Quantitative Evaluation of Advanced Traveler Information System Benefits

by

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ABSTRACT

Advanced Traveler Information Systems (ATIS) are a set of technologies that provide travelers with travel-related information that takes advantage of improvements in traffic sensing, information processing, system control, and modern communications media to provide personalized, reliable, and timely information to the service users. As ATIS projects are considered alongside other transportation investments, there is a need to be able to evaluate these projects in commensurate terms with other alternatives. The aim of ATIS benefits evaluation is to answer the following three questions: 1) Is a given project worthwhile? 2) Which project alternative is best? and 3) How do the benefits to the user compare to the benefits (or costs) to the rest of society? The last question is of particular importance for to the planning and deployment of ATIS. In this thesis, we develop a framework, methods, and tools for estimating benefits from ATIS.

The framework is based on modeling the impact linkages between ATIS deployment and the valuation of system impacts. The benefits estimation methods consider user and system benefits based on scenarios for changes in traveler behavior on a per trip basis. A spreadsheet tool implements these methods to estimate benefits using trip scenarios. The tool provides an organizational framework for collecting and inputting data, and provides output that aggregates benefits by market segments and trip scenarios.

The methods and tools developed here are being used for ATIS project evaluation in the Metropolitan Model Deployment Initiative (MMDI). The benefits analysis of these projects were the initial motivation for this research. The methods and tools developed here are being used to guide the data collection efforts. We will report on the results of the analysis of MMDI projects in the future.

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ATIS	Advanced Traveler Information Systems
ATMS	Advanced Traffic Management Systems
BCA	Benefit-Cost Analysis
CS	Consumer Surplus
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GPS	Global Positioning System
HOV	High-Occupancy Vehicles
HPC	Handheld Personal Computer
ISTEA	Intermodal Surface Transportation Efficiency Act
ITI	Intelligent Transportation Infrastructure
ITS	Intelligent Transportation Systems
JPO	Joint Programs Office
MMDI	Metropolitan Model Deployment Initiative
NPV	Net Present Value
PC	Personal Computer
SOV	Single-Occupancy Vehicles
TT	Travel Time
USDOT	United States Department of Transportation
VHT	Vehicle-Hours Traveled
VMT	Vehicle-Miles Traveled
VOT or VT	Value of Time
WTP	Willingness-To-Pay

Chapter 1. Introduction

Advanced Traveler Information Systems (ATIS) are a subset of Intelligent Transportation Systems (ITS), the collective name given to the broad range of technologies that apply traffic sensing, information processing, control theory, and telecommunications to the management of transportation systems and the dissemination of information to travelers. ATIS offers travelers services that provide transportation information, such as real-time traffic conditions, accident locations, transit schedules, parking availability, lane closures, trip planning, and route guidance. The information can be descriptive or prescriptive, pre-trip or en-route, and quantitative or qualitative. Travelers are expected to benefit from these new information services, and the resulting modifications they make to their travel activities are expected to impact both their own travel costs and those imposed on the environment and the transportation system.

Objective

The purpose of this thesis is to develop an approach to evaluating the benefits of ATIS projects in the context of a Benefit-Cost Analysis (BCA). As ATIS (and ITS in general) are being considered as alternatives to traditional transportation investment, there is a need to evaluate these technologies in commensurate terms with other transportation investments. BCA is an important evaluation criterion for guiding transportation investment decisions.

The need to evaluate the benefits of ATIS presents some different issues than that of traditional transportation infrastructure investments, such as highway capacity expansion, due to the unique nature of the service and the opportunities for both public and private investment. The business models of ATIS markets are still evolving, and the long-term roles of the private and public sector in providing these services is yet to be determined. BCA provides decision support for answering questions such as *Is a given project worthwhile?* (e.g. are the net benefits positive?) or *Which investment or project alternative is the best?* (e.g. how does the value of the benefits compare to that of other projects?) For ATIS, we also pose an additional question, *How do the benefits to the user compare to the benefits (or costs) to the rest of society?* Therefore, in addition to providing us with knowledge about the magnitude of the net benefits of ATIS, the benefits evaluation should also distinguish between user benefits and system or environmental benefits (or costs). This knowledge will help guide the public and private sectors involvement in the evolution of ATIS markets and business models.

The original motivation for this research was ATIS benefits evaluation for the Metropolitan Model Deployment Initiative (MMDI), a program initiated by the United States Department of Transportation (USDOT) in 1996. Over the past decade, legislation in the United States has led to the development and promotion of the domestic ITS industry. Government funding has been used for ITS deployment in field tests, pilot applications, and components of local transportation management systems. The MMDI program is the next step (at the time of this writing) in the USDOT's plan to evaluate ITS. In the program, four metropolitan areas—Seattle, San Antonio, Phoenix, and New York—have been selected by the USDOT in order to demonstrate the benefits of integrated transportation management systems and multimodal traveler information services. The program offers a unique opportunity to evaluate all ITS technologies at these four sites in the context of a fully-integrated, region-wide, ITS-rich environment.

Methodology

This thesis presents an integrated framework, methods, and analytic tool for evaluating the benefits of ATIS within a Benefit-Cost Analysis (BCA) structure. The framework is based on modeling the impact linkages ranging from the preconditions for deployment to the valuation of transportation-related impacts. From the framework, we develop methodologies for valuing internal and external impacts. The methodology is based on modeling impacts at the level of the trip. We enumerate a set of trip scenarios based on changes in traveler behavior, information type used, and modal orientation of the traveler to organize a series of models for valuing internal and external impacts of each scenario. An analytic tool in the form of a spreadsheet was developed based on the evaluation frameworks and methods developed in this thesis. The tool will be used to conduct the analysis and guide the data collection in the MMDI evaluation.

Organization

This thesis is organized as follows. In Chapter 2, we provide background on the nature of ATIS and prior research on ATIS evaluation. In Chapter 3, we present the framework for evaluating ATIS. The framework gives an overview of the approach to benefits evaluation developed in this thesis. In Chapter 4, we provide methods for evaluating the external, or system impacts and benefits of ATIS. In Chapter 5, we provide methods for evaluating the internal, or user impacts and benefits of ATIS. In Chapter 6, we model internal and external benefits at the trip level, introducing the concept of the trip scenario and integrating the methods presented in the two preceding chapters. In Chapter 7, we implement the methods of the previous chapters in the form of a spreadsheet tool. The spreadsheet tool is comprised of a series of linked worksheet modules that estimate benefits for an ATIS project. In Chapter 8, we summarize the contributions of this thesis, and present future research directions.

Chapter 2. Background

In this chapter we describe the background of ATIS by defining the technology itself as well as the nature of previous research and evaluation. We need to define the nature of the technology and how it is used in order to understand how we expect the technology to lead to benefits. Previous research on ATIS has considered traveler behavior, impacts, and some of the likely benefits. At the end of this chapter, we define the needs for ATIS evaluation efforts, and why the benefits evaluation framework presented here is a unique and useful contribution for helping us to learn about how ATIS may lead to transportation-related benefits.

This chapter is organized as follows:

In Section 2.1 we provide a clearer understanding of ATIS by defining the range of technologies and their attributes. We also look specifically at one of the projects in the MMDI. In Section 2.2 we provide a background on previous ATIS evaluation efforts and why the BCA framework developed in this thesis will be useful for evaluating benefits from ATIS.

2.1 Advanced Traveler Information Systems: What is it?

Advanced Traveler Information Systems (ATIS) refers to a new set of traveler information services that relies on improved data collection and advanced technology for information processing and dissemination to provide the user with better knowledge about the transportation system and potentially improve travel times across a network through improved guidance. To gain a better understanding of ATIS, we provide an overview of the functional differences among ATIS, and then give an example of an ATIS project that is being implemented as part of the MMDI.

2.1.1 ATIS Functionality

In this section we examine characteristics of ATIS and define the differences between contrasting forms of information.

The primary characteristics that separate ATIS from previous sources of traveler information (such as radio traffic reports) are:

- Geographic Personalization. Instead of travelers being given information about major incidents in an entire metropolitan area, they have the opportunity to receive only information that is pertinent to their trip or route.
- On-Demand Information. Travelers have the opportunity to determine when they receive information and through which media they receive it. For example, a traveler may choose to receive a fax everyday at 5:00 PM updating the work-to-home trip.
- Improved Real-Time Information. Improved methods of data collection, due to the implementation of other ITS technologies, have increased the quality and reliability of available information, especially for describing real-time travel conditions or giving up-to-date travel times.

A variety of media are utilized to provide traveler information services. The medium may be fixed and publicly owned, such as a kiosk, or it may be mobile and privately owned, such as an in-vehicle navigation system. The range of ATIS media that are currently deployed or planned for deployment include:

- Kiosks
- Web sites
- In-vehicle navigation systems
- Handheld PC's
- Personalized Messaging Services (Pages, e-mails, faxes)
- Television (Broadcast and Cable)

- Telephone Call-In Services
- Variable Message Signs

Each media has different capabilities for providing information. Next, we list and describe some of the characteristics of the information provided by different ATIS:

Trip/Route Planning: A core function of many ATIS services such as in-vehicle navigation systems, web sites, and kiosks is to provide instructions or directions on how to take a trip, whether driving or using transit.

Transportation Mode: The information may refer to a single mode, such as auto, or it may be multi-modal, providing information about highways, transit, airlines, etc.

Route Guidance: Route guidance can be either on-screen, voice-instructed, or both, and is generally a key function of devices such as in-vehicle navigation systems or handheld PC's. This function is sometimes coupled with a vehicle location system, such as GPS (global-positioning system) which maintains vehicle location to complement turn-by-turn route guidance.

Predictive: The ATIS service may forecast travel conditions under normally uncertain circumstances (e.g. estimating incident clearance time or anticipating the diversion behavior of other drivers on the network). Predictive ATIS that forecast the behavior of other drivers may serve as transportation management tools as well, since they may be strategically used to minimize average travel times on the network.

In the next list we continue to describe some information features by focusing on the major distinctions among contrasting forms of information types found in ATIS. ATIS may provide either or both of each information type:

Static vs. Dynamic: Static information is predictable information, that may be stored on a device, such as a CD-ROM. It may include data such as expected travel times during different times of the week or scheduled transit service. Dynamic information is information that is updated to reflect current system conditions based on data received and disseminated via a system of transportation network monitors. These monitors may include probe vehicles, loop detectors, or traffic video surveillance. The ATIS device receives this information via link-up with an external information source. Dynamic information provides information about unpredicted incidents and delays or confirms predicted traffic or transit travel conditions.

Quantitative vs. Qualitative: A way to explain this difference is by example. If a traveler is told that an evening commute would take the usual amount of time, a qualitative message might say "situation normal" or "all clear", whereas a quantitative message would give the estimated trip time.

Descriptive vs. Prescriptive: We explain this difference by example as well. IN the case of an incident, descriptive information informs the user of the incident and the expected additional travel time. Prescriptive information would report the incident and prescribe an alternate route, mode, departure time, or other travel choice to the user.

Pre-trip vs. En-route: The traveler information may be received either before the traveler has embarked on a trip or while the traveler is en-route. Certain devices, such as kiosks or web pages, can only be used for pre-trip information due to the logistics of use. In-vehicle navigation systems and pagers, however, may be used to alert users while en-route of dynamic conditions affecting their trip.

Adaptive vs. Non-Adaptive: This distinction is important for route guidance and trip planning features. "Adaptive" refers to the ability of ATIS to modify its suggested route plan or guidance as a result of changes in traffic network conditions.

2.1.2 Description of an MMDI ATIS Project

As of March 1998, there are 27 planned ATIS projects across the four MMDI sites: New York, Phoenix, San Antonio, and Seattle. The projects cover the range of devices described in Section 2.1. Table A-1 lists the planned MMDI ATIS projects, along with some brief descriptions of information usage and other attributes. To develop a strategy for evaluating the benefits of these projects, we first need to understand the specific attributes and the expected impacts of each project. MMDI evaluation planning documents (Sitabkhan *et al.* 1998) contain descriptions for all the projects listed in Table A-1. In this section we give a detailed overview of one ATIS project in order to develop a "case study" that we can refer to at other points in this thesis to better explain how we evaluated a project and how we expect the traveler to use the ATIS service.

The project we use for this example is the Fastline "Embarc" Handheld Personal Computer Software developed for handheld personal computers (HPCs) that use the Windows CE software platform. We choose this project because it is rich in terms of the type of information and the potential for a wide variety of uses. The choice to describe this project as an example is not based on any opinion about the potential for this particular project's success relative to other ATIS projects.

This ATIS application is being deployed for the MMDI in both Seattle and Phoenix. The project information provided in the following sections is based primarily on the details of the Seattle deployment. (Sitabkhan *et al.* 1998)

2.1.2.1 Capsule Description

MMDI funds have been used to aid software development for an interactive hand-held personal computer program that displays traffic flows and incidents, area maps, turn-by-turn route planning, transit schedules and conditions, yellow pages, and general information (e.g., news, weather, sports, etc.). The organization developing the software is Fastline, a software company with previous experience in providing real-time traffic and travel information products and services. The program will be made to work on any device running the Windows CE software platform, such as Casio and Hewlett-Packard handheld personal computers. Dynamic information updates will be accessible via a server which is connected to the Internet.

This project was officially deployed in Seattle as of April 1998. Fastline estimates that there are around 400,000 HPC users nationwide. They do not know the estimated number of HPC users for either Seattle or Phoenix.

2.1.2.2 Technology Components and Information Flows

Figure 2-1 shows the information flow for this ATIS project in Seattle. The ITS Information Backbone integrates information provided by other Seattle MMDI ITS initiatives, such as Freeway Management, Incident Management, Traffic Signal Control, and Transit Management. A content server maintained by Fastline will obtain regional traffic information and transit information from Seattle's ITS Information Backbone. HPCs may interface with Fastline's content server via modem. The modem may be the traditional wireline, or it may be wireless to allow a greater degree of user mobility and en-route access to real-time information. The Fastline content server provides traffic information (congestion map, incidents, maintenance, closures, and detours), area maps, turn-by-turn route planning, transit schedules, routes, fares, delays, bus locations, yellow pages, and other information (news, weather, sports, events etc.).

The information provided by the Fastline *Embarc* application for the Seattle area includes the following:

- Display of current traffic condition(s)
- Navigational advice and display
- Incident and advisory alerts
- Bus and Ferry information
- Points of Interest information

Future enhancements are possible, and they will probably be based on the extent of the use and acceptance of the application.

