., costs and benefits) to the transit agency, information system users, road users and society in general that result from real-time information system investments. Based on OMB Circular A-4, it recommended that benefits be reported in three categories:[2]

I. Monetized
II. Quantifiable, but not monetized

[2] *Office of Management and Budget, Circular A-4 issued September 17, 2003, page 45.*

III. Qualitative, but not quantifiable

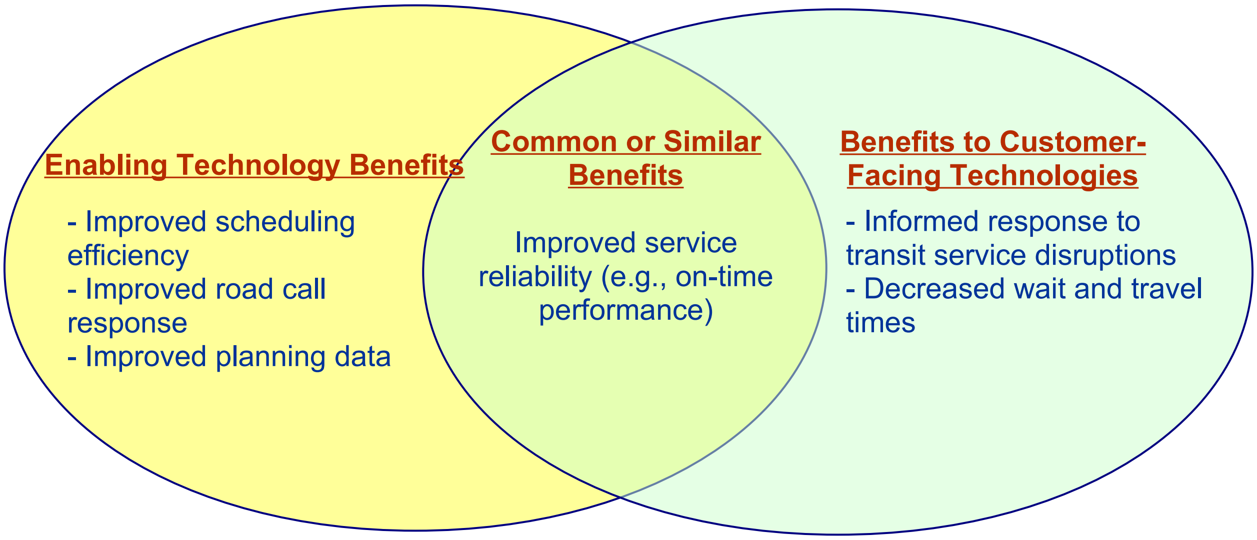
Benefits should be monetized or at least quantifiable in order to apply a benefit-cost analysis. However, it is often difficult to monetize benefits because they are often influenced by numerous contributing factors, are vaguely defined, or are difficult to measure. For instance, it is difficult to attribute a ridership increase to a particular real-time passenger information system implementation without conducting a controlled experiment[3]. Short of this, a before/after passenger survey may suggest an approximate relationship between a change in customer satisfaction or revealed preference to the frequency of use or aggregate ridership figures.

5.5 System Boundaries

Investment in real-time information systems requires investment both in the "customer facing" technologies that the riding public can access (e.g., web sites, phone servers, electronic information signs) and also in "enabling" technologies that are required for real-time information systems to function *but which may be implemented independently of the real-time information system* (e.g., AVL, CAD, Automatic Passenger Counters). **Figure 5-1** illustrates the independent benefit categories of the customer facing and enabling technologies. Given that agencies can and do invest in the enabling technologies without "adding on" an investment in real-time information systems for riders, the question arises as to which benefits and costs to include in a benefit-cost analysis of the real-time information system. In other words, should the benefit-cost analysis include the costs and benefits of the enabling technologies or not?

Figure 5-1
Benefits of Enabling Versus Customer Facing Technologies

[3] *Ridership increases can result from a wide variety of factors included economic and population growth, changes in passenger fares, seasonal fluctuations and other factors. Given these sources of variation, it is difficult to attribute changes in ridership to any specific sources (e.g., introduction of a real-time information system). Hence, to effectively identify any ridership increases resulting specifically from a real-time information system investment would require a controlled experiment where the information system is only deployed on a portion of an agency's bus network, thus providing a basis to distinguish increases in ridership from the new information system versus other factors.*



There are two cases to consider here. First, if the transit agency implemented the enabling technologies as a "stand alone" investment and only implemented the real-time information system "after the fact", then the real-time information system should be assessed in isolation of all enabling technology costs and benefits. In contrast, if the transit agency invested in all technologies simultaneously (both enabling and customer facing), then the analyst needs to determine whether the real-time component should or even can be evaluated independently of the other investments required to support it, but which offer benefits independent of real-time information to passengers (e.g., AVL). If the decision is made to include all technologies, then it is only appropriate to include the benefits of all technologies, not just those relating to real-time information to passengers. If the purpose of the analysis is solely to evaluate the return on (the incremental) investment in real-time information systems, then the benefit-cost analysis should be limited to costs and benefits relating to the incremental investment.

5.6 Hierarchy of Investment Benefits

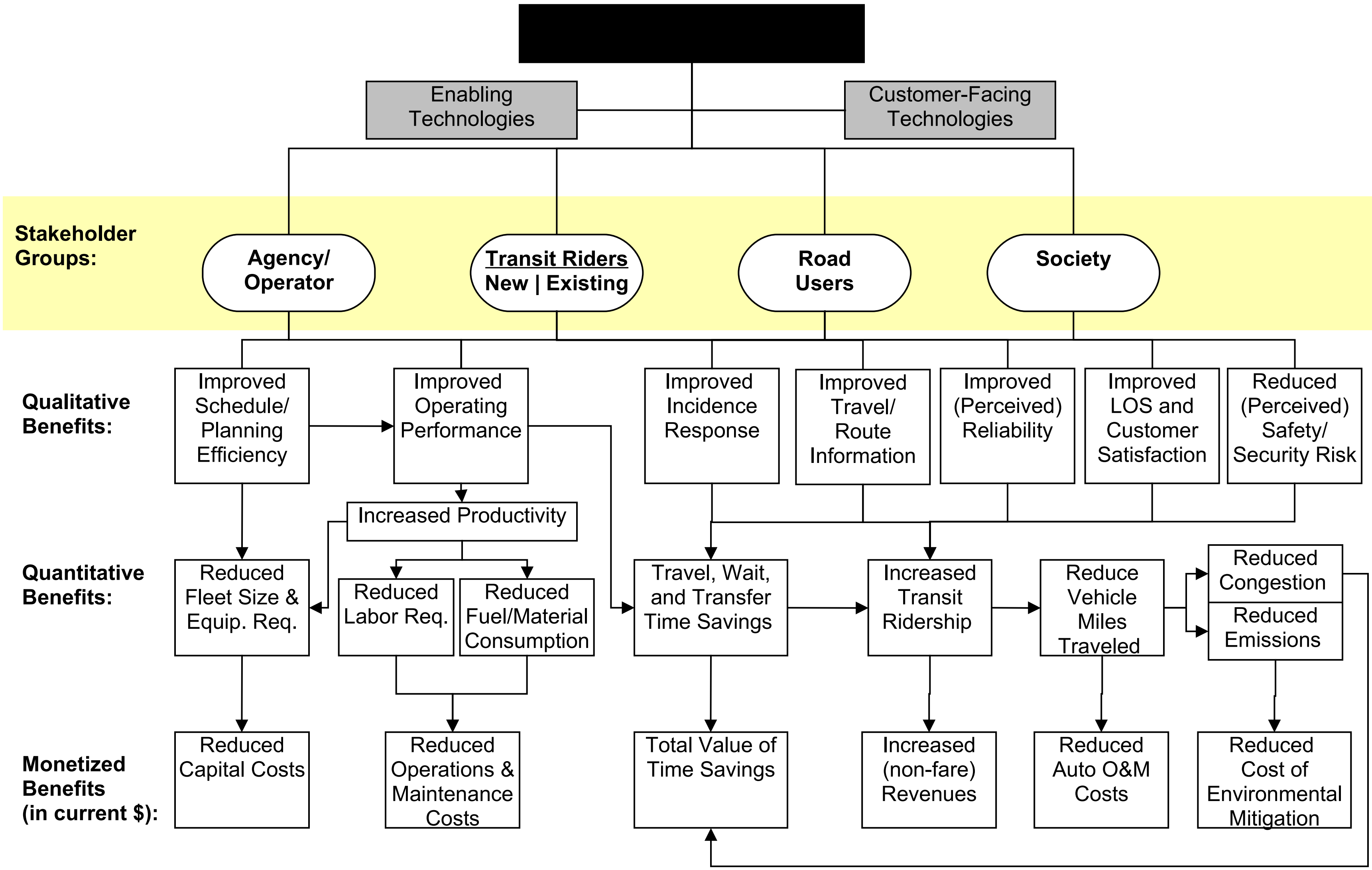
A hierarchical listing or "tree" diagram of the potential benefits of investment in real-time information systems is provided in **Figure 5-2**. Here, the white boxes represent all of the qualitative, quantitative, and monetized benefits discussed during the expert panel workshop, as well as those documented in the panel surveys or in the literature. Ideally, the list of benefits should be comprehensive, non-redundant, and mutually-exclusive. In practice, this can be difficult to accomplish because of interrelationships between benefits and the challenge of converting non-monetized benefits into current dollar values for NPV calculations.

The tree diagram captures the linkages between interrelated benefits and their possible conversion to quantitative measures. If monetized benefits are not available or not are directly measurable, then a next best measure may be one of the quantitative benefits presented in the diagram. There are standard methodologies for transforming quantitative measures into monetized measures. For example, wait-time or transfer-time savings as a result of real-time information can be monetized using a standard "value of time" for different time components and wage levels[4]. It is generally accepted that wait time is perceived to be twice as valuable as time-route or in-vehicle time.

The monetized benefits identified in Figure 5-2 capture all of the potential benefits of enabling (e.g., communications network, location technology, computer-aided dispatching) or customer-facing technologies (e.g., real-time prediction process, pre-trip information, way-side and in-vehicle information). All are applicable for a benefit-cost analysis (subject to the caveats of the system boundaries discussion above) with the exception of increased fare revenue, which would be considered a transfer between transit riders and the agency/operator. Controlled experiments or sophisticated survey methods are frequently used to capture qualitative benefits and convert them to quantitative measures.

[4] *For further information on value of time, the reader is referred to Chapter 3 of TCRP Report 78 "Estimating the Benefits and Costs of Public Transit Projects: A Guidebook for Practitioners," 2002.*

Figure 5-2


[redacted]
Enabling Technologies
Customer-Facing Technologies
Stakeholder Groups:
Agency/ Operator
Transit Riders New | Existing
Road Users
Society
Qualitative Benefits:
Improved Schedule/ Planning Efficiency
Improved Operating Performance
Improved Incidence Response
Improved Travel/ Route Information
Improved (Perceived) Reliability
Improved LOS and Customer Satisfaction
Reduced (Perceived) Safety/ Security Risk
Increased Productivity
Quantitative Benefits:
Reduced Fleet Size & Equip. Req.
Reduced Labor Req.
Reduced Fuel/Material Consumption
Travel, Wait, and Transfer Time Savings
Increased Transit Ridership
Reduce Vehicle Miles Traveled
Reduced Congestion
Reduced Emissions
Monetized Benefits (in current $):
Reduced Capital Costs
Reduced Operations & Maintenance Costs
Total Value of Time Savings
Increased (non-fare) Revenues
Reduced Auto O&M Costs
Reduced Cost of Environmental Mitigation

5.7 Customer-Facing Technology Benefits

The qualitative benefits and their relationship to quantifiable benefits are described in the following paragraphs.

5.7.1 Improved Travel/Route Information

Existing or potential transit riders can use real-time schedule information to make better decisions about when to initiate a trip, which services to use, and the expected duration of trips. This can reduce the overall travel time for users by reducing the wait or transfer time. Similarly, the availability of vehicle arrival time reduces traveler uncertainty and the related "wait-time anxiety" experienced by passengers waiting for the next vehicle to arrive at their stop. It may also induce new or existing transit riders to select better travel options/services that have lower travel times than they would have originally experienced. This can ultimately result in more frequent or new transit trips. In turn, new transit trips replacing private vehicle trips can reduce the operations and maintenance costs of road users by reducing the vehicle miles traveled by private vehicles including fuel, wear and tear, and insurance rates due to fewer accidents. It may also reduce congestion levels on roads with fewer vehicles, which can reduce environmental impact (i.e., air, noise and water pollution) and save travel time for road users.

5.7.2 Improved (actual or perceived) Reliability

Transit riders may experience or perceive greater service reliability if enabling technologies are being used to manage and operate the system. Even if a transit rider does not use "pre-trip" information provided by customer-facing technologies, studies have shown that passengers are more satisfied knowing how long the wait will be for the next bus or when a delay has occurred. Transit riders are more likely to use the service and potential transit riders are more likely to consider using the service with improved reliability.

5.7.3 Reduced (actual or perceived) Safety/Security Risk

Some research suggests that enabling and customer-facing technologies can at least improve the perceived safety and security of passengers [5], shifting ridership patterns if not ultimately increasing ridership overall. Transit riders may find comfort in knowing

[5] *USDOT Report by SAIC, "Oregon Regional Intelligent Transportation Systems Integration Program: Final Phase III Report: Transit Tracker Information Displays," November 2003.*

that the location of all vehicles is tracked or in knowing how long they will have to wait until the next bus arrives.

5.7.4 Improved Level Of Service (LOS)/Customer Satisfaction

Customer-facing technologies can increase convenience and quality of services, and reduce anxiety over delays and other problems. Moreover, customer complaints about poor or lack of service can be better handled with documented evidence of actual performance.

5.8 Enabling Technology Benefits

5.8.1 Improved Schedule/Planning Efficiency

The monitoring capability of enabling technologies together with the analysis of the data allows the agency/operator to make better long-term decisions about service planning. For example, an analysis of operations and maintenance data provided by enabling technologies can help improve the accuracy of fleet, labor, equipment and other future requirements. In essence, better matching the planned supply of services with the anticipated demand can reduce future vehicle service miles (VSM) and/or vehicle service hours (VSH). This can ultimately optimize planned capital investments in vehicles, facilities, and equipment.

5.8.2 Improved Operating Performance

Enabling technologies may improve short-term productivity by identifying and resolving short-term problems in operations and maintenance more quickly. For example, services that show poor operating performance (e.g. poor schedule adherence due to recurring congestion) can be altered to improve productivity and reduce the fleet, labor, equipment and other material requirements for operations. In essence, enabling technologies can help utilize resources more efficiently by reducing VSM and/or VSH while maintaining the level of service.

In addition, enabling technologies enhance the ability to streamline administrative processes (e.g., billing and payroll) and allow the flexibility of introducing elements of demand-responsive service (such as route deviation) into the regular fixed-route services. For example, paratransit services without AVL/CAD systems required several hours or even days of advance notice for trip reservations. With modern technologies, the reservation can be done in much less time or in real-time.[6]

[6] *Zhong-Ren Peng, et al. "Evaluation of the Benefits of Automated Vehicle Location Systems for Small and Medium Sized Transit Agencies." paper presented at the Transportation Research Board Annual Meeting, 1999.*

5.8.3 Improved Incident Response

Enabling technologies can improve the response to incidents with reliable communication channels and location information between a control center and the vehicles on the street. The control center may be able to track the location of all vehicles with a certain level of confidence to determine the impact of an incident or non-recurring congestion on operations. Dispatchers can use this information to devise service interventions or emergency operations in real-time.

6.0 DEMONSTRATION OF BENEFIT-COST ANALYSIS PROCESS TRANSIT TRACKER

This section provides a demonstration of how the benefit-cost evaluation process described in the last section can be applied to an actual real-time information system investment. The demonstration uses Portland TriMet's "Transit Tracker" system as the test case.

6.1 Introduction

The Transit Tracker system was selected for this demonstration for two key reasons. First, Transit Tracker has been the subject of multiple studies. Together, these studies provide a wealth of data regarding system investment costs (capital and operating), rider use of the Transit Tracker system and user perceptions of Transit Tracker and how it has impacted their transit experience (e.g., ease of use, impact on wait times and wait-time uncertainty). While these studies do not furnish all of the parameters required for a complete benefit-cost analysis, they do provide a reliable baseline for formulating that analysis.

Second, Transit Tracker represents an incremental investment "on top of" TriMet's existing ITS investments. In other words, TriMet completed investments in all of those ITS systems required to support Transit Tracker (i.e., AVL, CAD, communications, etc.) prior to and independent of its investment in the Transit Tracker system. Hence, investment in these "supporting" technologies would have occurred even if TriMet had not made the decision to develop Transit Tracker. This separation of Transit Tracker from all the preceding (and supporting) ITS investments provides the case for limiting the benefit-cost analysis to those costs and benefits directly attributable to the Transit Tracker investment.

At the same time, Transit Tracker has two key limitations that impose constraints on this benefit-cost demonstration. First, there are currently no data on key parameters required to complete a comprehensive benefit cost analysis. These parameters include the number of trips made using Transit Tracker information, the average time savings realized from using Transit Tracker (if any) and the value of reductions in wait-time uncertainty to patrons using Transit Tracker's real-time information. Second, the Transit Tracker system was designed to be used by both bus and rail passengers. Because of this, there is no clear and objective means of fully segmenting either the costs

or benefits of the Transit Tracker system between bus and rail users. For this reason, the analysis that follows represents an evaluation of the benefits and costs of Transit Tracker to *all* users (both bus and rail) and not just bus riders.
It is important to emphasize that the analysis presented here is only a *demonstration* and does not constitute a full scale benefit-cost evaluation of the Transit Tracker system. As will become apparent from the discussion below, there are currently no data available on many of the key parameters required to conduct a comprehensive benefit-cost assessment of the Transit Tracker (or any other) real-time information system. Therefore, the goals of this demonstration are only to (1) demonstrate *how* a benefit-cost analysis can be completed for a specific real-time system investment, (2) to highlight the *types of data* required to conduct a more comprehensive assessment and (3) to highlight those circumstances required to attain a positive return on investment in the Transit Tracker system. Ultimately, this analysis suggests that Transit Tracker likely enjoys appreciable positive net (social) benefits.

Comprehensive Analysis Guidelines: As noted above, this chapter is intended to provide a demonstration of the application of benefit-cost principles to a specific real-time information system investment. To assist in the completion of any future assessments using these principles, the text below includes shaded boxes (similar to this one) that outline additional data, steps or analyses that should be included in a more comprehensive analysis of real-time investment costs and benefits.

6.2 TriMet's Transit Tracker System

Transit Tracker is a real-time traveler information system deployed by Portland TriMet beginning in 2001. The Transit Tracker system provides TriMet riders with a real-time estimate of the expected time until the next transit vehicle arrives at a specific stop (bus) or station (rail). Transit Tracker covers all rail stops and each of TriMet's 7,700 bus stops.