2.1.2.3 "Project" versus "No Project" Scenarios

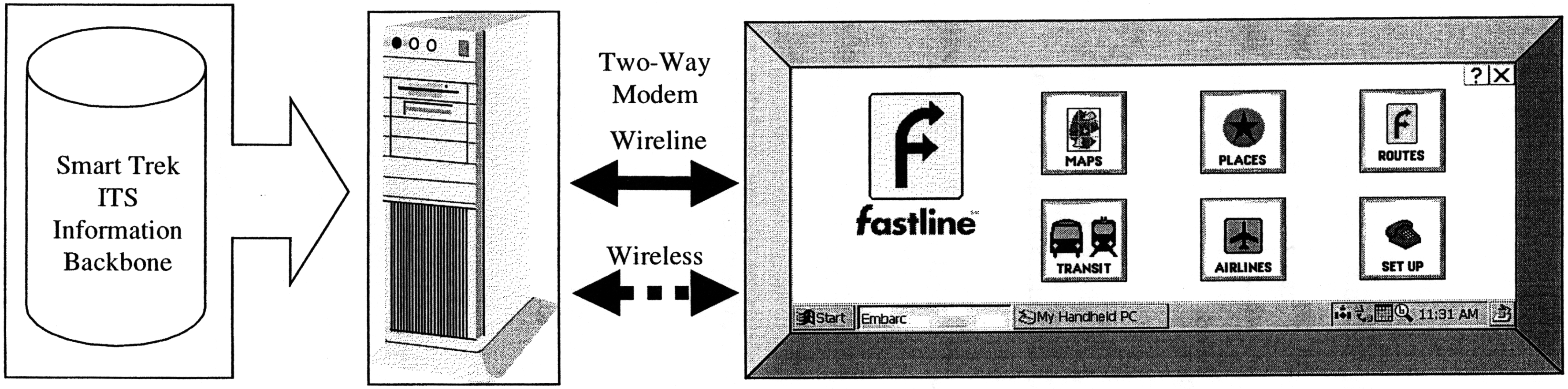
For the benefits analysis, we must organize the expected outcomes or "impacts" that result from a project. To do this, we have to understand the difference between the "project" versus "no project" scenarios.

We describe the "no project" scenario as the "base case". Naturally, these are the conditions would exist if this project were not implemented:

- Tourists rely on road maps and local residents for directions and point-of-interest information.
- Commuters and business people are unable to add point-of-interest or errand stops in new destinations without asking for directions from locals.
- Travelers must rely on radio, television reports, or other ATIS products for real-time traffic information.

We describe the conditions that would exist if the project *is* implemented as the "project alternative" case or "project" scenario. These are the expected outcomes or impacts which we use to evaluate benefits:

- Changes in traveler behavior. This may include some or all of the following: change mode, add a trip, eliminate a trip, change destination, change departure time, change route, or increased confidence.
- Reduced travel costs for the user. These may be related to travel time savings or other components of travel costs. The other components may relate to confidence, predictability, less stress.



Fastline Content Server

Handheld Personal Computer Windows CE Display

Figure 2-1. Information Flows and User Interface for *Fastline* Traveler Information Service.

- Changes in vehicle miles traveled (VMT) and changes in the share of trips taken under congestion. These changes will produce savings or additional costs of emissions, accidents, or congestion.

The reduced travel costs and changes in VMT or the share of trips under congestion are results of changes in travel behavior. We explore this linkage in subsequent chapters.

2.1.2.4 Costs

The expenditures required to implement this project are classified as direct or shared. These are shown in Table 2-1. Direct costs are unique to the Fastline project. Shared costs are those that are incurred by all projects using the ITS Information Backbone in Seattle. For benefit-cost analysis, these costs will also need to be distinguished as fixed or variable and one-time or recurring in order to forecast project lifecycle costs.

Direct	• Fastline software development • Attachment of the Fastline server to the Internet at the required bandwidth • Fastline server data collection • Fastline server data processing • Marketing • Customer support • Potential fees for accessing the data from the ITS information backbone • Potential licensing fees to Navigation Technologies if Fastline begins to charge for its services
Shared	• ITS information backbone server data collection • ITS information backbone server data processing

Table 2-1. Direct and Shared Costs of Seattle Fastline HPC ATIS Project (adapted from Sitabkhan *et al.* 1998)

We have no further information on specific cost components at this time. The contribution of this thesis is primarily in the realm of evaluating benefits. We include this cost section here to alert the reader that this is key part of the project description, and a key consideration for project evaluation.

2.2 ATIS Research Background and Evaluation Needs

In this section, we discuss the findings of previous research on the adoption, usage, and impacts of ATIS. The research to date has sought to examine the potential for ATIS by analyzing user response and system impacts. The literature has ranged from theoretical assessments of the proposed impacts and benefits of ATIS, econometric studies of the causal relationships that affect traveler behavior, traffic modeling and simulation to assess system impacts of widespread ATIS use, and questionnaire studies to assess early user perceptions or experiences with the technology. In Section 2.2.1 we present some of the relevant findings from this research, and why these lessons are important to current and future ATIS project evaluations. In Section 2.2.2 we discuss the future needs of ATIS evaluations relative to prior transportation investment analyses *and* prior ATIS research.

2.2.1 ATIS Research Background

Various types of ATIS research efforts were examined in reviewing literature for this thesis. The relevant research can be categorized into three groups:

1. Dynamics of user response to ATIS
2. Systems effects of real-time information and/or route guidance
3. Studies of impacts and benefits of ATIS

In this section, we discuss some of the representative findings of these three streams of research, and conclude with a summary of important lessons and their relevance for the ATIS project evaluation framework proposed here.

2.2.1.1 User Response to ATIS

Econometric studies of revealed and stated preference surveys have been the primary tool set for analyzing user acceptance and response to ATIS.

Polydoropoulou and Ben-Akiva (1998), Polydoropoulou *et al.* (1997), and Khattak *et al.* (1997) studied traveler response to ATIS by studying travelers in the San Francisco Bay Area and the Boston Metropolitan Area. The researchers developed a framework of ATIS user adoption and examined factors affecting market penetration, pre-trip behavior changes, and en-route behavior changes. They found that the sources and types of information affect diversion behavior. ATIS increases the likelihood for trip diversion relative to previously available traffic information sources. ATIS encourages travelers to overcome "behavioral inertia"[1]. The type of information affects the likelihood and distribution of behavior change. For example, in the pre-trip case, a table of behavior frequencies for various information types was derived from stated preference and revealed preference data. Table 2-2 shows a summary of these results. Traveler preferences were also different in the case of en-route information vs. pre-trip information. For en-route information, travelers were most likely to change behavior based on descriptive, quantitative information.

Traveler Behavior	Current Sources	Qualitative	Quantitative	Predictive	Prescriptive Route	Prescriptive Mode
Do not Change	39.92	39.04	25.77	23.76	27.89	29.95
Change Route	16.77	12.72	13.38	14.13	46.72	17.56
Leave Earlier	22.75	28.69	33.02	35.87	17.39	19.19
Leave Later	10.78	11.22	20.04	29	4.09	6.58
Change Mode	2.2	8.32	7.79	7.23	3.89	26.71
CR and LE	6.39					
Cancel Trip	1.2					

Table 2-2. Predicted Choice Frequencies from Different Types of Pre-Trip Traveler Information (Khattak *et al.*, 1997)

Several other studies have also examined various aspects of user response.

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[1] Travelers are reluctant to change their route or any other aspect of their trip even if they are aware of problems on their current route. This may be due to lack of confidence in taking an alternate route, for example. ATIS provides this confidence, thus overcoming the "behavioral inertia" that keeps travelers from diverting in spite of some knowledge of problems on their route.

Small *et al.* (1995) used stated preference surveys to estimate demand models that consider separately the components of travel time that relate to uncertainty and reliability. The researchers found that scheduling decisions interact with reliability, and to the extent that ATIS affects reliability, it effects scheduling. The uncertainty of travel time was broken down into the probabilities of being early or late and the associated costs. They found systematic differences among occupational groups, since the costs of tardiness varied by occupation. The models estimated by the authors showed that schedule delay costs due to unreliability are significant costs of congestion.

Wohlschlaeger (1997) surveyed motorists on route preferences. The survey results indicated that travelers preferred the most direct route[2], followed by the fastest routes and the least congested routes. Most respondents also indicated that they would travel further distance to avoid congestion, and that there was a minimum time savings required before they would change routes.

Charles River Associates, Inc. (1997b) surveyed commuters in the Seattle area who had experience with ATIS. The surveys were used to estimate part-worth utilities of different ATIS attributes (e.g., real-time traffic data, route guidance, etc.). The results indicated that the value of ATIS varies with socioeconomic characteristics such as gender, income, and commute time.

Khattak and Khattak (1998) modeled en-route diversion in San Francisco and Chicago. They found that spatial differences and driver characteristic differences accounted for different behavior in the two cities. Because propensity for diversion was higher in one city than the other, the research warns against the generalization of ATIS behavior models to different geographic contexts.

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[2] "Most direct route" is not specifically defined in this paper, but we may infer that this refers to the route with the fewest turns.

2.2.1.2 System Impacts of ATIS

The effect of ATIS on the transportation network and its potential as a transportation demand management tool for reducing average travel times for all users is another significant area of research. Simplified transportation networks, queuing models, and complex traffic simulation tools have been employed to test the aggregate effects of ATIS-induced behavior on network travel times. The following two studies are indicative of research results:

Khattak *et al.* (1994) combined a traveler behavior model of route diversion (derived from both revealed and stated preference surveys) with a system performance model to evaluate ATIS impacts during incident conditions. The researchers concluded that system benefits of ATIS were more likely when the information is prescriptive. Network characteristics, socioeconomic characteristics, and user demographics were all factors in determining diversion likelihood and the level of system impacts.

Rakha and Van Aerde (1996) modeled traveler behavior observed in Minnesota during an operational test of an ATIS paging service in a traffic simulation model. The results showed that a 15-20% utilization resulted in pagers reducing average travel times, and that the impacts were more significant when the congestion was non-recurring and incident-related. Beyond this level of penetration, a degradation of travel times was observed due to increased congestion on alternate routes. The author also cite a high degree of variation among different origin-destination pairs.

2.2.1.3 Benefits of ATIS

Research examining the benefits of ATIS has come from government-sponsored field-operational tests of the technology. The research has focused on impacts and benefits for the travelers, not the transportation system.

Wetherby *et al.* (1997) studied Minneapolis-area pager and personal communications device users and found that travel times on alternate routes, taken as a result of ATIS use, are not consistently less than those on the normal routes during congestion, unless the congestion is incident-related.

Inman *et al.* (1995) conducted a controlled experiment on in-vehicle navigation system users in Orlando. Significant time savings were observed for planning time, but not for actual travel time. Users expressed less stress and an overall positive response to the technology. Despite insignificant increases in total travel time savings, the willingness-to-pay for this service was high.

Mitretek (1997) summarized ITS benefits research to-date. The report considered separately each sub-area of ITS, including ATIS. Benefits are categorized based on six measures of effectiveness: Time, Crashes, Fatalities, Throughput, Cost, and Customer Satisfaction. These measures of effectiveness were designated by the USDOT in 1996 as a means of organizing and communicating ITS benefits to policymakers and the public at-large. ATIS benefits were cited for all the measures of effectiveness except cost. The benefits cited were categorized as:

- "measured" - these outcomes resulted from field measurement of benefits through studies
- "anecdotal" - estimates made by people directly involved in fielded projects—less reliable than measured outcomes in terms of quantitative benefits estimates
- "predicted" - results from analysis and simulation

A table-summary of the ATIS results in the Mitretek report is given in Table A-1 in the Appendix. Some form of measured, anecdotal, or predicted benefits were found for each of the measures of effectiveness. The benefits were given in terms of natural units, not dollar valuations. Time benefits were the most often documented benefits of ATIS.

2.2.1.4 Conclusions from ATIS Research

Based on previous ATIS research, there are three major lessons that we find useful in creating an ATIS benefits evaluation framework:

(1) *Transferability.* User response to ATIS is a complex function of the socioeconomic and demographic characteristics of the user, the functionality of the ATIS, and the geographic context in which the ATIS is being deployed and used. The geographic context can refer to either inter- or intra- metropolitan area variations. Due to these complexities in user response, there are both opportunities for and limitations to transferring evaluation results across projects. Differences in the geographic context, the type of technology, and the user characteristics create limitations. To the extent that any of these three are similar in another (future) project, there are opportunities to use the results of one project evaluation to make generalizations about the likely value of future ones.

(2) *Marginal vs. non-marginal impacts.* Non-marginal system impacts of ATIS are likely at certain levels of market penetration. These impacts result when the average travel times of all travelers on certain portions of the network are affected by the diversion behavior of ATIS users. The likeliness of non-marginal impacts is a function of geographic context, the traffic conditions, and the nature of the ATIS information.

(3) *Elusive benefits.* Benefits of ATIS are not limited to travel time or vehicle operating cost savings—those attributes which are most easily measurable and quantifiable. Changes in levels of stress, confidence, reliability, and safety are also valued benefits of ATIS. As a result, system impacts and travel time savings are not sufficient for measuring the benefits of ATIS. Many of the benefits accrue at the user or passenger-trip level, and are different by region, user, and ATIS attributes. Our benefits evaluation framework must take these important benefits into consideration.

The benefits evaluation framework developed in this thesis should address these issues and how they relate to implementing and transferring evaluation results.

2.2.2 ATIS Evaluation Needs

As ATIS moves beyond the experimental phase to one where it is seen as a mainstream contributor to the functioning of the transportation system, there is the need for commensurate evaluation. Commensurate evaluation subsumes comparable criteria, such as net present value of benefits, for project comparability and project selection.

In this subsection, we discuss how the ATIS evaluation needs going forward differ from other common transportation investment analysis methods, and how previous ATIS research has contributed to the understanding of the technology and how it should be evaluated. Critical analyses by Hatcher *et al.* (1998) and Bristow *et al.* (1997) are cited in describing some of the reasons for the shortcomings, and the needs of new evaluation frameworks. Section 2.2.2.1 discusses the differences between traditional transportation investment analysis and the needs of ATIS transportation investment analysis. Subsection 2.2.2.2 discusses the differences between previous ATIS evaluations and the needs of future evaluations.

2.2.2.1 Traditional Transportation Project Evaluation vs. ATIS Evaluation Needs

The most important difference between ATIS and all previous transportation evaluation methods is information. Information has a value that cannot be measured at the systems level, since it may not have observable systems effects. The responses to information can be varied, ranging from changes in destination, routes, departure times, and even decisions on whether or not to take a trip. Even a response that does not relate to a specific change in physical travel behavior, such as increased confidence under the conditions of greater certainty due to ATIS, has benefits. Any attempt to try to aggregate the impacts in terms of vehicle-miles traveled or vehicle-hours traveled would give an incomplete view of the potential benefits from ATIS.

In describing the discrepancy between previous analytical frameworks and a new framework for ATIS, Hatcher *et al.* (1998) state that "traditional solutions to transportation problems and analyses that support them have tended to focus on long term facility/service improvements to meet capacity constraints arising during the typical day." ATIS, and ITS in general, are expected to generate maximum benefits during maximum congestion that occurs during non-recurring, incident-affected conditions.

A useful ATIS evaluation framework should be complete in addressing benefits. The nature of ATIS benefits, as illustrated by the examples from ATIS research discussed in Section 2.2.1, is clearly different from those evaluated in traditional transportation investment analysis. The approach proposed in this thesis addresses this need by considering use of ATIS under various trip scenarios and user behaviors in response to ATIS.

2.2.2.2 Previous ATIS Evaluations vs. Future ATIS Evaluation Needs

ATIS research and studies have not explicitly considered the socioeconomic analysis required for ATIS project evaluation. The research has been useful for proving technological viability, demonstrating the nature and significance of impacts, and describing the dynamics of consumer acceptance and response. The benefits research has presented changes in impacts without applying monetary valuation to estimate benefits. The studies have been experimental in nature, and have been important for providing early understanding of how the technology may perform within the dynamics of a real-world transportation network. The lessons learned from these studies and field tests of ATIS provide insight to the development of new evaluation tools.

Bristow *et al.* (1997) critiques previous ITS programs that have been deployed and evaluated in both Europe and the U.S. There is no consistent framework for evaluation, and different tools and measures of effectiveness are utilized for analysis. The "diversity of purpose" in evaluation has led to individual projects adopting individually tailored systems of evaluation. Two reasons for these weak frameworks are:

1. Difficulty in modeling the impacts of the new technologies, including the possibility of new or different impacts, beyond those normally considered in conventional infrastructure projects.
2. Wider ranges of uncertainty, both in terms of technological performance and the behavioral response of users.

The first problem is an important consideration for ATIS. The experimental research does provide direction as to the nature of impacts, and how to go about measuring them. The second problem is also addressed in the experimental research. While uncertainty in the behavioral response of users is ubiquitous, there are also opportunities to correlate certain user groups or information attributes with behavioral tendencies.

The authors assert that a new set of socioeconomic evaluation tools based on evaluating projects on commensurate terms such as benefit-cost analysis, is needed to carry out a complete evaluation of an ITS project. They also present two additional challenges for ITS evaluation:

- *Project appraisal.* Previous evaluations have been retrospective assessments based on observed impacts. In the future, we need a framework for prospective project assessment.
- *Transferability.* As a result of the wide range of assessments and the uncertainty in ITS projects, a strategy is required for transferring results from existing ITS deployments to future projects in other locations.

The likelihood of prospective assessment and transferable results is dependent on many issues. As stated above, ATIS has been shown to be unpredictable and sensitive to a wide range of factors (user, technology, and geographic attributes), presenting a challenge to the transferability of the results of one project evaluation to another. To the extent that any of these factors are similar from one context to the next, we have opportunities for predicting the benefits and impacts of future ATIS projects based on prior experiences.

The framework presented in this thesis attempts to overcome the major problems and issues explained here. By considering all the benefits of ATIS, many of which are quite different and difficult to measure from those considered in traditional transportation project evaluation, we present a socioeconomic benefits evaluation framework that is useful as a consistent means of evaluating ATIS and obtaining results that allow comparability of ATIS with other transportation-related improvements.

Chapter 3. Overview of an Approach for ATIS Benefits Evaluation

In this chapter, we present the framework of the approach for ATIS benefits evaluation that is the basis for the analytical methods and the evaluation tool developed in this thesis. The approach integrates ATIS impacts to the structure of Benefit-Cost Analysis (BCA).

First, we present a framework that shows the causal chain that results in the benefits that can be attributed to ATIS. This framework is a series of impact linkages showing the actions taken to deploy the ATIS, the effects of ATIS on traveler behavior, and the effects of traveler behavior that lead to benefits.

Next, we describe how these impact linkages relate to the structure of Benefit-Cost Analysis (BCA). BCA is the core evaluation criteria for transportation investment analysis (Lee, 1997). It provides the analytic framework for collecting and synthesizing data to obtain useful results that answer such questions as "Is this project worthwhile?" or "Which alternative is the most cost effective?" For ATIS, we also need to categorize these benefits into user and system benefits to aid in understanding the potential evolution of ATIS markets.

At the end of this chapter is a layout of the approach of this thesis, and how the next four chapters, which present the core of the methodology for the quantitative evaluation of ATIS benefits, are organized around this approach.

This chapter is organized as follows. In Section 3.1, we describe the impact linkages framework which we use to evaluate the causal chain that leads to ATIS benefits. In Section 3.2, we describe BCA in general and how we structure the ATIS evaluation within this framework. In Section 3.3, we show the approach to quantitative evaluation of ATIS benefits and how this approach relates to the organization of subsequent chapters.

3.1 Impact Linkages

Our approach towards benefits evaluation is to consider the impact linkages that connect the stages from the institutional preconditions necessary for deployment to the valuation of observed impacts. In contrast to modeling the impact linkages, other approaches that have been used in the past to analyze ATIS are based on system modeling (see for example Malchow *et al.*1996). In such approaches, impacts are measured and valued on an aggregate level. Our approach is based on modeling the linkages that lead to a user making specific travel changes in response to ATIS, and then observing and valuing the impacts of those changes. The impact linkages diagram is presented in Figure 3-1, and the details of the stages and relationships presented in this figure are discussed in this section. By modeling impact linkages, we look at each of the cause-effect relationships and how they lead to observing benefits of ATIS. If any of the cause-effect relationships are violated or broken, then we say that benefits will not accrue.

Sections 3.1.1 through 3.1.6 each describe a particular stage in the linkages diagram, Figure 3-1. Where it aids in explaining the concepts in this framework, we refer to the Fastline handheld personal computer ATIS project presented in Section 2.1.2 as an example to better illustrate these stages and linkages. Section 3.1.7 concludes the impact linkages discussion by presenting the principles of benefits evaluation that result from this framework.

3.1.1 Preconditions

In Figure 3-1, "Preconditions" represent the planning and coordination among agencies that has to occur before ITS can be deployed. The parties involved may be public agencies, public-private partnerships, or private agencies. The coordination may involve changing legislation or other agreements to accommodate ITS. As an example, we can describe the preconditions for the deployment of the Fastline *Embarc* handheld personal computer application, an MMDI ATIS project presented as an ATIS case study in Section

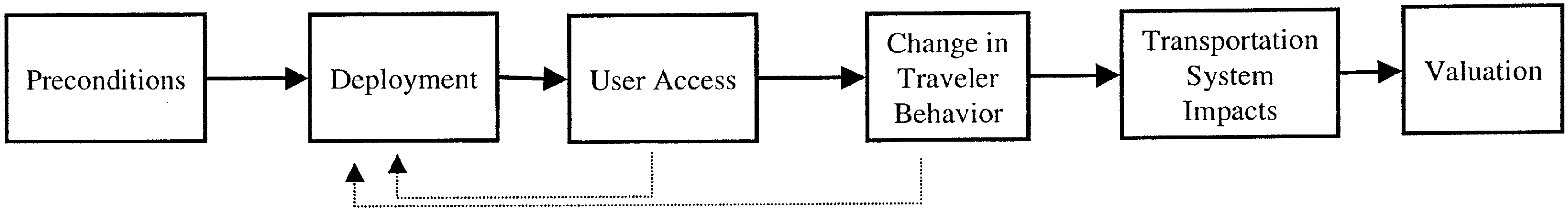
2.1.2. For that project, the parties involved are Fastline, the Washington State Department of Transportation, local transportation and planning agencies in the Seattle metropolitan area, and the U. S. Department of Transportation. The MMDI itself overcomes many of the business obstacles that may have prevented the deployment of this ATIS project by providing federal funding, negotiation, and a model for integration between the Fastline services and the Seattle Intelligent Transportation Infrastructure (ITI). If any of these conditions are unfulfilled, the deployment of the Fastline ATIS project would not occur. The linkages relationship would be broken, and the ensuing links in Figure 3-1 would be irrelevant. If the linkage chain remains intact, we can refer to the aggregated end-benefits of ATIS as "institutional benefits" that resulted from the preconditions described here.

3.1.2 Deployment

"Deployment" is the design, development, and market delivery of the product. We summarize these activities as they relate to the Fastline project as follows. In addition to developing the traveler information software, Fastline will be working with other Seattle area agencies involved in the MMDI effort to build an interface between their content server and the Seattle ITS information backbone. They are involved in the effort to market and provide the software application to HPC users in the region. For the MMDI, they are providing the software to users via free download from the company's website (Fastline, 1998). If all of these tasks are not carried out, then the product will not be successful in the market, and further linkages leading to benefits may be nonexistent.

3.1.3 User Access

The third stage in the linkages is "User Access". This is where the ATIS product is at the stage where the customer physically interacts with and uses the application. The desirability and usefulness of the product is examined. If the user is not satisfied with the



Institutional
- planning
- coordination
- negotiation
- liability
- obstacles

Product
- design
- acquisition
- installation
- software
- testing
- shakedown
- redesign
- operation
- marketing

Access Factors
- awareness
- location
- user interface
- functionality
- features
- perceived reliability

Individual Behaviors
- change route
- change time
- add/delete trip
- change mode
- change destination
- increase confidence

User and System Impacts
- vehicle miles
- passengers
- trips
- throughput
- delay
- reliability
- stress
- comfort
- waiting
- transfers
- emissions
- safety

Valuation ($/unit-impact)
- travel time savings
- additional travel cost reduction (consumer surplus)
- externalities
- capital and operating costs

Figure 3-1. Linkages between ATIS Projects and Benefits product, then redesign of the functions or the user interface may be necessary (as indicated by the dashed arrow in Figure 3-1 from "User Access" to "Deployment").

Polydoropoulou (1997) models this adoption process in greater detail, considering the stages between awareness of ATIS and travel response. The framework in Figure 3-2 is a generic representation of this awareness, trial use, and repeat use adoption model. In this structure, the consumer becomes aware of the service. The awareness is dependent on the level of marketing and advertising. The consumer then uses the product for the first time on a trial basis. If the consumer is satisfied with the product, they may choose to use it repeatedly. With repeat use, the likelihood of changes in traveler behavior increases. The changes in traveler behavior lead to impacts and benefits, which are the next two linkages. Market segments such as the socioeconomic, geographic, and demographic characteristics used to classify users may be observed at this stage. The market segment attributes affect the likelihood, frequency, and results of user access. In the case of Fastline's *Embarc* application, the awareness and use are primarily limited by HPC ownership. Depending on the how the application is delivered and priced, the traveler may or may not become a consistent user of the product. If user access is unsuccessful, then changes in travel behavior cannot be measured, the linkages chain is broken and no benefits are derived from the project.

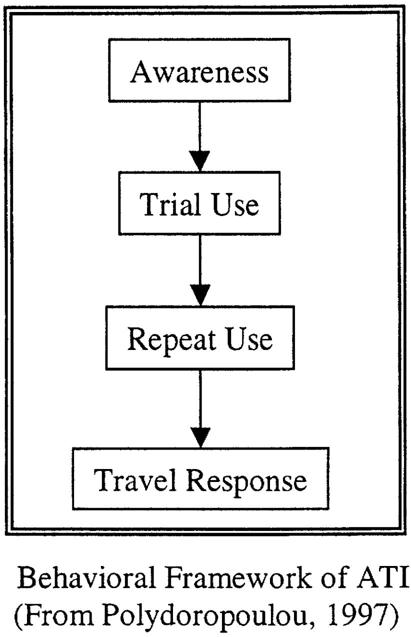


Figure 3-2. Behavioral Framework of ATIS Adoption
(From Polydoropoulou, 1997)

3.1.4 Traveler Behavior

The fourth linkage is "Changes in Traveler Behavior". A change in traveler behavior occurs when the user derives value from the ATIS such that they either physically alter their travel pattern *or* they express increased confidence due to reduced uncertainty or stress. This is the definition of traveler behavior used in this thesis. Travelers include all users of ATIS, regardless of whether or not they actually choose to make a trip based on the information accessed. The travel behaviors include changing mode, adding a trip, eliminating a trip, changing departure time, changing destination, changing route, and increased confidence. If the product delivers useful information, these traveler behavior changes are likely. If not, then the information or the product itself may have to be improved, as indicated by the dashed arrow in Figure 3-1 between "Traveler Behavior" and "Deployment". If we do not observe any of these changes in traveler behavior, then we do not have a causal relationship leading to impacts and benefits.

3.1.5 Transportation System Impacts

The fifth stage in the linkages diagram is "Transportation System Impacts". These are changes that affect either the ATIS user or the transportation system in general. These impacts are the direct result of changes in traveler behavior, and they will vary according to the specific scenarios that lead to changes in traveler behavior. Impacts include such effects as changes in travel time, changes in the number of vehicle-miles traveled, etc. Other impacts are listed on Figure 3-1. Among these impacts, we refer to those that affect the user as *internal* and those that affect the system as *external.* The relationship between changes in traveler behavior and internal and external impacts is presented in Chapter 6. At this stage, we are observing transportation-related changes due to ATIS, but we have not assessed the value of these changes.

3.1.6 Valuation

The final stage in the linkages chain is "Valuation". Valuation consists of two processes. The first is converting the transportation system impacts from their natural units (vehicle-miles, hours traveled, etc.) to dollars. The second is converting the dollars to present values. If all the links discussed so far are unbroken, then the traveler information should generate measurable benefits which may be positive or negative. If we do not have a means of valuing an impact, then we do not have a means of estimating the resulting benefits in commensurate terms.

3.1.7 Implications of Impact Linkages Model

There are some important implications for using the linkage model described above. These are useful to understanding how the impact linkages framework will be applied to ATIS benefits evaluation:

- We focus the analysis of this thesis at the point at which all of the linkages between the preconditions and user access have been resolved, so that we are considering a quasi-steady-state deployment of ATIS technologies. The stages and linkages ranging from user access to valuation are the focus of the benefits evaluation approach presented in this thesis.
- Project benefits can be aggregated at any point along this series of linkages. For example, in the case of user access, we can aggregate benefits for just one type of user. At the traveler behavior stage, we can aggregate benefits based on only one type of behavior change. Back at the preconditions stage, we can associate benefits with the institutional changes that led to the eventual benefits.
- We model linkages at optimum but compatible levels of precision. By this we mean that we want to be as precise as possible for modeling each linkage, but the precision is limited by the availability of the information needed to model that linkage. Therefore, our analysis may not be improved by precision gains in modeling one of the linkages if the other linkages cannot be improved to the same level of precision as

that one. For example, we describe this problem as it relates to the linkage between transportation system impacts and valuation. We may be able to observe impacts such as changes in travel time or vehicle-miles traveled at a certain level of precision, but the valuation parameters such as the value of time or the social costs of automobile use, may be much less precise. As a result, there is little gain to benefits evaluation from increased precision in measuring the system impacts. In the evaluation approach of ATIS developed in this thesis, we try to be as accurate as possible in representing the linkages, realizing that the state-of-the-art in the precise measurement of other linkages may continue to improve.

- The impacts may be marginal or non-marginal. When describing impacts, marginal means that changes in traveler behavior do not result in directly measurable aggregate impacts on the transportation system, but the impact is noticeable at the trip-level. Non-marginal implies that the effect of a series of impacts leads to non-linear changes in system characteristics such as volumes, congestion, distribution by mode, locations of popular destinations, and emissions as a result of the individual trip-level impacts. This linkages framework subsumes direct measurement of trip-level impacts from traveler behavior. If the impacts become non-marginal as a result of substantial travel diversions, then this framework may be incomplete in counting the benefits if it does not consider non-linear relationships along the linkages. Due to the expected levels of market penetration of MMDI projects and the uncertainty of system impacts, we begin the analysis by assuming impacts are marginal and can be directly measured in this framework. If traveler behavior and impacts data suggests that this is not a plausible assumption, then we will have to rely on system models, such as traffic simulation, to provide measures of aggregate system impacts to supplement our trip-level findings.