Riders can access Transit Tracker one of three ways:

1. At Stops/Stations: Electronic Transit Tracker information displays have been deployed at 13 bus stops (4 of which also include voice annunciation) and at all TriMet light rail stations (deployed January 2001).
2. By Phone: TriMet has a dedicated Transit Tracker customer service line, 503-238-RIDE (deployed September 2004).
3. Via the Web: TriMet has a dedicated Transit Tracker web page, http://www.trimet.org/arrivals/index.htm (deployed September 2002).

Transit Tracker uses global positioning system (GPS) technology to track the location of vehicles in revenue service. Every TriMet vehicle is equipped with a transmitter that allows continuous satellite tracking with an accuracy of approximately 30 feet. This real-time location information is used to calculate real-time bus and train arrival information. The information is then routed to electronic displays (**Figure 6-1**) in equipped bus shelters and rail stations as well as to the Transit Tracker Online Website (**Figure 6-2**) and related customer service phone line. Information is provided in the form of arrival countdowns (i.e., minutes to the next arrival).

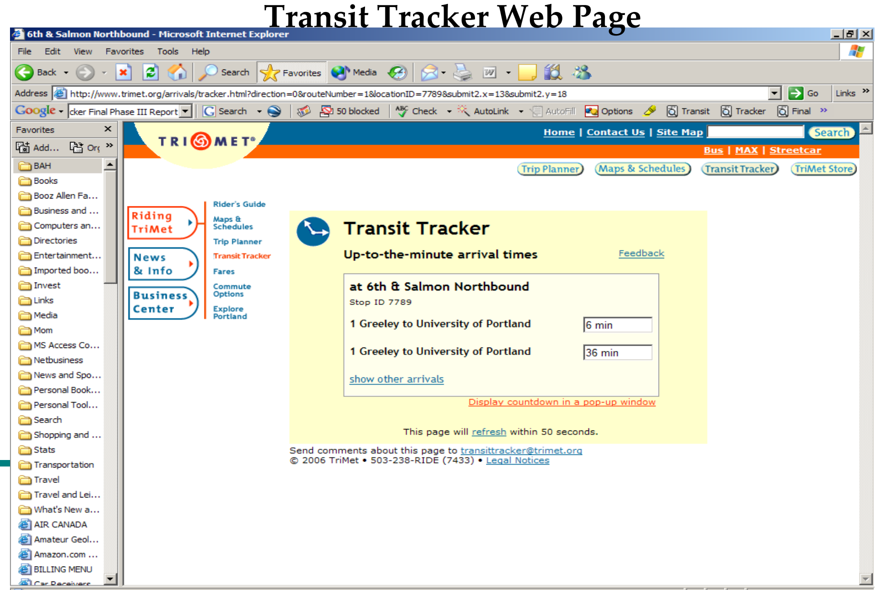
6.3 Evaluation Approach

It is hypothesized that the primary benefits of the Transit Tracker system accrue primarily to users in the form of (1) reductions in wait time (potentially), (2) reductions in rider's wait-time uncertainty (i.e., reduced uncertainty regarding the arrival time of the next transit vehicle) or (3) a combination of these two benefits. TriMet's surveys and analyses of Transit Tracker use provide a basis for evaluating these user benefits (e.g., in the form of rider perceptions regarding wait-time savings, reduced wait-time uncertainty).

Figure 6-1
Transit Tracker Information Display (Stop)

It is also possible that better vehicle arrival time information may also generate additional ridership for TriMet, potentially yielding additional benefits to society (e.g., from reduced auto use). However, the existing studies of Transit Tracker use do not provide a reasonable basis for assessing any potential increase in ridership resulting from implementation of the Transit Tracker system. Hence, the potential for increased ridership is not included as a benefit in this brief demonstration. Similarly, while TriMet may also enjoy some cost savings benefits

Figure 6-2
Transit Tracker Web Page



from Transit Tracker's implementation (e.g., a reduction in staff dedicated to customer service phone lines), TriMet has not conducted studies to measure any such potential agency cost savings from Transit Tracker implementation. Therefore such potential agency cost savings benefits are not considered in this demonstration analysis.

Given these considerations, *this analysis of the Transit Tracker investment will only focus on the potential benefits from wait-time savings and reductions in wait-time uncertainty for those travelers utilizing Transit Tracker information*. In addition, rather than estimating the aggregate benefits and aggregate costs of transit tracker use across all users of this information, and then comparing these two aggregate measures*, this analysis will assess the benefits and costs of Transit Tracker on a per "informed trip" basis*. This approach, (similar to the cost effectiveness measure used by FTA for New Starts investments) offers the benefit of evaluating the "effectiveness" of the Transit Tracker investment on each trip for which Transit Tracker's real-time information is used. This approach is also useful in demonstrating how the net benefits of real-time investment systems like Transit Tracker are dependent on the number of riders using the system and the types of benefits enjoyed for each trip for which real-time information is used. Specifically, net benefits increase as the number of riders using a real-time information system increases. Net benefits also increase as wait time decreases and/or as wait-time uncertainty decreases. A key lesson learned from this analysis is the importance of marketing real-time information systems to transit patrons to ensure utilization is as high as possible.

More specifically, the analysis here will consider Transit Tracker's net benefit per trip using the three individual cases:

Case 1 – Reductions in Wait Time Only: This case assumes that Transit Tracker only generates benefits in the form of reductions in wait time for Transit Tracker users. Here, it is hypothesized that Transit Tracker users reduce the amount of "padding" they would otherwise include in their wait time at transit stops as the next vehicle's arrival time is now known with reasonable certainty. In other words, Transit Tracker's real-time information allows users to delay the time they arrive at their transit stop (internet and phone based users) or leave the stop and return later (information display users) thus reducing their total wait time and enabling users devote the saved time to other uses (e.g., more time at home, in the office, running errands, etc).

The application of equation 5-3 for the calculation of the net benefits per trip (for trips using Transit Tracker) in this case is expressed in **Equation 6-1**.

$$Net\ \ Benefits\ \ Per\ \ Trip_{Case1} = \left\{ \frac{(Value\ of\ Time)*(Avg.Wait\ Time\ Savings)-(Annualized\ \ Capital\ Cost + Annual\ \ O\ \&\ M\ \ Cost)}{Annual\ \ Number\ of\ Trips\ Using\ Transit\ Tracker\ Information} \right\} \quad (6\text{-}1)$$

Note here that the value of time for passengers waiting for a transit vehicle has been well documented to be twice the value of time for passengers *after* they have boarded the vehicle. Given the US Department of Transportation's current value of time for transit passengers (in vehicle) of $11.20 per hour[7], the value of time for transit passengers waiting at stops is therefore estimated to be 2*$11.20 = $22.40 per hour. If Transit Tracker users no longer have to wait as long at transit stops, they can now apply their "saved" time to more productive uses and avoid the discomfort of time spent waiting at a transit stop. In effect, this eliminates the $11.20 in extra "cost" associated with the discomfort of waiting for the next transit vehicle to arrive, thus reducing the value of time from $22.40 per hour (the wait-time cost) to $22.40 -$11.20 = $11.20 per hour (the value of time spent in other activities). For this reason, the "value of time" used in equation 6-1 is actually *the reduction in the wait-time premium* (i.e., $11.20) and not the full value of wait time (i.e., $22.40).

While 95% of Transit Tracker users agreed the system reduces their wait time, there are at present, no solid measures of what the average reduction in wait time actually is. Survey responses from users of Transit Tracker information displays at equipped bus stops suggests that actual reductions in total wait time may be negligible. However, this seems unlikely to be the case for those users accessing Transit Tracker via either phone or the internet. Given the availability of accurate, real-time arrival information, riders accessing Transit Tracker via phone or internet have the opportunity of optimizing (i.e., delaying) their bus stop arrival time and thus reduce time spent waiting a transit stop. Given these considerations, the demonstration analysis below will explore the net benefits of Transit Tracker use over a range of reductions in average wait time. The analysis will similarly consider a range of values for the value of time (all based on DOT's published values). Finally, the determination of all remaining terms from equation 6-1 (e.g., capital costs, operating costs, annual trips using Transit Tracker) are considered below.

[7] *Determination of the value of time for use in Federal transportation analyses is provided the Office of Secretary of Transportation (OST). See: http://ostpxweb.dot.gov/policy/Data/VOTrevision1_2-11-03.pdf*

Reductions in Wait Time: As just discussed, the average reduction in passenger wait times resulting from Transit Tracker use remains uncertain, hence a range of values will be used for this demonstration analysis. As one of the primary potential sources of investment benefits from real-time information system investment, a more comprehensive future analyses of real-time investment benefits will need to better research these reductions in passenger wait times. Specifically such analyses should conduct separate analyses of the reduction in wait time for each of the three primary sources of information access, including: via information displays, via phone and via the internet. It is hypothesized that time savings will be more significant for those accessing real-time information via phone or internet as these users have better opportunity to optimize their bus strop arrival time. This hypotheses is partially supported by the results of Transit Tracker Web use surveys where 94% of users stated they can wait longer at home/work before leaving for the bus stop.