3.2 The General Benefit-Cost Framework Applied to ATIS

Conceptually, benefit-cost project evaluation is premised on comparing the scenario *with* the ATIS project deployed to the scenario *without* the deployment. These two scenarios are commonly referred to as the *project* alternative and the *base* alternative. In the impact linkages framework presented in the preceding section, we do not explicitly model these two scenarios. Instead, we explicitly model the impacts of the project alternative, which represent the changes in user and system benefits and costs (as related to travel) from the project and base alternatives. In this section we identify what those impacts are, in a broader sense, and what consequences they have for benefit-cost analysis.

In this thesis, when we refer to impacts, we are referring to transportation system impacts that are in their natural units. However, this term is also used in a broader sense in reference to the benefits, costs, and transfers that result from a project. In this section, we describe these last three terms and their role in benefit-cost analysis. Although only benefits are the topic of this thesis, we define what each of these three concepts are to avoid confusion about the definition of benefits used elsewhere in this thesis. The three terms are defined as follows:

(1) Benefits are the monetized impacts that result from a project being deployed and used, separate from the costs of actually deploying the project. These changes may be travel cost savings or changes in output that result from actions in response to the project. Travel cost savings could result from travel time savings, vehicle operating cost savings, accident cost savings, or other decreases in travel costs: convenience, confidence, reduced uncertainty, etc. We refer to these user-related impacts as user or *internal* benefits. The output changes could be measured as changes in travel by automobile or transit. We refer to these changes as system or *external* costs. The term *costs* is used when referring to the negative consequences of transportation (e.g. pollution, emissions, accidents, imposed time delay) that are separate from the mobility benefits to users. Because the term costs may cause confusion, we also refer to this set of system impacts as *externalities*. Benefits are obtained by applying a valuation to natural unit measures of transportation system impacts, such as changes in travel time or changes in Vehicle-Miles Traveled (VMT) to obtain quantities in commensurate terms. The valuation for these two natural unit measures

would be the value of travel time to the user or the social costs of automobile use, respectively. Benefits could be positive or negative. In theory, all transportation system impacts are quantifiable. The level of effort required to quantify a system impact and the usefulness or value of quantifying that impact are considered in the decision to include those system impacts in the BCA.

(2) Costs are the investment required to deploy and operate the project. These should include up-front capital expenditures as well as the variable, recurring costs due to continued operation and recurring capital investment. These costs are not the same as negative benefits, because they are not the result of the project being used—they are the costs of deploying the project, regardless of subsequent usage. In some cases, however, operating costs vary according to usage.

(3) Transfers are project impacts that should not be included in BCA unless an equity analysis is being performed (Lee, 1997). Examples of transfers include user revenues or taxes. Transfers are benefits or costs that are internalized by the system, where the system consists of the users and the transportation or transportation-related services provider. We recognize transfers here because they are often included in the BCA, although, as we state here, it is incorrect to do so. In Chapter 4, for example, we discuss costs of automobile use that are transfers.

The benefit-cost analysis should include all benefits and costs (but not transfers) as described above. In Table 3-1 we summarize how these two impacts are used for benefit-cost project evaluation. In this table, we list benefits that are likely results of ATIS. These benefits are discussed in greater detail in subsequent chapters.

Plus or minus signs in this table indicate the likelihood of a particular benefit to be a positive or negative contributor to net benefits. We see that the user's travel related benefits (travel time savings, additional travel cost reductions) must exceed the externalities and monetary project costs for the net benefits to be positive.

IMPACTS	VALUE (predicted sign)
Benefits	
To the ATIS user: Travel time savings	+$
To the ATIS user: Additional travel cost reductions or mobility benefits	+$
To the system: Changes in externalities	±$
Costs	
Capital costs of the ATIS project	-$
Operating costs of the ATIS project	-$
Net Benefits (Benefits *minus* Costs)	±$

Table 3-1. Benefit-Cost Framework for an ATIS Project

The criterion for project feasibility and project comparison is based on the Net Present Value (NPV) of the project. This is obtained by determining the forecasted total annual net benefits for each year in the project lifecycle, and then discounting them to the current year. If this value is positive, then it is feasible. If it is greater than that of other projects, then, based on the benefit-cost criterion, it is preferable to other projects. Benefit-to-cost ratios are also used when assessing the cost effectiveness among alternatives, but the project with the most value is, by definition, the one that has the highest net present value.

3.3 Approach towards Quantitative Evaluation of ATIS Benefits

The remainder of this thesis will address the methodological issues of how to evaluate the benefits from ATIS use, considering the impact linkages shown above and the information needs of benefit-cost analysis. The framework overview of this chapter shows how the benefits relate to other project stages, from preconditions to impacts. The details that remain to be addressed and explained are the specific user and system impacts and benefits that result from ATIS, and how we choose to approach the problem of measuring and valuing these natural unit impacts.

In the next four chapters, we take a bottom-up approach to showing how the benefits of ATIS should be evaluated. Figure 3-3 illustrates the structure of the next four chapters.

Comparing this approach with the impact linkages diagram (Figure 3-1), we are moving from the right to the left along the linkages chain. First, in Chapter 4 and Chapter 5, we discuss the external and internal benefits of ATIS usage. These are the imposed externalities on the transportation system and the benefits to the user that result from ATIS-induced behavior changes. We present theory and proposed methods and models for measuring user and system impacts and valuing them to estimate benefits. In Chapter 6, we define the trip scenario, which is based on conditions of user access (which includes user attributes and information usage) and changes in traveler behavior. Also in Chapter 6, we integrate the work of the previous two chapters using these different trip scenarios to organize how we distinctly model the internal and external impacts and benefits of different scenarios that result from ATIS user access and traveler behavior changes.

The purpose of this reverse approach is to first explain what the benefits of ATIS actually are and how we should measure them, and then explain how we can approach an ATIS project, incorporating elements of usage and information type, to estimate and categorize total benefits. In Chapter 7, we present a benefits-analysis spreadsheet tool which models scenarios, impacts, and benefits from an ATIS project based on this framework and the methodology developed in the four chapters shown in Figure 3-3.

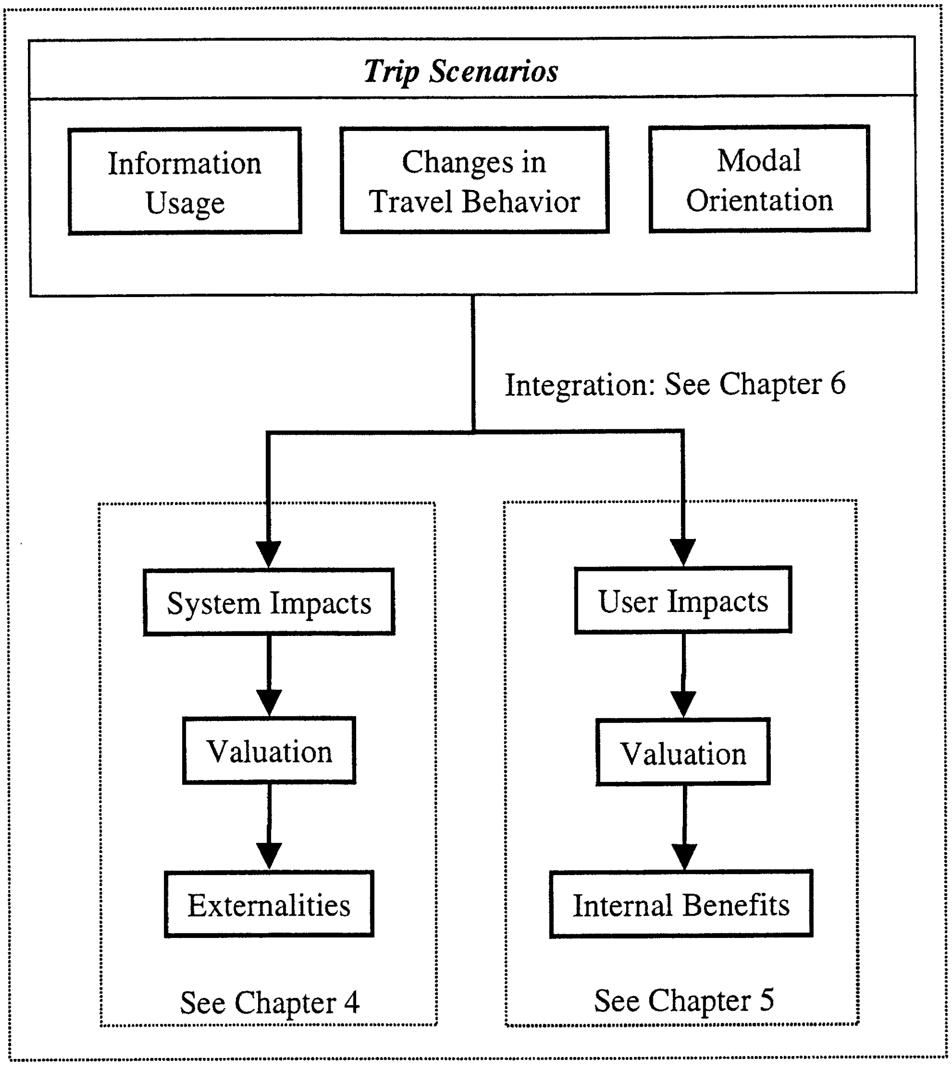


Figure 3-3. Organizational Framework of Chapters 4 through 6

Chapter 4. Quantitative Evaluation of the Externalities of ATIS Use

Externalities are the unintended costs experienced by those other than the individual as a consequence of that individual's decisions. In the case of advanced traveler information systems (ATIS), travelers weigh their own private costs of travel against the benefits they anticipate to determine the nature and extent of their travel. However, their driving also produces external costs, or "externalities". These include such costs as imposed time delay on other transportation users on the network, pollution costs (from air, water, and noise), increased risk of traffic accidents, and increased deterioration of roads (Kanninen, 1996). Since users do not pay for these imposed time delay and environmental costs, these externalities need to be included in the benefit-cost framework.

In this chapter, we discuss the theory, models, and parameters used in the quantitative evaluation of externalities from ATIS usage in order to answer two central questions:

1. What are the measurable external impacts due to traveler behavior changes?
2. How do we choose to value these external impacts?

We answer these questions by presenting a method for evaluating the incremental externalities of behavior changes at the "trip" level. The models presented here are based on the framework of the impact linkages diagram presented in Section 3.1. The models are designed to show the linkage between a specific change in traveler behavior and its effect on external costs. The impacts we consider are changes in VMT (vehicle-miles traveled) and the likelihood of trips occurring under congested conditions. The models presented here are not specifically aligned with changes in traveler behavior—they are presented to serve as the basis for the traveler behavior impact models presented in Chapter 6.

This chapter is organized as follows. In Section 4.1 we present the theory underlying the external costs of automobile use, and how these costs are measured and allocated. In

Section 4.2 we present the models we use in the analytical tool presented in this thesis to account for these externalities.

4.1 Externalities: Theory

In this Section we consider the theory underlying the externalities from ATIS usage. We begin by considering the nature of the system impacts that result from changes in traveler behavior due to ATIS use:

- Changes in vehicle-miles traveled using automobile
- Changes in vehicle-hours traveled using automobile
- Changes in the likelihood that an automobile trip occurs under congested conditions
- Changes in passenger-miles traveled using transit or paratransit

Each of these impacts have various unit costs associated with them. The format for estimating externalities can be summarized as:

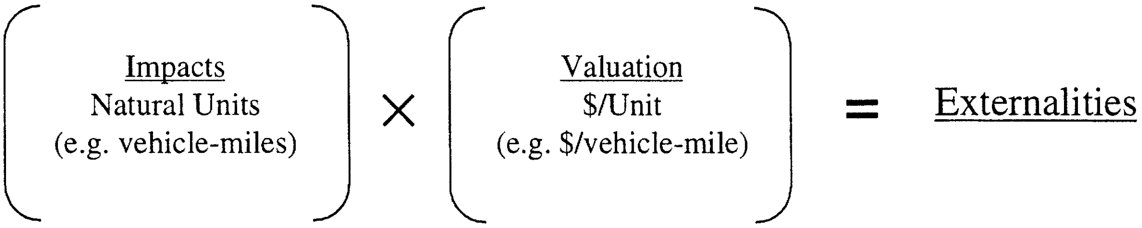


Figure 4-1. Framework for Relating External Impacts to External Costs (Externalities)

The unit costs associated with these impacts are:

- Environmental externalities from automobile use. These include emissions, pollution, and accident costs that result from increased automobile use. They are generally on a per vehicle-mile basis.
- Time delay externalities from automobile use. This is the effect on aggregate travel time imposed by an additional vehicle on the network. These are also on a per-vehicle mile basis.

We make a distinction between the cost of congested trips versus that of uncongested trips. The magnitude of unit costs due to environmental and time delay externalities differs for these two cases.

Not included among these valuation measures are unit costs for changes in the extent of transit use. In theory, there is a variable cost for each additional transit passenger-mile traveled (PMT). However, transit is an excess capacity service with high fixed costs and very low variable costs. We do not include these costs, because they are not of value to the benefit-cost analysis. By "value", we are referring to the fact that while the costs may theoretically exist, they are not of such significance (in terms of magnitude) to be included in the analysis. The framework developed in this and later chapters may be extended to include these costs if it is found that the impacts and costs of changes in transit use are valuable to the benefit-cost analysis.

In the remainder of this section, we discuss the theory underlying environmental and time delay externalities of automobile use. The environmental externalities are a subset of what is commonly referred to by economists as "the social costs of automobile use". In Section 4.1.1, we give an overview of the social costs of automobile use then discuss what subset of those costs is relevant for ATIS externalities. In Section 4.1.2 we discuss the theory and model behind the time delay externalities of automobile use. In Section 4.1.3 we estimate cost parameters for environmental and time delay externalities based on "state-of-the-art" results of the current literature that will be used for the models presented later.

4.1.1 Social Costs of Automobile Use

Considerable literature exists on the costs of transportation, and specifically, the social costs of motor vehicle use. This section reviews the analysis found in recent literature on this topic.

Delucchi (1997) presents the most rigorous framework for the classification of the costs of automobile use. Costs are classified according to the cost bearer, the pricing mechanisms, and the types of costs incurred by the various cost bearers. Cost bearers include the user, the private sector, the public sector, and the environment (transportation system). Figure 4-2 presents a high-level summary of Delucchi's classification scheme, showing the cost bearers and cost types. For the user, the costs are the personal monetary and nonmonetary costs of owning and operating an automobile. For the public sector, the costs are for the automobile goods and services provided by the government. For the private sector, the costs result from automobile goods and services produced and priced in the private sector. These may be separately priced (e.g., parking lot charges), or bundled along with other goods and services (e.g., office space rental amount). The final category shown in this figure does not have a cost bearer—these are the "unaccounted for" costs.

Not all of the costs presented in Figure 4-2 are relevant to valuing the externalities of impacts resulting from ATIS usage. The important category is that of the "unaccounted" for costs. These are, by definition, the externalities. We analyze the other cost categories here in order to understand the why we make the distinction between externalities and other costs in valuing ATIS impacts.

The reasons for excluding driver costs, private sector costs, and public sector costs are given in Table 4-1. Driver costs are internalized by the user. We assume that the user takes into account the personal monetary and nonmonetary costs of driving. Private sector costs are internalized via transfers. Users pay for automobile-related goods and services provided by the private sector service provider. Both user and private sector costs are implicitly include in the user's internal benefits valuation since they are part of the user's total automobile travel cost function. Public sector costs are also not included as an externality either. We offer two rationale for this exclusion in Table 4-1.