Case 2 – Reductions in Wait Time Uncertainty Only: While Case 1 considered the reduction in total wait time, this case assumes that Transit Tracker users only benefit from a reduction in wait-time *uncertainty*. As noted above, the value of time for transit riders waiting at stops is twice that for riders once they have boarded the vehicle. This wait-time premium reflects a variety of wait-time costs that are not experienced "in-vehicle" including reduced personal comfort (e.g., exposure to the elements), potential safety concerns and *uncertainty regarding the arrival time of the next transit vehicle*. A key consideration in modeling the value of reducing wait-time uncertainty is the absence of any empirical studies that estimate what the value of wait-time uncertainty is. In other words, how much of the estimated $11.20 wait-time premium can be attributed to wait-time uncertainty: one percent, ninety percent or somewhere in-between? This analysis will consider a range of values of the "cost of wait-time uncertainty".

The application of equation 5-3 for the calculation of the net benefits per trip (for trips using Transit Tracker) for Case 2 is expressed in **Equation 6-2**.

$$Net\ Benefit\ Per\ Trip_{Case\,2} = \left\{ \frac{(Value\ of\ Time) * (Uncertainty\ Share) * (Avg.Wait\ Time) - (Annualized\ Capital\ Cost + Annual\ O\ \&\ M\ Cost)}{Annual\ Number\ of\ Trips\ Using\ Transit\ Tracker\ Information} \right\} \tag{6-2}$$

Here, *Uncertainty Share* is the proportion of the wait-time premium associated the uncertainty of transit vehicle arrival times. The methodology demonstration will examine this equation with a range of wait times.

Case 3 – Reductions in Both Wait Time and Wait-Time Uncertainty: Finally, Case 3 considers the case where utilization of Transit Tracker information yields reductions in both wait time and wait-time uncertainty. The application of equation 5-3 for the calculation of the net benefits per trip (for trips using Transit Tracker) for Case 3 is expressed in **Equation 6-3**. The methodology demonstration will examine this equation with a range of wait times.

$$Net\ Benefit\ Per\ Trip_{Case\,3} = \left\{ \frac{(Value\ of\ Time) * \left[(Uncertainty\ Share) * (Avg.Wait\ Time) + (Wait\ Time\ Savings)\right] - (Annualized\ Capital\ Cost + Annual\ O\ \&\ M\ Cost)}{Annual\ Number\ of\ Trips\ Using\ Transit\ Tracker\ Information} \right\} \quad (6\text{-}3)$$

The following sections discuss the data sources for the annualized capital costs, annual operating costs and number of TriMet trips using Transit Tracker information.

6.4 Transit Tracker Capital and Operating Costs

Capital and operating costs for the Transit Tracker information system are provided in **Table 6-1**. These costs have been obtained from prior published analyses of Transit Tracker investment and operating costs as well as data obtained directly from TriMet staff (both through phone interviews and through TriMet's response to the survey for this study).

Table 6-1
Transit Tracker Capital and Operation Costs

Capital Costs	
Hardware (primarily field equipment)	$ 950,000
Servers & Software	$125,000
Total Capital Cost	$1,075,000
Useful Life (years)	
Hardware (primarily field equipment)	10
Servers & Software	5
Cost of Capital (discount rate)	
Based on OMB guidelines	7.0%
Annualized Capital Cost	
Hardware (primarily field equipment)	$ 135,259
Servers & Software	$ 30,486
Total Capital Cost	$ 165,745
Annual Operating & Maintenance Costs	
Annual Operating Costs	$93,750
Annual Maintenance Costs	$ 558
Total Annual Operation Cost	$94,308
Total Annualized Costs	$260,053

Collection of Comprehensive Cost Data: It is important to emphasize that the cost data collected for this demonstration analysis only provide a rough approximation of the total capital and operating costs of the Transit Tracker investment based on published sources and minimal supplementary data submitted by TriMet in support of this study. A more comprehensive benefit-cost analysis should include a detailed, primary data collection effort documenting all project costs. Specifically, a more detailed and comprehensive cost collection effort should consider:
Hard Costs (Capital): All "hard" costs including hardware (e.g., message signs, servers, conduit,), installation costs and parts.

Soft Costs (Capital): All "soft" costs including project planning, design and project management. These costs must include the cost of agency staff time invested in concept development. The cost of web site programming may be included as either a hard or soft cost.
Life Expectancy: The life expectancy (in years) of all hard and soft capital costs. As will be shown below, these life expectancy values can be used to calculate annualized costs for all project components.
Operating and Maintenance Costs: Operating and maintenance costs must be comprehensive of the cost of all inputs required to operate and maintain the real-time information system. In addition to the cost of staff assigned to maintain the equipment, operating costs must also include the cost of electricity required to power the systems, as well as parts and equipment utilized by maintenance staff (e.g., support vehicles) in conducting their work.

6.4.1 Capital Costs

Capital costs for Transit Tracker consist primarily of the cost of designing, purchasing and installing (including conduit) the Transit Tracker information displays (dynamic message signs) located at 13 bus stops and all rail stations. These costs represent the bulk of the $950,000 in field equipment cost line item in the Table 6-1[8]. The project also included roughly $125,000 in additional costs for the purchase of computer servers and web page development[9].

6.4.2 Useful Life, Cost of Capital and Annualized Cost

Useful life values for capital investments provide a means of annualizing the cost of project capital investments. The useful life values for project field equipment, servers and software (i.e., web page development) are presented above in Table 6-1. These values (in years) were selected based on the recommendation of TriMet project staff. Next, the annualization of capital costs requires selection of an appropriate discount rate or "cost of capital." The discount rate selected for this analysis was 7.0% as is recommended in the Federal Office of Management and Budget's guidelines for benefit-cost analyses (OMB Circular A-4, 2003).

[8] *Note: This includes roughly $750,000 for the initial investment (see TCRP #48) and an additional $200,000 to equip TriMet's Red Line.*

[9] *Web page development only required 640 programmer hours. In addition to the cost of web servers, the $125,000 for servers and software includes and estimate of the programmer's wage, fringe and overhead costs. Finally, the server and programming costs were further inflated by roughly forty percent to include the cost of project conceptual design and development by TriMet staff. As noted in the shaded box above, a more comprehensive analysis should document each of these costs in full based on TriMet records and additional interviews with project staff.*

Finally, the annualized project capital costs for project hardware, servers and software development are also presented in Table 6-1 and total roughly $166,000 annually. The formula, **Equation 6-4**, used to calculate the annualized capital cost of each project component is given by (same as Equation 5-4):

$$Annualization\ Value = \left\{ \frac{i}{1-(1+i)^{-(Useful\ Life)}} \right\} * Capital\ Cost \qquad (6\text{-}4)$$

Where *i* is the discount rate, Useful Life is the expected useful life of the project component in years, and Capital Cost is the total cost of acquiring each project component including design, development, hardware, installation and project management.

While not required for all approaches to project benefit-cost analyses, this demonstration analysis used annualized capitalized costs as an input to the calculation of the total cost of the Transit Tracker service on a per trip basis.

6.4.3 Annual Operating and Maintenance Costs

Operating and maintenance costs for Transit Tracker consist primarily of the cost of equipment maintenance (roughly 0.5 FTE annually) plus equipment power costs. The labor cost for this analysis includes wage, fringe and overhead. Power consumption was assumed to be 250 watts priced at 8.5 cents per kWh. While TriMet initially experienced high communications costs (having contracted communications to an outside service provider), Transit Tracker now runs on TriMet's own internal fiber optic communications system, and communications costs are now negligible.

Based on these assumptions, operating and maintenance costs for Transit Tracker are estimates to be roughly $95,000 per year.

6.4.4 Total Annual Costs

Summing the estimated annualized capital costs with the estimated operating and maintenance cost yields a total annual cost estimate for Transit Tracker of roughly $260,000. Once again, this estimate represents a best guess based on existing data sources and brief discussions with project staff solely for the purpose of supporting this benefit-cost demonstration. A more comprehensive analysis should include a detailed data collection and documentation effort for all capital, operating and maintenance costs.

6.5 Estimated Number of Uses of Transit Tracker

Calculation of the net benefits of transit Tracker use on a per trip basis requires an estimate of the number of trips for which Transit Tracker information was used. As noted above, TriMet riders can access Transit Tracker information from three different sources: from Transit Tracker equipped bus and rail stops, via the internet or via phone. Following are estimates of the number of trips for which Transit Tracker information was supplied by each data source.

Transit Tracker Information Displays – Bus Stops: Transit Tracker information displays are currently located at 13 of TriMet's higher use bus stops. Based on passenger survey analysis of three of these stops, each stop sees between 300 and 1,400 passenger boardings each weekday. Annualizing these trips (assuming weekend ridership is 20% of daily boardings) yields a *maximum* number of potential Transit Tracker users at the 13 equipped bus stops of roughly 2.5 million annually. However, it may be assumed that some proportion of these riders do not make use of the information provided (e.g., do not leave and return later if their bus's arrival time is more then ten minutes in the future or, in the case of regular riders, may not read the information displays on a regular basis). Similarly, some proportion of transit riders using Transit Tracker equipped stops will have already obtained bus arrival time information from Transit Tracker via either internet or phone *prior* to their arrival at the equipped bus stop. It is important therefore to make some further adjustment to bus passenger boarding counts when estimating the benefits of Transit Tracker use at stops to avoid any double counting (i.e., so as not to include web or phone based Transit Tracker users in counts of equipped stop users).

Transit Tracker Information Displays – Rail Stops: Transit Tracker information displays are also located at all TriMet rail stations. Based on National Transit Database (NTD) data, TriMet's light rail service had 181.7 million boardings in 2004. As with riders at Transit Tracker equipped bus stops, each of these light rail riders has the potential to use Transit Tracker information prior to boarding the next vehicle. Also similar to bus riders, there is likely a significant proportion of riders that either do not make use of information supplied by the Transit Tracker information displays or have already accessed Transit Tracker prior to arriving at the rail station, via either phone or the internet. Hence, 181.7 million represents a *ceiling* on annual Transit Tracker use at rail stations.

Use of Transit Tracker at Bus and Rail Stops: Passenger surveys indicate that 78% of riders at Transit Tracker Equipped bus stops use the information frequently or almost always, 11% on an infrequent basis and a further 11% rarely or almost never. This analysis did not collect similar utilization rate data for rail riders. While this data provides a rough means for assessing how many trips for which Transit Tracker information is accessed via information display, this demonstration will consider the net benefits of the Transit Tracker system under a range of trip volumes.

Transit Tracker Web Site: The number of transit riders accessing Transit Tracker via the internet has grown dramatically since the Transit Tracker web site was first introduced in September 2002. Specifically, web site use started at roughly 10,000 hits per month over the eight months the service was active and reached 66,000 per month as of December 2005. This latter usage rate translates to roughly 800,000 web hits annually. It is important to consider that users may access the Transit Tracker web site multiple times for any given trip. Hence, the number of web site "hits" does not necessarily represent the number of trips for which Transit Tracker web information was used (which is likely less).

Transit Tracker Web Queries per Trip: A more comprehensive analysis of a real-time information system accessible via the internet should attempt to determine the number of times riders query the web site for each trip that real-time information is used.

Transit Tracker Phone Line: As with web based access, the number of transit riders accessing Transit Tracker via phone has grown dramatically since this option was first introduced in September 2004. Here, the number of calls per month rose from roughly 65,000 calls per month over the first year the service was available to an average of roughly 225,000 per month over the last four months of 2005. This latter usage rate translates to roughly 2.6 million phone calls annually. As with web based access, it is important to consider that users may access the Transit Tracker phone line multiple times for each trip for which real-time information is used. Hence the number of phone calls does not necessarily represent the number of trips for which Transit Tracker information was used (which is likely less).

Based on this review, a number of conservative assumptions are considered to calculate a minimum estimated number of trips using Transit Tracker information, as shown in **Table 6-2**. It is conservatively estimated that Transit Tracker is likely used for at least 20 million bus and rail trips each year. Even if use at rail stations is excluded from the analysis, transit tracker information is likely used by an estimated 3.4 million trips per year.

Table 6-2
Estimated Annual Number of Trips Using Transit Tracker Information

Transit Tracker Information Source	Maximum Number of Trips	Assumed Usage Rate	Assumption / Justification	Minimum Estimated Number of Trips
Transit Tracker Equipped Bus Stops	2,491,866	50%	Passenger survey result that 78% use always or frequently	1,245,933
Transit Tracker Equipped Rail Stops	181,760,400	10%	Assumes 1 in 10 riders use information display	18,176,040
Web Page	792,000	50%	Assumes 2 web hits per trip	396,000
Phone	2,678,694	67%	Assumes 1.5 phone calls per trip	1,785,796
Total Trips using Transit Tracker	**187,722,960**			**21,603,769**
Total Trips Excluding Rail	**5,962,560**			**3,427,729**

6.6 Case Evaluations

This demonstration concludes with an analysis of the three cases outlined in the "Evaluation Approach" section above. Specifically, these cases examine the potential net benefits of the Transit Tracker system under the following assumptions regarding system benefits:

Case 1: Transit Tracker only yields benefits in the form of reduced wait times

Case 2: Transit Tracker only yields benefits in the form of reduced wait-time uncertainty

Case 3: Transit Tracker yields benefits in the form of both reduced wait times and reduced wait-time uncertainty

As discussed above, at present there are no definitive values for several key parameters required to complete a comprehensive benefit-cost test. These include the number of trips for which Transit Tracker information is used, the reduction in wait times for each Transit tracker "informed trip" and the extent to which the elimination of wait-time uncertainty reduces the value of time for patrons waiting at transit stops. Hence, rather than provide a specific benefit-cost return value for the Transit Tracker system, this analysis will provide graphical representations of the range of trip volumes, reductions in wait time and reductions in wait-time uncertainty for which net benefits of are positive.

Case 1: First consider Case 1 (were Transit Tracker yields user benefits in the form of a reduction in average wait time). The net benefits for this case were outlined above in equation 6-1. Now consider the circumstances under which the net benefits for this case are non-negative. This is provided in **Equation 6-1a**:

$$\left\{ \frac{(Value\ of\ Time)*(Avg.Wait\ Time\ Savings)-(Annualized\ \ Capital\ Cost + Annual\ \ O\ \&\ M\ Cost)}{Annual\ \ Number\ of\ Trips\ Using\ Transit\ Tracker\ Information} \right\} \geq 0$$

(6-1a)

Substituting in DOT's average value of time and the estimated annualized capital and operating costs leaves only two remaining variables: average wait-time savings and annual number of trips using Transit Tracker, as per **Equation 6-1b**:

$$\left\{ \frac{(\$11.20)*(Avg.Wait\ Time\ Savings)-(\$260{,}053)}{Annual\ \ Number\ of\ Trips\ Using\ Transit\ Tracker\ Information} \right\} \geq 0 \qquad (6\text{-}1b)$$

The informed trip volumes and wait-time savings combinations under which equation 6-1b hold true are presented in **Figure 6-3**. Specifically, this chart shows the range of informed trip counts and reductions in average wait time for which the net benefits of investment are greater than zero. Areas shown in grey have positive net benefits while the area highlighted in white has negative net benefits. The level of net benefits increases steadily both as the number of annual informed trips increases and also as the average reduction in wait times increases. Note also that the chart presents "break-even" contours for three different values of time (all from US DOT): the average value of time ($11.20 per hour), a low value of time ($7.90 per hour) and a high value of time ($13.40 per hour).

Figure 6-3

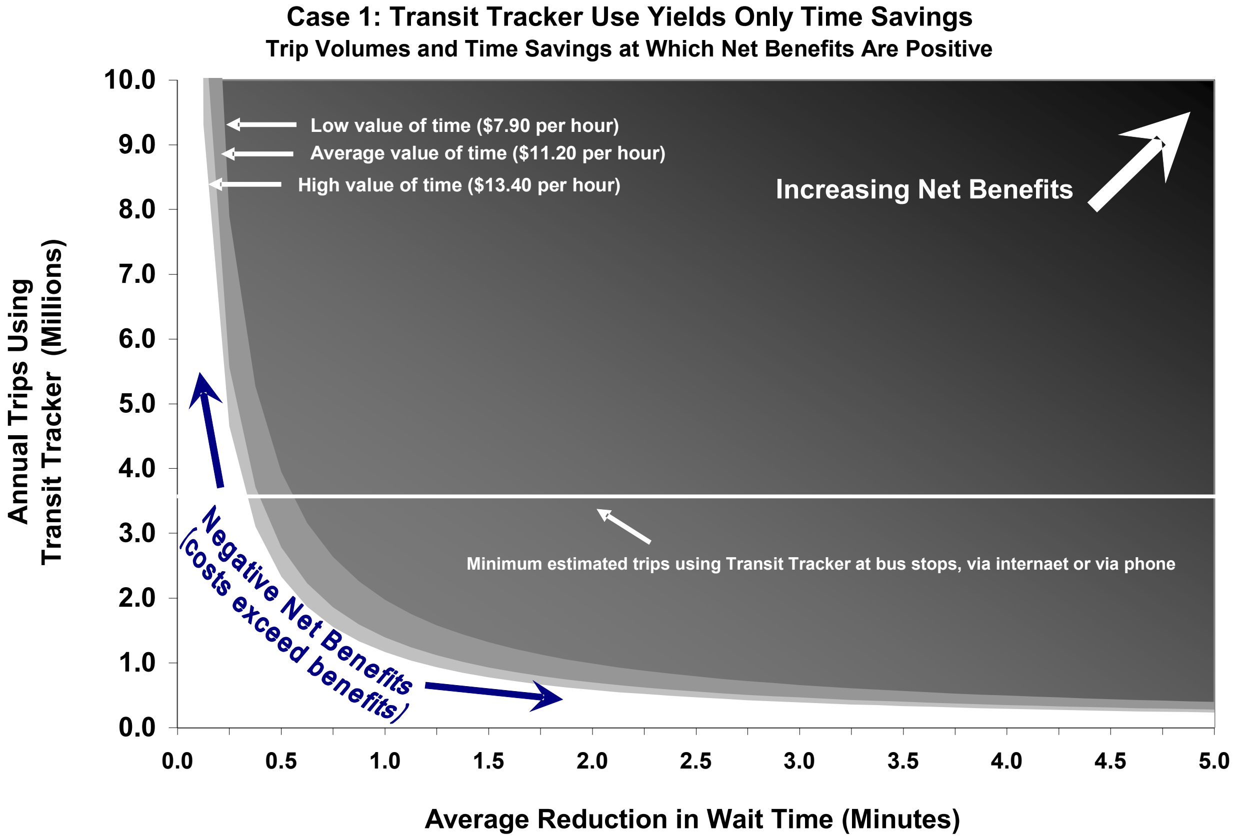


Figure 6-3, provides the following lessons learned:

- Positive Net Benefits Under Reasonable Assumptions: The chart demonstrates that net benefits for the Transit Tracker investment are positive at relatively small "informed trip" volumes and for relatively low reductions in wait times. For example, the horizontal white line on the chart shows a very conservative, minimum estimate (see Table 6-2) of 3.4 million annual trips for which Transit Tracker is used[10]. At this informed trip volume, only a small reduction in total wait time (between 0.5 and 0.75 minutes per informed trip) is required to attain a positive net return. As discussed above, the minimum number of annual trips (bus and rail) made using Transit Tracker is estimated at close to 20 million. For higher informed trip volumes, the total required time savings for a positive return drops below 0.25 minutes per informed trip.
- Minimal Sensitivity to Value of Time: The chart also shows little difference in the positions of the three "break-even" counters for the low, average and high values of time. Hence, even when the value of time is low, Transit Tracker appears to easily generate positive net returns at modest informed trip volumes and wait-time reduction levels.
- Importance of Marketing Availability of Real-Time Information: Finally, the chart makes it clear that the benefits of Transit Tracker use are directly related to the number of trips made using this information. This relationship highlights the importance of marketing the availability of passenger real-time information to transit riders. The greater the number of users, the greater the net benefits. This is especially true in the case of information offered via phone or internet, sources that are not as apparent to riders as a display sign located at their transit stop (these sources also offer the greatest opportunity for a reduction in wait time, as these users obtain this information *before* they reach their transit stop and hence have better opportunity to convert wait time to other, more productive uses).