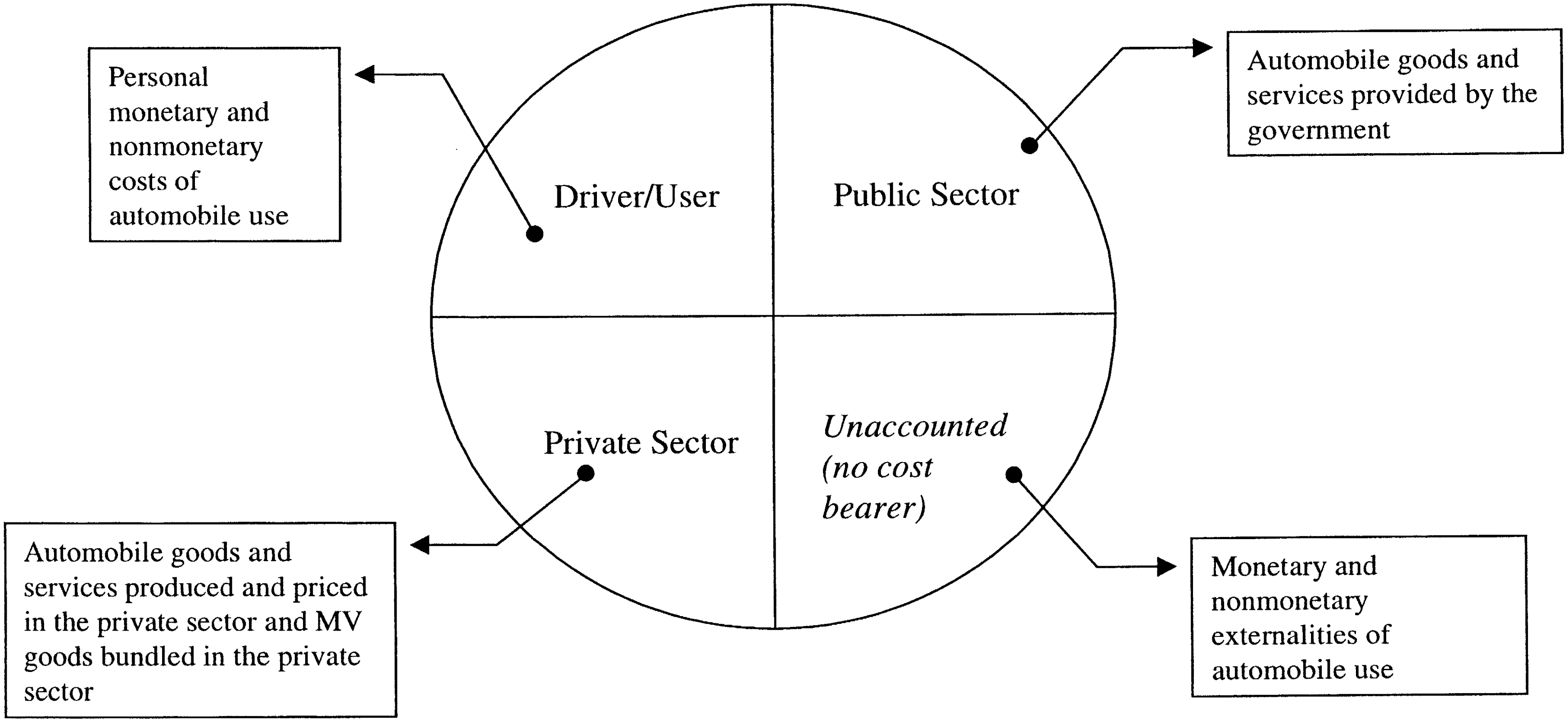


Figure 4-2. Social Costs of Automobile Use: Cost Bearers and Cost Types (Delucchi, 1997)

(1) These costs are transfers that are paid for by the user via gasoline taxes or tolls, in which case they are implicitly included in the internal benefits analysis for the same reason cited above.

(2) The public sector costs, which are comprised mainly of infrastructure and government services, are largely fixed and therefore, like the transit impact case discussed earlier, are not of significant value to the benefit-cost analysis.

Cost Bearer	*Examples of Costs in this Category*	*Reason for exclusion from VMT benefits valuation*
User	• Personal travel time • Vehicle purchase, maintenance	Costs are implicitly included in the internal benefits valuation. (They are directly considered by the user and internalized.)
Private Sector	• Fleet ownership costs • Priced commercial or residential parking (bundled or unbundled)	Costs are implicitly included in the internal benefits valuation. (They are internalized by the user via payment to the appropriate private sector goods or services provider.)
Public Sector	• Annualized highway costs (excluding private investment in roads and/or parking) that includes capital, O&M, etc. • Government services: fire, police, justice	These could be included since they are not internalized by the user and are of interest to the evaluating party (government or planning agency), but two assumptions can be used to justify their exclusion: 1. Costs are implicitly included in the internal benefits valuation via gasoline taxes and/or tolls. 2. Many of the public sector costs are fixed and are therefore not needed in the valuation of incremental changes in vehicle-miles.

Table 4-1. Automobile Social Cost Categories Excluded from ATIS Benefits Evaluation

The externalities are comprised of several separate components. Delucchi (1997) breaks the externalities down into monetary and nonmonetary costs, and estimates low and high values of the total cost (on an annual, aggregate basis) due to each category of externalities. Data for the United States in 1991 was used in the analysis. Table 4-2 shows these aggregate results by externality component. For a more detailed explanation of the sub-components and the methodology of estimating the cost, the reader can refer to Delucchi (1997).

Externality	Low	High
Accidents	23.3	169
Air, noise, water pollution	35.4	523
Global warming (U.S. damages only)	0.5	9.2
Other	6.5	42.6
Total	*66.3*	*743.8*

Table 4-2. Summary of Externalities of Motor-Vehicle Use, 1991 from Delucchi (1997). Results are in Billions of U.S. Dollars for 1991.

The total externalities of automobile use in the United States in 1991 could be anywhere from $66.3 billion to $744 billion. The obvious observation is that the range of externality costs varies significantly. Valuation is a critical aspect of benefit-cost analysis, but even the state-of-the-art in automobile social cost analysis carries an order of magnitude differential between the high and low estimates presented. Delucchi (1997) warns that even this low and high range should not be misconstrued as lower and upper bounds on the costs because there are still other externalities that were not estimable given existing data sources.

Some of the reasons for this imprecision is that these costs vary depending on many characteristics such as the vehicle type, vehicle size, vehicle age, the amount and kind of emissions, the ambient conditions, the "exposed" population, and traffic conditions. Traffic conditions include speed, acceleration, and levels of congestion. Also, specific pollutants, such as carbon dioxide, sulfur dioxide, and nitrous oxide, are emitted at different rates depending on the traffic conditions. The effects of impacts, and the cost of impacts also vary greatly. For example, when a vehicle emits pollutants there are resulting health effects on some segment of the population. The relationship between pollution and the health effects is an uncertain one. To compound matters, pricing the health effects and the costs that they lead to is also uncertain. As a result, the ability to value these effects with precision is undermined.

In the impact linkages framework (see Section 3.1, Figure 3-1), we note that the level of detail at which we model each linkage should be consistent. In this case, the valuation parameters—the social costs of automobile use—vary considerably. Other attributes such as ambient conditions, vehicle characteristics, exposed population, etc., would have to be modeled in detail in order to allocate costs to travel changes that affect any of these. The uncertainty in these parameters means that we should not model impacts any more precisely than at the level of those presented so far (vehicle-miles under congested or freeflow conditions). Therefore, we choose to model the externalities as a function of changes in vehicle-miles traveled, noting a distinction in costs among trips occurring under congested conditions versus those occurring under freeflow conditions.

The remaining challenge, then, is for us to convert these aggregate results from the social cost literature into unit costs (per vehicle-mile) that distinguish between congested and freeflow conditions.

Delucchi (1997) provides cost allocation factors and transportation quantities based on vehicle-miles, ton-miles, freight ton-miles, and fuel for different vehicles, classified as light- or heavy-duty and gasoline or diesel. We assume that most ATIS users are in the category of light-duty vehicles, which include automobiles, station wagons, minivans, vans, jeeps, and utility vehicles. Vehicle-mile and fuel usage factors are most relevant because pollution and emissions are correlated to fuel usage, while the natural units for impacts are vehicle-miles. Allocation factors and transportation quantities relating to the vehicle-mile and fuel usage quantities for light-duty vehicles are given in Table 4-3.

Cost allocation factors	Usage Attributed to Light-Density Vehicles
Vehicle travel	1,995 billion VMT
Fraction of total travel	*0.918*
Highway fuel	100,361 million gallons
Fraction of total highway fuel	*0.781*

Table 4-3. Selected Transportation Quantities and Allocation Factors for Gasoline and Diesel Motor Vehicles in the U.S., 1991. (Delucchi, 1997)

We apply the values in Table 4-3 to the total costs in Table 4-2 to obtain unit cost estimates. Highway fuel quantities were used to determine the portion of the total costs that could be attributed to light-density vehicles. The method for calculating these values is External Cost/VMT = (Total Costs)×(Fraction of total highway fuel/Vehicle-miles). For the high estimation of total costs, the calculated unit cost is $0.291 per VMT. For the low estimation of total costs, the unit cost is $0.026 per VMT. These unit costs take into account externalities due to accidents, pollution, and global warming.

Delucchi concludes with two relevant warnings on the use of these social costs estimates:

- There is considerable uncertainty in these social cost estimates. Delucchi warns that the low and high estimates should not be interpreted as lower or upper bounds, and any analysis using these costs should incorporate a sensitivity analysis via scenario analyses, probability distributions, or other techniques.
- The analysis presented considers the *total* social cost of motor-vehicle use. The ATIS external costs evaluation involves costs that are incremental or decremental to the total. Delucchi warns that "one should not use [his] average-cost estimates in marginal analyses, unless one believes that the total-cost function is approximately linear and hence that any marginal-cost rate is close to the average rate." We explicitly assume that the total-cost function is linear based on the assumption that impacts are marginal (see section 3.1.5).

4.1.2 Time Delay Externalities of Motor Vehicle Use

Imposed time delay is defined as the difference between the average personal travel time related cost and the marginal travel time cost (imposed by the user on other travelers on the transportation network). Imposed time delay is the *system* impact of changes in traveler behavior. It is a system impact in the sense that there is an effect on the travel times of other vehicles on the network.

Road pricing has been suggested as a strategy for controlling this market inefficiency, and the literature in this area has dealt with the issue of estimating imposed travel delay costs. Imposed time delay is mainly a function of the travelers' value of time, the volume-to-capacity ratio on the road, and the elasticity of travel demand with respect to travel time. Figure 4-3 illustrates how the average and marginal travel time related costs vary as a transportation facility becomes more congested. The costs are given as dollars per vehicle mile.

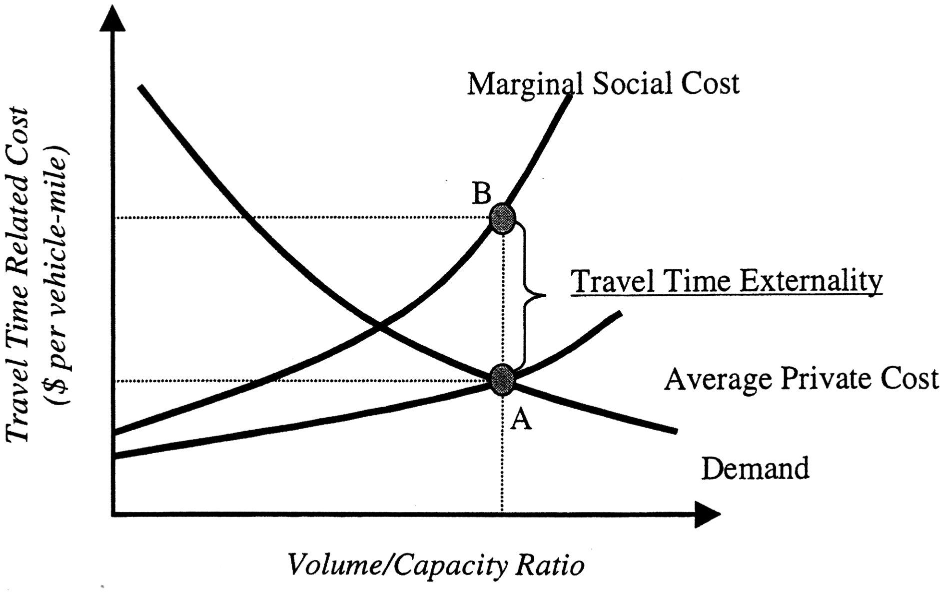


Figure 4-3. Simplified Travel Time Externality Illustration

In this figure, we have three curves. The average private cost curve is the personal travel time cost incurred by each user. This increases as a function of the volume-to-capacity ratio. The marginal social cost curve is the sum of the personal travel time cost and the aggregate imposed travel time delay due to each additional vehicle on the network. This value also increases nonlinearly with the volume-to-capacity ratio. The difference between these two curves is the "gap" or "travel time externality". The "gap" widens as the number of vehicles increase. The third curve is the Demand curve. This curve gives us a traffic volume equilibrium at point "A", because personal drivers choose to use the facility based on their average private cost—they do not take into account the travel time cost they impose on others.

Anderson and Mohring (1997) modeled the road network of the Minneapolis-St. Paul Twin Cities Metropolitan Area to examine the congestion costs and potential for congestion tolls. The authors found that "if, during the morning peak hour, the occupants of each vehicle on the road network value their travel time at $12.50 an hour, the 'gap' between the costs vehicles experience and the full marginal costs of their trips averages about $0.26 per vehicle mile." In their analysis, this value ranged from $0.025 to $0.62 (on a 10-mile stretch of the most congested freeway).

We recognize two implications for the application of these results:

- If the effect of VMT changes due to ATIS use are non-marginal, then the current equilibrium point, shown at A (where the demand curve intersects the average cost curve) may change, resulting in different-sized gap. As discussed above for the environmental externalities, we assume for now that these impacts are marginal, so we assume that the equilibrium point does not change.

- The results presented assume a specific value of travel time and are limited to the Twin Cities Metropolitan Area, although the range of values may be typical. The value of time (VOT) should be consistent with those used in the internal benefits evaluation, discussed in the next chapter. The difference between the marginal cost and the average cost in Figure 4-3 is calculated in minutes and multiplied by a value of time to represent average and marginal costs. If we use a different value of time, we can estimate the travel time externality by multiplying the calculated externality by (New VOT)/($12.50/hour).

4.1.3 External Costs Parameters Based on the Literature

In the two preceding subsections, we have shown how costs of automobile travel are estimated, and the uncertainty in their estimation. In this subsection, we propose how we can use these cost estimates to model the linkage between external impacts and benefits.

We make a distinction between trips that occur under congested conditions and those that occur under "freeflow" conditions. We make this binary simplification to distinguish between two levels in the magnitude of the externality costs. This simplification is expressed by denoting separate external cost parameters for congested versus freeflow trips. By making this simplification, we are not accounting for a range of congestion levels. If the state-of-the-art in externality estimation were to improve such that the unit costs per VMT could be estimated with a high degree of precision, then our analysis would be improved if we were to consider this range of traffic conditions. However, given the limitations of current cost estimates, this is a reasonable simplification.

Exhibit 4-1 summarizes the results of the environmental externalities and time delay externalities, and separates them for freeflow costs and congestion costs. The costs are expressed as dollars per vehicle-mile traveled. The values are based on the following:

1. freeflow environmental externality: based on the low estimate from Delucchi (1997)
2. freeflow time delay externality: we choose not to assign a value for the imposed time delay under freeflow conditions.
3. marginal environmental externality under congestion: based on the high estimate from Delucchi (1997)

(4) marginal time delay externality under congestion: based on the average estimated by Anderson and Mohring (1997)

		Environmental	Time Delay	Total
$/VMT	Freeflow Costs	0.03 (1)	0 (2)	0.03 (ϕ)
	Marginal Cost of Congestion	0.26 (3)	0.26 (4)	0.52 (π)

Exhibit 4-1. Externality Parameters for Valuing Vehicle-Miles

"ϕ" is used to denote the external costs of automobile use during freeflow conditions. The difference between the external costs during freeflow versus those in congested or "peak" conditions is denoted as "π". Therefore, the total external cost of congested travel is "ϕ + π".

Note that in order to differentiate between the freeflow and congestion environmental externality costs we choose to use Delucchi's low and high estimates. If these costs can be better estimated in the future, these parameters can be changed. Our decision to use these high and low estimates is essentially arbitrary, with the only rationale being that we expect environmental costs to be higher during congested conditions than freeflow conditions.

4.2 Externalities: Modeling Impacts and Benefits of ATIS Usage

In this section we present the benefits models for changes in trips and vehicle-miles traveled (VMT's) resulting from ATIS usage. We consider four cases that are relevant for the impact models presented in Chapter 6:

1. Freeflow Trips

2. Congested Trips
3. "Mixed" Trips
4. Changes in both Trip Length and the Likelihood of Trips Under Congestion

The relationships between each of these models and the changes in traveler behavior that lead to these external impacts are presented in detail by behavior type, modal orientation, and information type in Chapter 6.

As proposed in the previous section, we make the distinction between trips that occur under congested conditions and those that occur under freeflow conditions. This simplification used to distinguish between the magnitudes of the externality costs. This is expressed in the models by denoting separate external cost parameters for congested versus freeflow trips. "ϕ" is used to denote the external costs of automobile use during freeflow. The difference between the external costs during freeflow versus those in congested or "peak" conditions is denoted as "π". Therefore, the total external cost of congested travel is "$\phi + \pi$". Both of these parameters are expressed as a dollar cost per vehicle-mile. The components and values of ϕ and π are estimated in Section 4.1.3.

4.2.1 External Cost of Freeflow Trips

We need to estimate the cost of freeflow trips in the benefits model since ATIS information may result in traveler behavior leading to the addition or deletion of freeflow trips. For example, ATIS may induce a freeflow trip if the information presented to the user leads them to take a trip that would not have been taken otherwise, and ATIS may lead to the removal of a freeflow trip if the information causes the user to determine that changing mode results in a preferable trip. In this case, the cost of such a trip, whether added or foregone, must be recognized and accounted for as an external benefit or cost. For freeflow trips, we can estimate the trip cost by multiplying the average trip length in VMT's, X, by the freeflow unit cost per VMT, ϕ, so that the externality of a freeflow trip, $E_{freeflow}$, is given as

$$E_{freeflow} = X\phi$$

X may be positive or negative corresponding to whether the trip is being added or eliminated. The cost, ϕ, should be a negative value so that the sign of the product represents a cost, or negative externality, for added trips, and a benefit, or positive externality, for eliminated trips.

4.2.2 External Cost of Congested Trips

Similar to the freeflow case, the addition or elimination of congested trips needs to be accounted for in the benefits model as well. For this case, our unit cost becomes "$\phi + \pi$" instead of "ϕ". Following the assumptions about the sign of X, and the negative values of ϕ and π, the externality of a congested trip, $E_{congested}$, is given as

$$E_{congested}(\pi, X) = X(\phi + \pi)$$

4.2.3 External Cost of Mixed Trips

By "mixed" trips, we are referring to trips that occur during congested conditions with some probability or likelihood. As a result of ATIS, it is likely that traveler behavior changes will lead to a change in the likelihood of a trip occurring under congested conditions. For example, trips occurring under incident-affected conditions are going to have a much greater probability (up to 100%) of occurring under congestion. Day-to-day trips may occur during recurrent congestion, in which case some percentage of the trips actually encounter the congested conditions. By saying that some percentage of the trips occur under congestion, we could mean either of the following:

- For a single trip, part of the trip occurs under congested conditions and part occurs under freeflow conditions.
- For all trips in a certain category (e.g. commute trips) a certain share or percentage of the trips occur under congested conditions.

For our purposes, these are interchangeable. Many planning agencies collect and maintain data that tracks shares of average trips that are under congested conditions or different service levels, as defined by the volume-to-capacity ratio. We plan to use this data to estimate changes in the likelihood of trips occurring under congestion for the externalities model. We model the costs of the trip as a linear interpolation between the freeflow and congested trip costs.

To model this cost, we need to define an additional variable, p, as the probability of a trip occurring under congested conditions. Likewise, the probability of trips occurring under freeflow conditions is "1 – p". The externality cost of these mixed trips, E_{mixed}, is defined as

$$\begin{aligned} E_{mixed}(\pi, \phi, X, p) &= (1-p)E_{freeflow} + (p)E_{congested} \\ &= (1-p)X\phi + (p)X(\phi + \pi) \\ &= X(\phi + p\pi) \end{aligned}$$

Note that if p=1, then E_{mixed} is equivalent to $E_{congested}$, and if p=0, then E_{mixed} is equivalent to $E_{freeflow}$.

4.2.4 External Costs due to Changes in Trip Lengths and the Likelihood of Trips Occurring Under Congestion

In many cases ATIS traveler behavior may result in a change in either the vehicle-miles traveled, X, the likelihood of trips occurring under congested conditions, p, or both. In these cases we need to estimate the change in externalities that results from these impacts. This change in cost is determined by estimating the difference between the before and after conditions.

We consider the possibility of a portion or the trips occurring under congestion, so we use the mixed trip case for estimating externalities. The externalities for the "without ATIS" or "base" case is given as:

$$E_{base}(\pi, \phi, X, p) = X_{base}(\phi + p_{base}\pi)$$

where X_{base} and p_{base} are the trip length in the base case and the probability of a trip occurring under congestion in the base case, respectively.

The new external cost, in the "with ATIS" or "project" case is written in the same form:

$$E_{project}(\pi, \phi, X, p) = (X_{project})(\phi + p_{project}\, \pi)$$

where $X_{project}$ and $p_{project}$ are the trip length in the base case and the probability of a trip occurring under congestion, respectively for the project or "with ATIS" case.

The cost of interest to the benefits model is the incremental externality from ATIS, or the difference between the two above equations. We call this incremental externality $\Delta E_{project}$ and define it as

$$\begin{aligned} \Delta E_{project}(\pi, \phi, X, p) &= X_{project}(\phi + p_{project}\, \pi) - X_{base}\,(\phi + p_{base}\pi) \\ &= \Delta X\phi + (X_{project}\, p_{project} - X_{base}\, p_{base})\, \pi \end{aligned}$$

where ΔX is the difference between $X_{project}$ and X_{base}.

In some cases, we will want to simplify this equation when only X or p change from the base case to the project case. When only the probability of trips occurring under congestion changes, then the change in externalities simplifies to

$$\Delta E^{(1)}{}_{project}(\pi, X, p) = (X)(\Delta p)(\pi)$$

where Δp is the difference between $p_{project}$ and p_{base} that could result when a new trip is more or less likely to be congested than the old trip.

Likewise, a case may exist where the congestion level remains the same while the overall distance traveled changes. We simplify this change in externalities to:

$$\Delta E^{(2)}_{project}(\pi, \phi, X, p) = \Delta X(\phi + p\pi)$$

In essence, the most important equation in this entire section is $\Delta E_{project,}$ because all of the other cases for freeflow trips, congested trips, and changes in p or X can be drawn from simplification of this model.

4.2.5 Example Externality Calculation

In this subsection, we demonstrate how the costs from the literature can be applied by illustrating a sample traveler behavior change scenario and its impacts.

Chapter 6 presents the relationships between traveler behavior and external impacts and costs. Here we consider an example of such a relationship for which the traveler changes behavior due to dynamic information obtained from an ATIS. The traveler is restricted to using an automobile, and the result is that he/she changes his/her route.

For our example, a traveler chooses an alternate route for his/her morning commute to avoid unexpected congestion on the normal route. The commuter typically travels twenty miles to work in the morning, where there is a 50% likelihood that the trip is congested due to normal, recurrent congestion during the peak commute period. In this situation, there is an incident and congestion is higher than normal. Real-time, pre-trip incident information leads the commuter to change his/her route to avoid the higher congestion levels resulting from the incident. Without ATIS, the commuter would have experienced more congestion on his/her trip than he normally does. We estimate that because of the incident, 90% of that trip that would have occurred under congested conditions. With ATIS, the commuter changes route and travels under conditions more typical of his/her normal commute. We summarize the parameters and variables for this case, distinguishing among the "base" and "project" cases for assessing benefits:

- X_{base} = 20 vehicle-miles
- $X_{projects}$ = 23 miles (assuming user takes a longer but less congested route)
- ΔX = 3 vehicle-miles (23 – 20 = 3)
- p_{base} = 90% (higher share of the trip occurs under congestion due to the incident—this is the trip the user would have taken along his/her normal route without the real-time, pre-trip information)
- $p_{project}$ = 50% (the share of the trip occurring under congestion on the alternate route is typical of the user's normal peak hour trip congestion conditions)
- ϕ = -\$0.03 per vehicle-mile (freeflow externality—from Exhibit 4-1; value is negative because it is a cost)
- π = -\$0.52 per vehicle-mile (marginal externality due to congestion—from Exhibit 4-1; negative to denote that it is a cost)

This situation requires the model presented in the previous subsection:

$$\begin{aligned}\Delta E_{project}(\pi, \phi, X, p) &= \Delta X\phi + \{X_{project}\, p_{project} - X_{base}\, p_{base}\}\,\pi \\ &= (3\text{ VMT})(\$\text{-}0.03/\text{VMT}) + \\ &\quad \{(23\text{ VMT})(0.5)\text{-}(20\text{ VMT})(0.9)\}(\$\text{-}0.52/\text{VMT}) \\ &= \textit{\$3.29}\end{aligned}$$

The positive value indicates that the externalities of automobile use, which are classified as costs, have been reduced by \$3.29 as a result of the driver modifying behavior due to ATIS usage. Another way of looking at this is that the \$3.29 represents "costs foregone".

In practice, we should consider the sensitivity of our analysis to the social cost parameters, due to the nature of their precision. The spreadsheet tool developed in parallel with the theory and models presented in this thesis provides a means of analyzing changes in the end results from different input parameters.

In this chapter, we have shown how we can value the external impacts of ATIS-induced behavior by considering the social costs of automobile use for congested and freeflow trips. We have shown how the costs differ for these two kinds of trips, and how can value trips which have a certain probability or likelihood of occurring under congested conditions. This benefits valuation strategy is incorporated into the spreadsheet model for evaluating ATIS projects. This model is presented in Chapter 7.

Chapter 5. Quantitative Evaluation of the Internal Benefits of ATIS Use

In this chapter, we discuss the benefits to users of Advanced Traveler Information Systems (ATIS). Following the impact linkages framework presented in Section 3.1, we now consider the linkage between traveler behavior and user benefits.

The user is the traveler or customer who interacts with the ATIS technology and changes his/her travel behavior in some observable way. We interchangeably refer to the impacts and benefits to users as being either internal or user impacts and benefits. The term internal in this context means that the costs of the action in response to ATIS are *accounted for* or *internalized* by the user.

We present the theory, models, and parameters used in the quantitative evaluation of internal benefits from ATIS usage. The goal of this chapter is to answer two central questions, which are parallel to those presented in the external benefits evaluation in 0:

1. What are the measurable internal impacts due to traveler behavior changes?
2. How can we value these internal impacts?

The result of this chapter is that we actually have two approaches to measuring user benefits. One approach is to consider travel time impacts and value them at the appropriate rates. The second approach is to forgo measuring impacts, and directly estimate the benefit based on a change in the generalized cost of travel.

This chapter is organized as follows. In Section 5.1, we discuss from a theoretical perspective what the internal benefits from ATIS actually are, and how they compare to those benefits normally measured by traditional transportation-related evaluations. In Section 5.2, we consider the theory and approaches discussed in Section 5.1 with application to the impact linkages framework and ATIS benefits evaluation in the spreadsheet tool.

5.1 Internal Benefits: Theory

The internal benefits of any decision are the expected net benefits that result from trading off the expected benefits and costs of a decision. By *expected* benefits and costs we are referring to those that are accounted for by the party making the decision. The case of a change in traveler behavior is an example. A traveler changes behavior by taking a trip, changing mode, changing route, etc., and in doing so considers tradeoffs among time, convenience, out-of-pocket costs, travel time uncertainty, and any number of other factors. The change in behavior may also include change in confidence due to decreased uncertainty. The reason for the change in behavior is based on the expectation that benefits will be greater or costs will be less. There is a certain risk that a change in behavior could result in negative net benefits, but the traveler implicitly takes this risk into account when changing behavior as described based on traveler information.

The factors affecting the benefits and costs of a trip are part of what is commonly referred to by economists as the generalized price or cost of travel. When we consider a transportation investment such as highway capacity expansion or new traffic management strategies, we are interested in measuring changes in the price of travel for users as part of assessing the potential project benefits. This price or cost includes both the transportation costs and the value of the end-trip opportunity. According to basic economic theory, a decrease in the price of a good results in an increase in the quantity demanded. ATIS may lead to a decrease in the cost of travel due to a decrease in transportation related costs or an increase in the perceived benefits of a trip. When the generalized price changes, travelers are expected to move up or down their demand curves accordingly. The result is changes in travel due to changes in the costs or benefits of trips. Figure 5-1 presents the framework for illustrating the interaction between the travel demand curve and travel changes.

As the price of travel decreases from P_0 to P_1, the quantity demanded increases from Q_0 to Q_1. We refer to this as a downward movement along the demand curve. As a result of this change, the Q_0 travelers who would have traveled at P_0 experience a cost savings, as the difference between what they were willing to pay and what they actually pay increases. The Q_1-Q_0 travelers represent induced demand. The benefit to the induced travelers is represented by the darkened lower triangular region labeled the "Change in Consumer Surplus". The change in consumer surplus includes the benefits of both diverted and induced trips by existing users (Lee, 1997).