Case 2: For Case 2, Transit Tracker is assumed to only yield user benefits in the from of a reduction in wait-time uncertainty (as users are now reasonably certain of the next vehicle's arrival time). The net benefits for this case were outlined above in equation 6-2. Now consider the circumstances under which the net benefits for this case are non-negative. This is provided in **Equation 6-2a**:

$$\left\{ \frac{(Value\ of\ Time)*(Uncertainty\ Share)*(Avg.Wait\ Time)-(Annualized\ Capital\ Cost + Annual\ O\&M\ Cost)}{Annual\ Number\ of\ Trips\ Using\ Transit\ Tracker\ Information} \right\} \geq 0$$

(6-2a)

10 *This estimate of 3.4 million annual "Transit Tracker informed" trips assumes that: (1) Transit Tracker is only used by half of bus riders at equipped stops, (2) that web users access the Transit Tracker web site twice on average per trip and (3) that phone users access Transit Tracker 1.5 time per trip on average. This estimate also excludes use at rail stations. Per trip here refers to the number of trips for which Transit Tracker information was used, not the total number of transit trips.*

Substituting in DOT's average value of time and the estimated annualized capital and operating costs again leaves only three remaining variables: uncertainty share, average wait time and annual number of trips using Transit Tracker, as per **Equation 6-2b**:

$$\left\{ \frac{(\$11.20) * (Uncertainty\ Share) * (Avg.Wait\ Time) - (\$260{,}053)}{Annual\ \ Number\ \ of\ Trips\ Using\ Transit\ Tracker\ Information} \right\} \geq 0 \qquad (6\text{-}2b)$$

The informed trip volumes and average wait time combinations under which equation 6-2b hold true are presented in **Figure 6-4**[11]. Specifically, areas shown in grey have positive net benefits (depending on the uncertainty share) while the area highlighted in white has negative net benefits. The level of net benefits increases steadily both as the annual number of informed trips increases and also as the total wait time increases. Finally, note that the chart shows varying "uncertainty shares". As discussed above, this is the proportion of the wait-time premium that is attributable to wait-time uncertainty. Once again, the wait-time premium is a measure of rider discomfort due to exposure to the elements, potential safety concerns as well as wait-time uncertainty experienced while waiting at a transit stop. Given that the proportion of the wait-time premium attributable to wait-time uncertainty is unknown, this analysis considers a range of values from a minimum of 5% to a maximum of 50%.

Figure 6-4

[11] *Note: This chart assumes an average value of time of $11.20 per hour.*

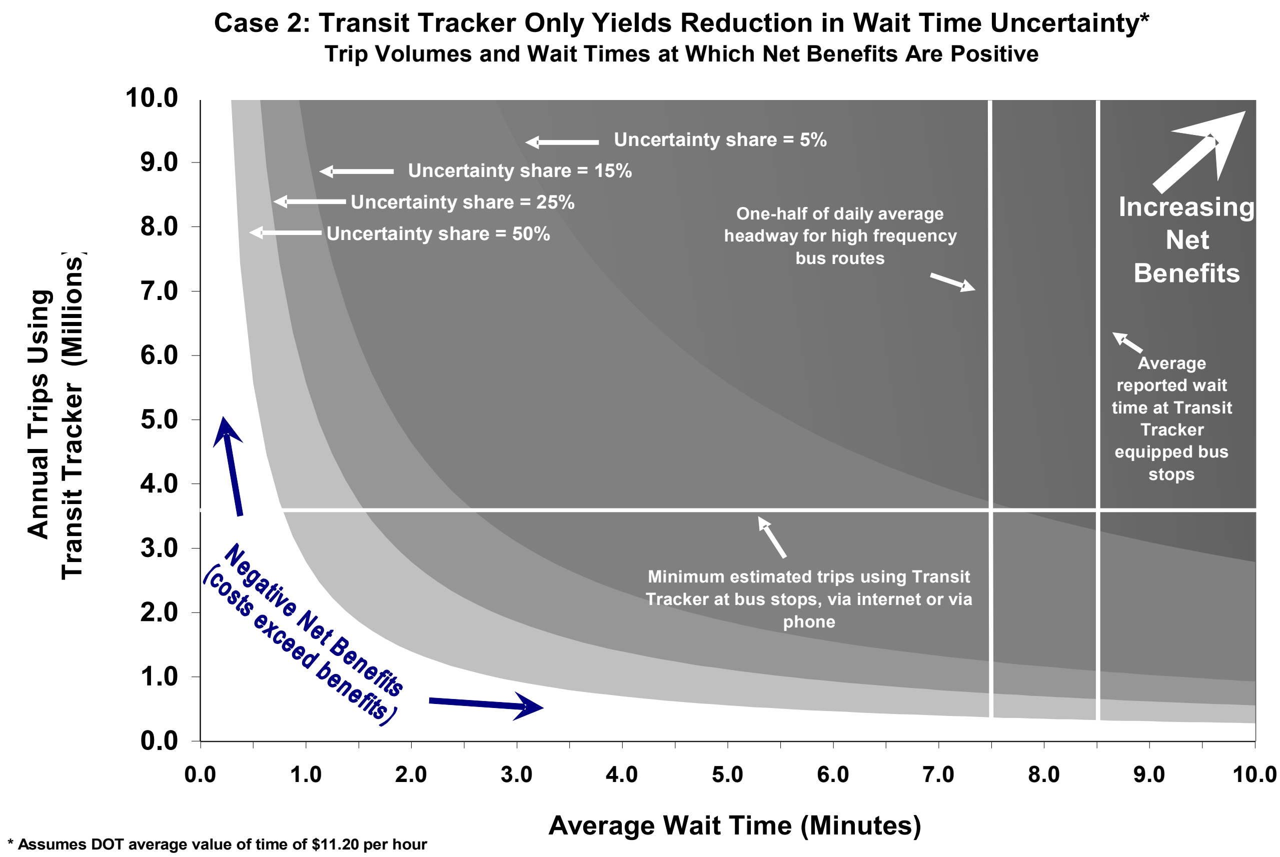


Figure 6-4, provides the following lessons learned:

- Positive Net Benefits Under Reasonable Assumptions: The chart demonstrates that net benefits for the Transit Tracker investment are again positive at relatively small informed trip volumes and for typical wait times. For example, the horizontal white line on the chart once again shows the very conservative estimate of 3.4 million annual trips for which Transit Tracker is used (see Table 6-2). Similarly, the vertical lines show both the average wait time at Transit Tracker equipped bus stops (8.5 minutes) as well as one-half the average headway on TriMet's higher frequency bus routes (roughly 7.5 minutes). Hence, the coordinates of TriMet's actual average wait time and Transit Tracker informed trips most likely lie *above* the horizontal line and *near* the two vertical lines. Note that all of these potential points only require a 5% reduction in the wait-time premium (or even less) to attain a positive net benefit.

- Sensitivity to Uncertainty Share: As the uncertainty share increases from 5% to 15% or more, the average wait time required for a positive net benefit drops from roughly eight minutes to only three minutes or less at low informed trip volumes and to one minute or less for high informed trip volumes.

Case 3: Finally, Case 3 represents a combination of Case 1 and Case 2. Here, it is assumed that Transit Tracker use yields reductions in both average wait time and wait-time uncertainty. The net benefits for this case were outlined above in Equation 6-3. Now consider the circumstances under which the net benefits for Case 3 are non-negative. This is provided in **Equation 6-3a**:

$$\left\{ \frac{(Value\ of\ Time) * [(Uncertainty\ Share) * (Avg.Wait\ Time) + (Wait\ Time\ Savings)] - (Annualized\ Capital\ Cost + Annual\ O\ \&\ M\ Cost)}{Annual\ Number\ of\ Trips\ Using\ Transit\ Tracker\ Information} \right\} \geq 0 \quad (6\text{-}3a)$$

Substituting in DOT's average value of time, the estimated annualized capital and operating costs and an assumed uncertainty share of 25% now leaves *three* remaining variables: average wait time, average wait-time savings and annual number of trips using Transit Tracker. This yields **Equation 6-3b**:

$$\left\{ \frac{(\$11.20) * [(25\%) * (Avg.Wait\ Time) + (Wait\ Time\ Savings)] - (\$260{,}053)}{Annual\ Number\ of\ Trips\ Using\ Transit\ Tracker\ Information} \right\} \geq 0 \quad (6\text{-}3b)$$

The conditions under which **Equation 6-3b** hold true are presented in **Figure 6-5**[12]. In order to represent the three unknown variables in this equation, the points at which the net benefits of Transit Tracker investment are zero is represented in this chart as a three dimensional surface. Hence, any point *above* this surface represents a positive net benefit for Transit Tracker. Specifically, this chart shows the range of informed trip counts, average wait times and reductions in wait time for which the net benefits of investment are greater than zero. Once again, this chart suggests positive net returns under fairly conservative assumptions. For example, under the assumption of an average wait time of six minutes (less than half the average headway for high-frequency bus routes) and a two-minute reduction in average wait time, Case 3 predicts that Transit Tracker only needs to be used on roughly 400,000 trips annually to generate a positive net benefit. **Table 6-3** provides a range of informed trip volumes required to attain positive net benefits for given average wait times and Transit Tracker induced reductions in wait times.