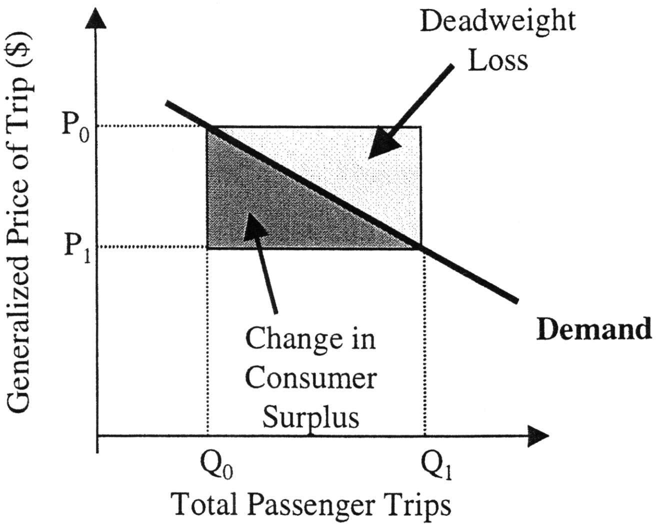


Figure 5-1. Travel Demand and Consumer Surplus from Induced Travel

In theory, this change in consumer surplus is the benefit that results from ATIS. In some cases, ATIS may lead to the user not taking a trip. In that case, the information has led the user to avoid making a choice for which they would have incurred costs greater than they were willing to occur. This is a decrease in consumer surplus, also referred to by economists as deadweight loss (Nicholson, 1995). This is represented by the upper triangle in the figure. In this example, without ATIS the user expected the price of the trip to be P_1. But the actual price of the trip is P_0, which is not desirable to the traveler because it is above the demand curve. Because of ATIS, the user does not make the trip. We account for the decrease in deadweight loss as an increase in the consumer surplus.

However, to measure this benefit as presented in this model, we would need to observe induced demand on an aggregate level. We should consider what this framework means to a single user, since eventually we would like to know how to value a travel behavior change at the level of the trip. We call the benefit of the change in the price of travel for a trip the change in consumer surplus for that trip. We assume that if the cost of trips is somehow decreased, it will lead to induced trips for that user, due to income and substitution effects. Furthermore, we can generalize the induced travel to reflect both new trips and diverted trips. By diverted, we mean diversion by mode, destination, departure time, or route.

Now we come to the core problem in determining user benefits from any transportation investment. The primary question is how do we measure changes in the generalized price of travel in order to estimate the benefit from the change in consumer surplus? A secondary question, which is critical in the case of ATIS internal benefits evaluation, is how do we attribute these changes to traveler behavior resulting from using ATIS?

The remainder of this section is organized as follows:

In subsection 5.1.1 we present a framework for the generalized price of travel, and consider the various components and sub-components. In subsection 5.1.2 we examine a progressive approach towards travel time savings that fits within the generalized price framework and gives us a method for estimating benefits via travel time impacts. In subsection 5.1.3 we consider the recent approach to estimating benefits of ATIS known as "customer satisfaction".

5.1.1 Framework for the Generalized Price of Travel

The generalized price of travel is a multi-faceted cost function with both monetary and non-monetary components. To show how the traveler may "price" a trip, we examine the framework presented in Figure 5-2.

The purpose of this framework is to show a trip, and the major cost and benefit categories that the traveler may incur if the trip is taken. The figure shows an origin and a destination, and benefits or costs that accrue at either of these points or in between. Below we discuss in detail what each of these categories shown in the figure mean, and how ATIS may affect the cost of each of these.

Out-of-Pocket Costs

These are the monetary expenses of traveling. This could include tolls, fuel costs, transit fares, vehicle operating costs, vehicle depreciation, parking fees, etc. Generally, when a traveler considers the cost of a trip it is the variable and incremental costs that are considered. For example, a traveler is not likely to think about the average cost of automobile insurance per trip, since that is a sunk cost. They are also unlikely to allocate a fraction of the vehicle purchase price to that trip. Tolls, transit fares, and fuel costs are the most obvious variable costs. This category is shown in Figure 5-2 as extending from the origin to the destination. This implies that out-of-pocket expenses may occur anywhere along this path. They could occur continuously (e.g., fuel consumption) or occur at discrete points in the trip (e.g., tolls).

ATIS may provide the user with information that decreases their out-of-pocket costs. For example, an in-vehicle navigation system may be able to plan a trip to minimize tolls. Or, a kiosk may provide the user with transit schedule information that leads the user to use the less-expensive transit service instead of taking a taxicab.

Travel Time: Resource Value of Time

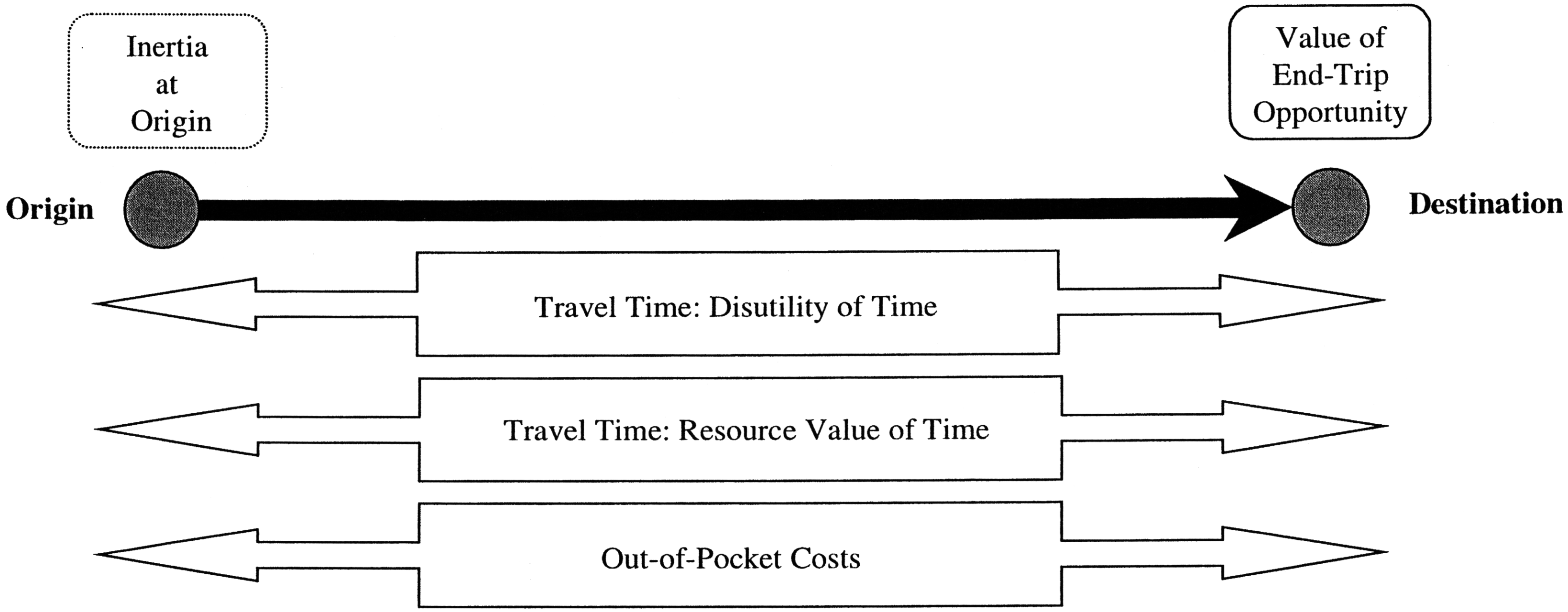
This represents the opportunity cost of travel time, which is also known as the resource value of time. This is the time spent traveling that could have been put to other activities. If one is able to spend this time involved in productive activities, such as a teleconference via cellular phone, then the resource cost of the travel time may be reduced in proportion to the gain in efficiency. Travel time is the entire time spent for taking a trip between the two points. This could include time spent at the origin for trip planning or schedule delay. During the actual trip, this could include time spent waiting, transferring, driving, or in-transit. At the destination this might include schedule delay from arriving early. The box representing the resource value of time costs extends from the origin to the destination in Figure 5-2, since it includes time spent at both locations in addition to time spent in between.

ATIS may affect the quantitative aspects of travel time in many ways. For example, the traveler may reduce planning time by using a handheld PC or web page to plan a route with turn-by-turn directions. Without ATIS, they could have obtained similar information using a map, but it could have taken them longer. ATIS may also provide information about congestion that leads the user to modify travel plans that reduce in-vehicle travel time.

Travel Time: Disutility of Travel Time

In addition to the opportunity cost of travel time, there is a discomfort or "disutility" associated with travel time which causes one's desire to minimize travel time further. The disutility may be a function of several factors: convenience, confidence, reliability, stress, serenity, control, risk of accident, exposure to pollutants, degree of privacy, standing vs. seated, driving vs. non-driving, waiting vs. in-transit, driving in congestion vs. driving in freeflow traffic, etc. The disutility cost also extends across the entire origin-to-destination range, meaning that this cost is incurred throughout the trip.

ATIS affects disutility primarily by simply providing the traveler with information. The information may lead to confidence, a greater sense of control, serenity, certainty, less stress, driving in less congestion, spending fewer minutes waiting, etc. The disutility of travel time can decrease even as the resource cost of the travel time remains the same.



1. Each box represents a benefit or cost to the traveler.
2. The position of a box indicates the point along the trip path where the benefits or costs may accrue.
3. The left-to-right axis can be interpreted to represent time or distance.

Figure 5-2. Framework for the Generalized Cost of a Trip

Value of End-Trip Opportunity

The final cost listed here is actually the single most important benefit—the value to the user of being at the destination. The purpose of the trip may be business, pleasure, shopping, education, etc. The end-destination may or may not have substitutes, depending on the trip purpose. A tourist, for example, has more flexibility in choosing alternate destinations than a commuter or business traveler.

Many ATIS provide information about end-trip opportunities. For example, information about the nearest gas station, nearest automated teller machine, or nearest fast food restaurant is featured in some ATIS services. In many cases, the ATIS can provide the user with alternate or substitute end-trip opportunities that result in decreases in other travel-related costs such as those discussed above.

Inertia at Origin

After the user has weighed all those costs and benefits listed above, they have some idea of the net benefits of a trip and choose whether or not to take the trip. However, even if the net benefits are positive, they may need to be above a certain threshold before the user will take the trip. In general, whether the choice involves taking or not taking a trip or diverting or not diverting from one's original route, there is always a benefit threshold. For example, Wohlschlaeger (1997) found that travelers would change route only if the time savings was at least 10 minutes. This threshold can also be explained by the concept of "bounded rationality" (Malchow *et al.* 1996). The benefit must exceed a certain amount before the user is willing to modify behavior.

ATIS studies have suggested that ATIS reduces this inertia relative to other sources of traffic information. Polydoropoulou (1997) found that ATIS reduces behavioral inertia. Travelers are more likely to switch route or departure time based on ATIS information than from radio traffic reports.

Given these components of the generalized cost of travel and the likelihood of ATIS to affect how the user perceives these costs, the next challenge is to determine which of these costs can be measured in an economical manner in order to provide input to our benefit-cost analysis. The next two sections suggest two approaches to doing so.

5.1.2 Travel Time Savings Methods for Estimating User Benefits

Lee and Pickrell (1997) present an approach to travel time valuations as a means of measuring ATIS benefits through categorical value-of-time (VOT) adjustments that lead to estimable travel time savings.

As explained above, we define travel time as having two types of cost components: the opportunity cost (or "resource value") of travel time and the disutility of the travel itself. As a result of ATIS usage, the travel time cost may change if some of the elements that contribute to the disutility of travel are affected, while the opportunity cost due to the actual amount of time spent traveling may not change.

The approach proposed by Lee and Pickrell is illustrated in Figure 5-3. The approach is consistent with the impact linkages approach where we separate impacts, measured in natural units, from their valuation. In the figure, we show how this travel time savings approach is a modification of the general approach that was also shown in Figure 4-1 for relating external impacts to externalities. The general approach is the top half of the figure. The valuation in the travel time costs case is a combination of the baseline time valuation adjusted by certain factors which we explain below. Given the travel time in natural units, we assign baseline value of time (VOT) parameters. The baseline VOT is the opportunity cost of time, and it may vary according to income, mode, or trip purpose. The travel time valuation may be some percentage of the average hourly wage rate, and it may be greater for work-related trips than personal trips. Lee and Pickrell refer to the U.S. Department of Transportation Guidance (Office of the Secretary of Transportation, 1997) which suggests using national averages by mode and trip purpose in all transportation investment analyses to ensure consistency. Finally, the product of the travel time and the baseline time valuation is adjusted by a single or series of time valuation adjustment factors. Examples of time valuation adjustment factors suggested by Lee and Pickrell are listed in Table 5-1.

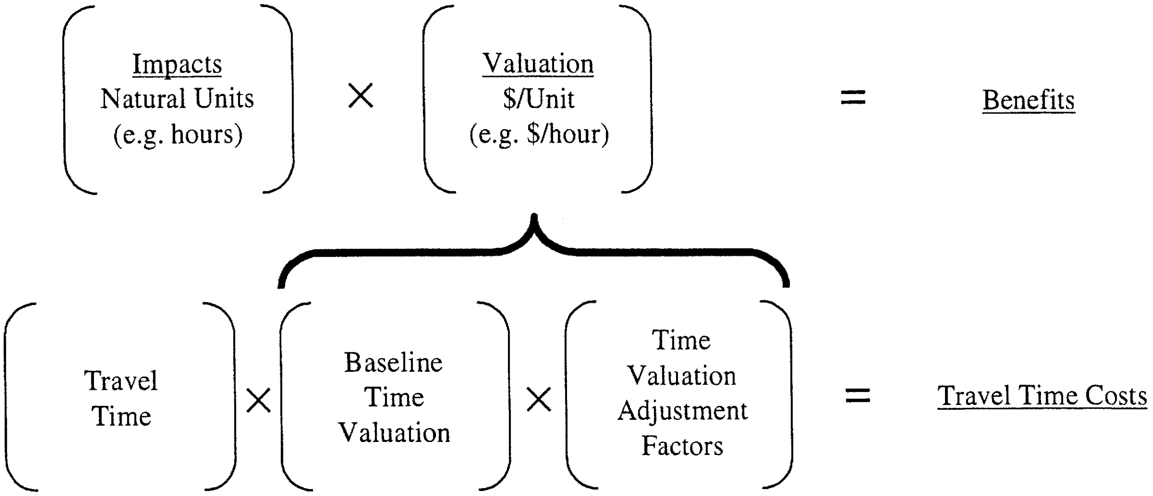


Figure 5-3. Adjusting Travel Time Valuation

Adjustment Factor	Estimated Multiplier
Below- or above- average income	0.5 to 1.5
Pleasure versus emergency trip purpose	0 to 3
Productivity of travel time	1-% efficiency remaining
Standing, waiting, access (transit)	1.5
Congested (auto)	1.1
Reliability	1.0 to 0.8
Alternative time use inflexibility	1.0 to 1.1
Confidence or serenity	0.9
Schedule delay	(no values suggested)

Table 5-1. Time Valuation Adjustment Factors
(From Lee and Pickrell (1997))

The adjustment factors denote a change in the disutility or resource cost of travel time as a result of some condition described by the adjustment factor definition. The adjustments are applied to the average, baseline value of time. For example, higher income groups may value time at a higher rate than the average, whereas lower income groups value time at a lower rate than the average. The same can be said in comparing emergency trips to pleasure trips. The productivity adjustment suggests that if the traveler is able to use the time spent traveling to be conduct other activities whether for leisure or business (e.g., listening to music, talking on the phone), then the time spent traveling is less costly. Adjustment factors for transit wait and access times suggest that the activities have a relatively greater disutility than the average value of travel time. Under congested conditions, we expect greater disutility, hence an adjustment factor greater than 1. Increased reliability or serenity reduces the disutility of travel time, hence an adjustment factor less than 1. The authors do not propose an adjustment factor for schedule delay. Since this is partially usable time, this adjustment factor can be derived based on the productivity during the schedule delay.