Figure 6-5

[12] *Note: This chart assumes an average value of time of $11.20 per hour.*

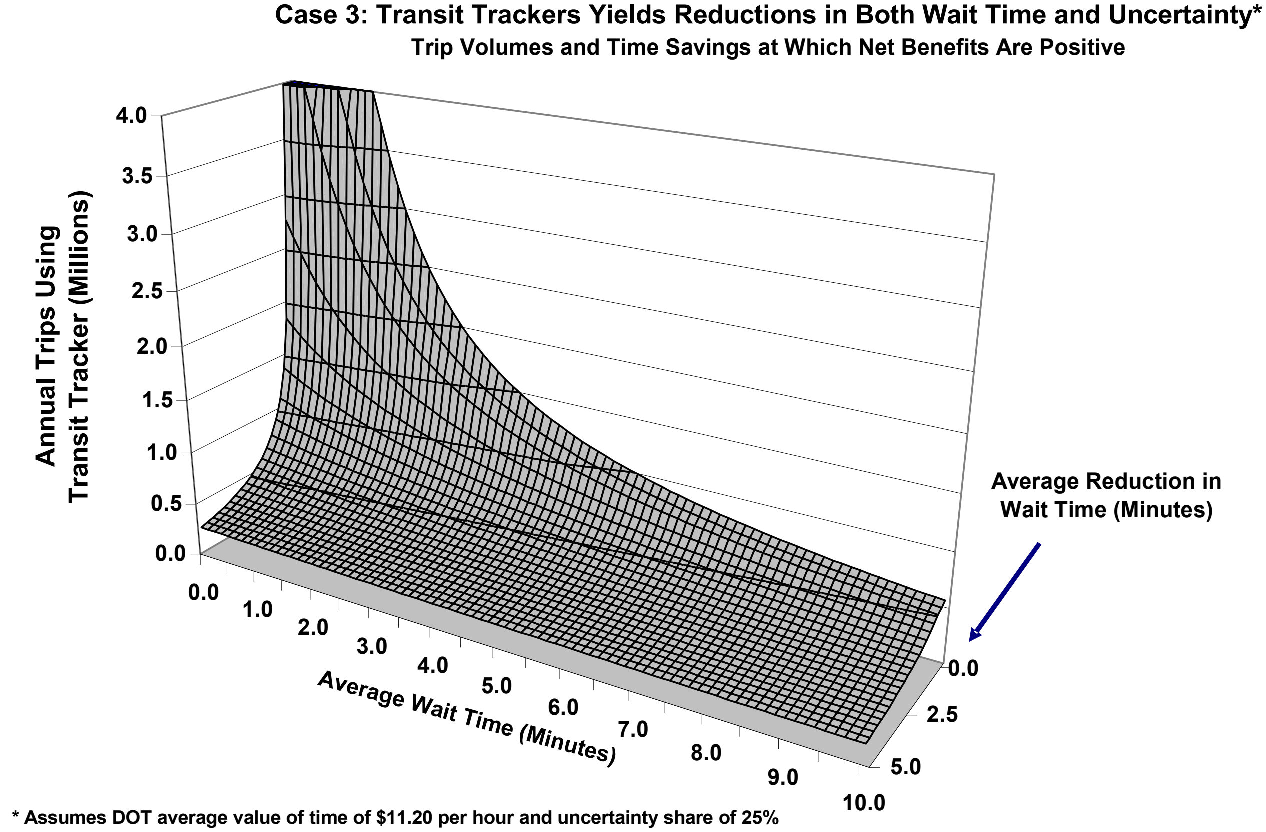


Table 6-3
Case 3: Minimum Number of Annual Transit Tracker Informed Trips Required to Attain Positive Net Benefits

Average Wait Time (minutes)	Average Reduction in Wait Time (minutes)				
Determines wait-time uncertainty	1.0	2.0	3.0	4.0	5.0
2.0	928,762	557,257	398,041	309,587	253,299
4.0	696,572	557,257	398,041	309,587	253,299
6.0	557,257	398,041	309,587	253,299	214,330
8.0	464,381	348,286	278,629	232,191	199,020

* Assumes $11.20 value of time and 25% reduction in wait-time premium (i.e., 25% uncertainty share)

6.6 Conclusion

This brief demonstration has outlined the types of information required to conduct a benefit-cost analysis of a real-time information system, using TriMet's Transit Tracker system as a test case. In addition to highlighting the information needs associated with this type of analysis, this demonstration has also outlined the circumstances required to attain a positive net benefit for the Transit Tracker system. Using fairly conservative assumptions regarding, informed trip volumes, reductions in wait time and reduction in the cost of wait-time uncertainty, it was shown that Transit Tracker most likely achieves positive net (social) benefits.

6.7 Future Applications and Enhancements

The results from this development of the return on investment approach for real-time bus arrival passenger information systems may be applied in a potential, future field test and return-on-investment study. As existing systems become more widely implemented and accepted by the transit rider, the benefits of these systems can be more clearly demonstrated. Options include those transit systems with existing passenger information systems such as:

- TriMet
- Los Angeles County MTA
- King County Metro
- San Francisco Muni
- Pace (suburban Chicago)
- Denver RTD
- Fairfax CUE
- Cape Cod Regional Transit Authority
- AC Transit (Oakland, CA)
- Portland Streetcar

This process can also be applied with other systems investments within the overall Intelligent Transportation Systems (ITS) realm. The FTA will determine if the subsequent field test and return-on-investment study are needed.

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1.0 APPLICABLE DOCUMENTS

The following documents may be used as resources.

- *Guidance for Developing and Deploying Real-time Traveler Information for Transit*, developed by Battelle for the Federal Transit Administration and U.S. DOT ITS Joint Program Office, April 30, 2003, U.S. DOT # FTA-OH-26-7017-2003.1
- *TCRP Synthesis 48: Real-time Bus Arrival Information Systems*, Transit Cooperative Research Program, Transportation Research Board, 2003
- *Oregon Regional Intelligent Transportation Systems (ITS) Integration Program Draft Phase III Report: Transit Tracker Information Displays*, developed by Science Applications International Corporation (SAIC) for the U.S. DOT ITS Joint Program Office, October 7, 2003
- *Oregon Regional Intelligent Transportation Systems (ITS) Integration Program Final Phase II Report*, developed by Science Applications International Corporation (SAIC) for the U.S. DOT ITS Joint Program Office, July 12, 2002
- *Transit Tracker Evaluation Final Report*, Tri-County Metropolitan Transportation District of Oregon (TriMet) Marketing Information Department, June 2002

APPENDIX A: Agenda – August 9, 2005

FTA Real-Time Bus Arrival Information Systems ROI Study
Expert Panel Meeting

Montgomery County Public Safety Communications Center (PSCC), "Situation Room"
1300 Quince Orchard Blvd., Gaithersburg, Maryland 20878

9:00 AM	Reception	
9:15	Welcome	Alfie Steele, Montgomery County
	Opening Remarks and Overview of Study Objectives	Brian Cronin, FTA
	Introductions	
	Motivation for Study and Role of Expert Panel	Donald Schneck, Booz Allen George Darido, Booz Allen
	Discussion of Technologies and System Boundaries	David Jackson, Booz Allen
	Proposed Benefit-cost Analysis Approach - Methods for evaluating return-on-investment - Identification of costs and benefits	Rick Laver, Booz Allen
12:00 PM	Lunch	
1:00	On-Site Tour/Demonstrations	
	Continued Discussions to Quantify Costs and Benefits - Unit cost information - Documented studies on system impacts - Other data available	
	Discussion of Barriers to Successful Implementation	Rick Laver, Booz Allen
4:00	Summary and Wrap-up	Donald Schneck, Booz Allen
4:30	Adjourn	

APPENDIX B: List of Participants to August 9, 2005 Expert Panel Workshop

	Name	Title	Organization	Phone	Email
1	Ms. Lurae Stuart	Program Manager	APTA	202-496-4844	lstuart@apta.com
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3	Mr. Don Schneck	Senior Associate	Booz Allen	267-330-7992	schneck donald@bah.com
4	Mr. Rick Laver	Associate	Booz Allen	703-902-4676	Laver richard@bah.com
5	Mr. Dave Jackson	Associate	Booz Allen	319-361-0007	Jackson David@bah.com
6	Mr. George Darido	Sr. Consultant	Booz Allen	703-377-4059	Darido georges@bah.com
7	Mr. Gerry Tumbali	Manager, Engineering & Technology	Chicago RTA	312-913-3251	tumbalig@rtachicago.org
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11	Mr. Eric Pihl	Community Planner	FTA		Eric.pihl@fta.dot.gov
12	Mr. Paul Marx	Economist	FTA	202-366-1675	Paul.marx@fta.dot.gov
13	Mr. Brian Cronin	ITS Team Leader	FTA	202-366-8841	Brian.cronin@fta.dot.gov
14	Ms. Aletha Goodine	Transp. Program Spec.	FTA	202-366-4148	Aletha.goodine@fta.dot.gov
15	Mr. Sebastien Renaud	General Engineer	FTA	202-366-0244	Sebastien.renaud@fta.dot.gov
16	Mr. Tom Friedman	Project/Program Manager	King County Metro Transit	206-684-1513	tom.friedman@metrokc.gov
17	Ms. Carri Sabel	Project Manager	Long Beach Transit	562-599-8527	csabel@lbtransit.com
18	Mr. Joe Vicente	Asst. Director of Information Systems	LACMTA	213-922-3877	vicentej@mta.net
19	Mr. Steve Mortensen	Lead Transport Planner	Mitretek Systems	202-488-1504	Steven.mortensen@mitretek.org
20	Mr. Alfie Steele	Ride On Transit Central Dispatch	Montgomery County	240-777-5845	alfie.steele@montgomerycountymd.gov
21	Mr. Joe Monaco	National Sales Director	Next Bus	415-218-7926	jmonaco@nextbus.com
22	Mr. Marc Gordon	Deputy GM	Orbital TMS	443-259-7163	gordon marc@orbital.com
23	Mr. Mike Bolton	Asst Exec Director	Pace Suburban Bus	847-228-2305	michael.bolton@pacebus.com
24	Mr. Eric Marx	Director of Planning and Operations	Potomac and Rappahannock TC	703-580-6117	emarx@omniride.com
25	Ms. Patty DeVlieg	Project Manager	San Francisco MUNI	415-701-4303	patty.devlieg@sfmta.com
26	Mr. Bill Hiller	Manager Business Development	Siemens	319-743-1011	bill.hiller@siemens.com
27	Mr. Jack Requa	Chief of Bus Operations	WMATA	202-962-1319	jrequa@wmata.com
28	Mr. Peter Meenehan	IT Project Manager	WMATA	202-962-2614	jmeenehan@wmata.com

APPENDIX C: Survey Description

1. Technologies

The first block of the survey consisted of indicating the agency's current deployment and level of investment in Real-Time Bus Information Systems. Agencies were asked to provide the following inputs for each of the types of technologies indicated:

Technology	**Utilization**	**Cost**	**Scale of Implementation**	**Date Implemented**
	Type of technology in use	*Capital, Operating and Maintenance (total or per unit)*	*Level of deployment (number of buses, sites, etc.)*	*When did the technology become operational?*
• Communications Network Investments (integration of system components)				
• Automatic Vehicle Location (AVL/CAD and AVL only)				
• Real-Time Prediction Process (software, servers)				
• Passenger Information Web-site				
• Phone-Based Information Systems				
• Wayside Activity Center / In-Vehicle Information				

2. Customer Use of Real-Time Information Systems

The second block of the survey was a series of questions regarding rider use of real-time information systems. Participants were asked to answer the following questions:

1. Has your agency determined how many riders utilize your real-time information system options? If yes, how did your agency measure the rate of utilization and what was the estimated rate of use (e.g., web site hits)?

2. Is use of your real-time information confined to a limited set of knowledgeable users (e.g., younger users with greater technology awareness)? Do you know how frequently riders make use of such information (daily, weekly, monthly, less)?

3. If you have more than one real-time information source option, which source(s) do riders use most of (e.g., phone based, internet, kiosk, other)?

4. Has your agency conducted marketing campaigns to generate awareness of the real-time information systems?

5. Have riders provided feedback on the usefulness and quality of real-time information systems?

6. Has your agency evaluated the benefits to riders of using real-time information (e.g., time savings, awareness of service disruptions)?

7. Has your agency collected data or completed studies on rider use of real-time information that could be of use to this study? Can you provide copies of these materials?

1.1. Customer Use of Real-Time Information Systems

The responses of survey questions are tabulated below.

1) *Has your agency determined how many riders utilize your real-time information system options? If yes, how did your agency measure the rate of utilization and what was the estimated rate of use (e.g., web site hits)?*

Survey Number	Response
1	No
2	~65,000 calls/month. ~12,500 web site hits/month.
3	Based on our normal website visitors sessions, the average is running around 4000 per month, which translates into about 6% of ridership
4	Not yet. Real-time information not implemented on our web site: planned for end of October 2005. Intend to incorporate questions about our VMS into our annual customer satisfaction survey.
5	No real-time information system available for all our services: on a limited basis. Several bus stops on our Rapid Bus Systems display next bus arrival time: not operating at this time due to equipment upgrade.
6	Webwatch is the system provided to passengers. In January 2005, 12000 visits to the site, it is being used about 7000 times per month on average. IP addresses are tracked to know unique users: on average there are 3361 unique users per month.
7	Survey to evaluate LED demo project yielded positive feedback on reliability of messages displayed and making transfers easier. Survey conducted at two transit centers where bus status video monitors were installed: 3 of 4 respondents were aware of system (22% always use it, 28% sometimes use it, 26% rarely use it, 25% never seen it)

2) *Is use of your real-time information confined to a limited set of knowledgeable users (e.g., younger users with greater technology awareness). Do you know how frequently riders make use of such information (daily, weekly, monthly, less)*

Survey Number	Response
1	Don't know
2	Web site: 76% use it frequently or almost always; 37% female, 63% male; 81% <45 years, none 65+, 42% 25-34; 32% ride bus every day. Wayside: 75% use it frequently; 54% female, 46% male; 79% <45 years, 1% 65+, 38% 17-24; 68% 30 bus trips in previous month.
3	Real-time will be available to all riders.
4	No. Real-time information currently only provided on 4 VMS on a single corridor and 9 kiosks at our Downtown Transit Mall
5	No real-time information system available for all our services: on a limited basis. Several bus stops on our Rapid Bus Systems display next bus arrival time: not operating at this time due to equipment upgrade.
6	Do not have profile for the typical user other than the anecdotal number. Not yet surveyed to find out how often people make use of the info.
7	LED signs installed as a demo project (2 bus stops).

	Survey of bus status video monitors: Regular users (responded to always using system) are slightly younger, more educated, and technologically savvy. Majority of survey respondents were long-term bus users with high awareness of schedules.

3) *If you have more than one real-time information source option, which source(s) do riders use most of (e.g., phone based, internet, kiosk, other)?*

Survey Number	Response
1	Don't know
2	Probably web.
3	Undetermined at this point
4	N/A
5	Not applicable at this time except for a few bus stops on the Rapid Bus Lines where next bus arrival time is displayed. There is a project to provide real-time information by phone, internet and kiosk.
6	Most customers still use the phone. Kiosk information in the beginning stages, data unknown at this moment.
7	N/A

4) *Has your agency conducted marketing campaigns to generate awareness of the real-time information systems?*

Survey Number	Response
1	No
2	Yes; mostly for phone and web systems.
3	An extensive plan is in place to launch system wide: forums, info on websites, management meetings at metro stops, press releases, etc.
4	Initial marketing campaign done when larger system was deployed, which included info on our web site, brochures available on all buses, bus kings and tails and a television commercial.
5	No
6	We had a campaign that made people aware of the new system. We are planning a bigger campaign when we have the map option available on line.
7	No marketing of LED demo project

5) *Have riders provided feedback on the usefulness and quality of real-time information systems?*

Survey Number	Response
1	Very little
2	Web site: 96% agreed easy to use; 95% agreed saves time. 86% frequently or almost always accurate. Wayside: 60% placed highest value of all amenities; 89% frequently or almost always accurate.
3	No live data available yet but based on the frequency of requests from passengers, it is believed it will be very successful. Currently, alerts via Website, PDA, email.
4	N/A
5	No, no real-time traveler information system except in a few bus stops on the Rapid Bus.
6	Unsolicited comments have been quite favorable.

7	Survey after LED demo project reveal positive responses on LED signs. Respondents were satisfied with quality of message (information displayed, length of message, etc.) Survey of bus status video monitors: 80% of regular and occasional users of the system felt monitors were accurate all or most of the time. 75% of regular users indicated information about actual and scheduled departure times and description of route numbers was very useful (most occasional users found these "somewhat useful"). Most respondents thought quality and location of screens were acceptable ("good" or "ok")

6) *Has your agency evaluated the benefits to riders of using real-time information (e.g., time savings, awareness of service disruptions)?*

Survey Number	Response
1	No
2	Web site: 95% agreed saves time, 94% decided to wait longer before leaving home or work for bus stop after checking web site. 90% used it to minimize their wait time. Wayside: 42% now know how long they have to wait; 19% know exactly when the bus will arrive. 60% cited reduced anxiety.
3	See # 5, Data used internally to test new routes & tweak current routes
4	No. This is something that is being pushed from the bottom up. Currently reviewing an ITS Strategic Plan that recommends a Steering Committee take on this task.
5	Not yet. Will do after real-time traveler information system is implemented
6	Questions will be included on customer satisfaction survey that will be conducted next spring.
7	Survey of bus status video monitors asked attitudinal and behavioral questions of users: analyses suggest users view system as real benefit (more than just cosmetic), through peace of mind or flexibility. However, it does not significantly increase satisfaction with decision to use the bus.

7) *Has your agency collected data or completed studies on rider use of real-time information that could be of use to this study? Can you provide copies of these materials?*

- "Customer Satisfaction with Real-time Arrival Information in Portland, Oregon," submitted to 83rd Annual TRB Meeting, January 2004, Science Applications International Corporation.
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