The adjustment factors can be applied in order to estimate changes in travel disutility that result from travel behavior changes. The approach is especially useful for ATIS benefits measurement because we can measure travel time savings as a function of both the change in travel time and the change in the valuation of the travel time, based on one or multiple relevant factors given in Table 5-1. Lee and Pickrell suggest that the multipliers can be used in series if several affects are at work at the same time, and the results should still be plausible in magnitude. Integrating the travel time impacts, baseline value of time, and travel time adjustment factors, we set up the following model for estimating user benefits from changes in travel time costs:

$$\begin{aligned}\text{User Benefit} &= \Delta\ \text{Travel Time Costs}\\ &= (TT_{project} \times VT_{baseline} \times A_{project}) - (TT_{base} \times VT_{baseline} \times A_{base})\end{aligned}$$

where

$TT_{project}$ = total travel time in the *project* (with ATIS) case

$VT_{baseline}$ = unadjusted baseline value per hour of travel

$A_{project}$ = the travel time valuation adjustment factors in the *project* case

TT_{base} = total travel time in the *base* (without ATIS) case

A_{base} = the travel time valuation adjustment factors in the *base* case

This equation is similar to that for the change in externalities (Section 4.2), in that we are considering the change in costs from the base case to the project case. It follows the form of "impacts times valuation equals benefits".

As an example of how this benefits estimation could be applied in the context of an ATIS-induced travel behavior change, we present a hypothetical scenario.

We consider the case where a driver obtains information about an incident that is causing travel delays on the route that he would have taken. The driver chooses to divert, taking an alternate route that is shorter in terms of travel time and occurs under less congested conditions. We use the following values (created for this example) to represent the impacts and valuation parameters:

- $TT_{project}$ = 0.75 hours (the shorter travel time for taking an alternate route)
- $VT_{baseline}$ = -\$10.00/hour (because this is a cost, it is negative)
- $A_{project}$ = 0.9 (lower disutility; travel occurs under confident, serene conditions)
- TT_{base} = 1.0 hours (this is what the trip would have taken if the driver was subjected to the delay)
- A_{base} = 1.1 (higher disutility; travel occurs under stressful, congested driving conditions)

$$\begin{aligned}\text{Travel Time Savings} &= (TT_{project} \times VT_{baseline} \times A_{project}) - (TT_{base} \times VT_{baseline} \times A_{base}) \\ &= ((0.75\text{ hrs}) \times (-\$10/\text{hr}) \times (0.9)) - ((1.0\text{ hrs}) \times (-\$10/\text{hr}) \times (1.1)) \\ &= \$4.25\end{aligned}$$

In this example, the traveler accrued benefits of about \$4 from using the ATIS. Other travel behavior changes due to ATIS may result in changes in wait time, travel time, driving conditions, planning time, or schedule delay. We could include the costs for each of these terms in both the base and project cases in estimating travel time savings.

The travel time savings calculation shown above accommodates the fact that although actual travel time may or may not change, other non-time components of the travel cost utility function will be affected by ATIS. The approach allows for the fact that user benefits may accrue even as the actual travel time *increases*. Brand (1998) suggests that a homeostasis is likely to be operating in which a longer trip time is exchanged to gain some other non-travel time benefits from ATIS. This trend has been observed in past experience with ATIS. For example, in a field-operational test for in-vehicle navigation systems, users expressed a willingness-to-pay for the service (after considerable experience using it) in spite of the fact that statistically significant decreases in travel time were *not* observed (Inman, Sanchez, and Bernstein, 1995).

The key challenge facing the implementation of this method is that we do not have observed estimates for this travel time valuation adjustment factors. The evaluation of the MMDI (Metropolitan Model Deployment Initiative) ATIS projects provides an opportunity to collect empirical data that can be used to estimate these factors.

In terms of the generalized cost of travel framework in the previous section and the costs shown in Figure 5-2, this framework covers the travel time costs only. The out-of-pocket expenses and the value of end-trip opportunities would require separate consideration. As the rationale for travel behavior and responses to ATIS becomes more complex, we need to consider combinations of all of these factors. This may become both costly and tedious. In the next section, we look at a method for user benefits estimation that bypasses the impacts and attempts to directly estimate the benefits as a dollar amount.

5.1.3 Customer Satisfaction Methods for Estimating User Benefits

Customer satisfaction methods for estimating user benefits from ATIS have been an important contribution of early ATIS research. The motivation for customer satisfaction research has been the desire to assess the market viability and user acceptance of ATIS by estimating user Willingness-To-Pay (WTP) for the services. To understand why this method is useful for estimating the user benefits of ATIS, we will first discuss why this approach is used for evaluating ATIS, and then discuss the methodology itself.

In evaluating major investments in conventional transportation infrastructure—new highway capacity or new transit systems—the level of customer acceptance (trips, vehicles, or vehicle-miles diverted to or induced by the new facility) is usually forecast quantitatively using a series of mathematical models. System measures such as aggregate changes in Vehicle-Miles Traveled (VMT) or Vehicle-Hours Traveled (VHT) are estimated in order to measure the benefits and costs of the project. The problem with this evaluation approach is that it is not likely to capture all the benefits from ATIS. ATIS differs from these conventional transportation improvements by changing the way in which information about the transportation systems operation is communicated, and this results in benefits not accounted for by the system measures. Information about destinations and events ("trip end opportunities"), the status of the transportation system, and travel services available en route are now communicated to the traveler.

Charles River Associates, Inc. (CRAI, 1996) summarizes the main arguments for why traditional transportation planning tools are not up to the task of forecasting traveler adjustments and benefits to ATIS. Three foundational issues in their argument are:

1. Traditional transportation planning tools are not sensitive to factors that ATIS will change (additional traveler information and the characteristics of that information).
2. ATIS applications will affect travel behavior in ways that do not permit us to predict, in a simple manner, future travel times (and other costs and benefits) that individual travelers will experience when making their decisions.
3. As travelers come to rely on more dependable information on travel times and costs, they are likely to value those attributes of travel much more highly than they do now. (e.g., the cost of missing deadlines and appointments becomes greater as people depend more on the reliable performance of the transportation system.)

The benefits of ATIS have also been referred to as mobility benefits. We define mobility benefits as a function of the opportunities for, and the benefits of, travel (CRAI, 1996). ATIS improves mobility by providing information. If the users acquire the information, and find it useful, they may be able to reduce the costs of transportation (Brand, 1998). The costs may involve any of the categories presented in Figure 5-2, but the impacts and values are too complex to individually observe and model. As a result, we need to directly estimate the benefit, bypassing the measured impacts altogether.

The proposed methodology for measuring the mobility benefit is to measure the incremental change in consumer surplus via customer satisfaction. As we discussed earlier, consumer surplus is the benefit of induced travel due to the change in travel cost. When we consider consumer surplus and the travel cost in general, we are not being specific as to the specific components of cost that are changing, but we are recognizing that somehow costs are decreasing in some unobservable way.

The most acceptable methods for measuring this benefit involve conducting surveys that ask questions in which the users trade off costs with use or preference for an ATIS product or service. The surveys are distributed to respondents using ATIS (e.g., users in MMDI cities) and the results are analyzed using discrete choice models to quantify the dollar values or willingness-to-pay (WTP) for the benefits. (Brand, 1998) Previous studies (Polydoropoulou, 1997) have attempted to obtain a measurement of willingness-to-pay for ATIS and its specific features (personalization, dynamic information, etc.).

For benefit-cost analysis, we would like to be able to derive the incremental consumer surplus for particular change in traveler behavior so that internal and external benefits can be examined as parallel linkages. The difference between this need and previous evaluations is shown in Figure 5-4.

The top two tiers in this diagram are the Product-Level WTP and the User-Level WTP. ATIS customer satisfaction research has focused on these two tiers. WTP has been estimated for different ATIS service bundles, and the partial WTP for certain features has been estimated. WTP users by market segments (differentiated by user attributes) has also been the subject of analysis (CRAI, 1997).

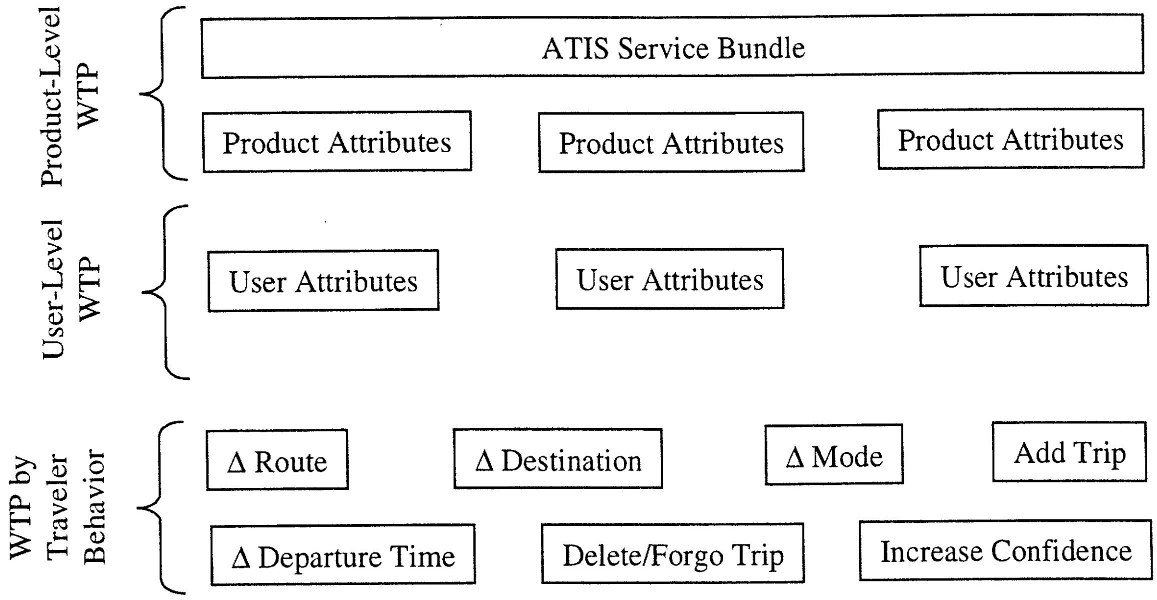


Figure 5-4. Categories for Estimating Willingness-To-Pay (WTP) for ATIS

For our analysis, we would like to obtain measurements of willingness-to-pay by the effect on traveler behavior. This follows from the principles of the impact linkages framework (see Section 3.1), where we want to model each linkage at the optimum level of detail. If we have estimates of willingness-to-pay for the ATIS product bundle irrespective of the travel behavior, then we bypass important linkages between from user access to impacts. Our results are more transferable if we maintain the integrity of each linkage. In the case of changes in the generalized cost of travel, we argue that impacts are difficult to measure in certain cases, and we are forced to directly estimate benefits from traveler behavior. This need is represented in the last tier of Figure 5-4. Customer satisfaction methods should be used to collect benefits information in order to do estimate trip-level changes in consumer surplus.

5.2 Internal Benefits: Modeling Impacts and Benefits from ATIS Usage

Given the travel time savings and customer satisfaction methods presented in Section 5.1, we have two options for deciding how to measure user benefits. The method we present is to use both of these options selectively. We make a tactical choice as to how to measure the internal benefits based on our ability to break down the rationale for changes in traveler behavior. The decision process for this choice is illustrated in Figure 5-5.

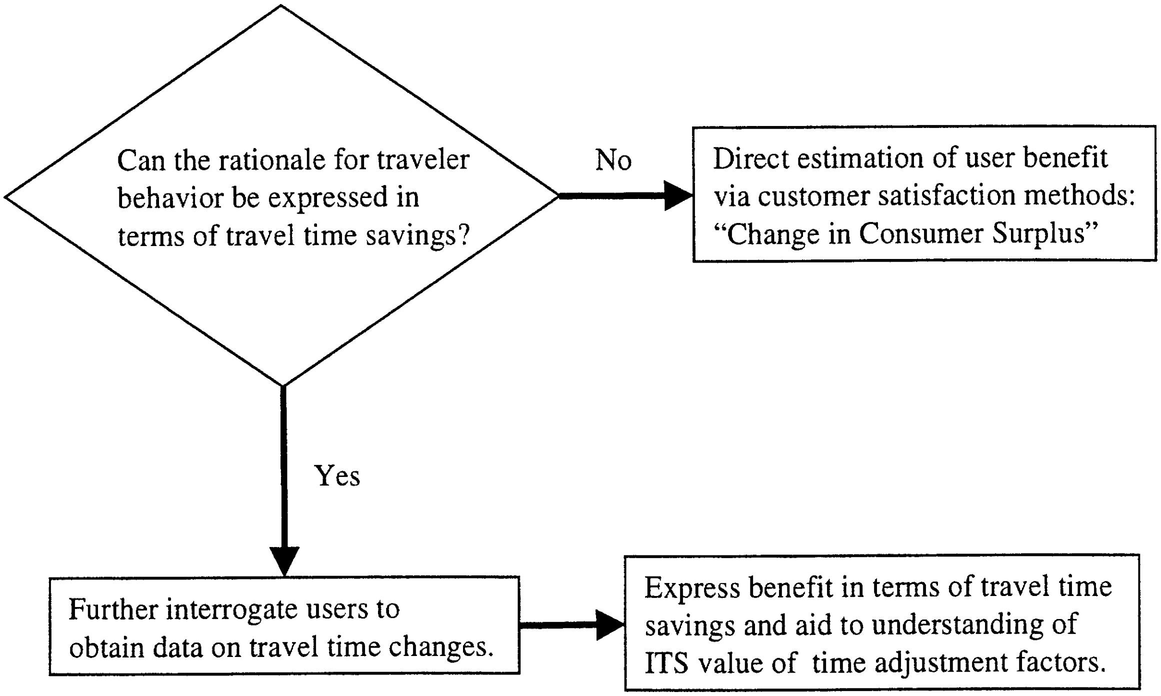


Figure 5-5. Decision Process for Choosing Internal Benefits Evaluation Strategy

The first question we ask, as shown by the decision-diamond in this diagram, is "can the rationale for traveler behavior be expressed in terms of travel time savings?" Depending on the behavior change, the nature of the information made available to the user, and the modal orientation of the user, we may or may not be able to express the decision rationale on the basis of travel time savings. When travelers switch modes, change destinations, add trips, or forgo travel altogether we have difficulty in modeling the decision as one based on travel time. Depending on the answer to this first question, we choose a method for user benefits evaluation.

If we are able to model the rationale for travel behavior in terms of travel time savings, we should do so since this maintains the integrity of the impact linkages. In the MMDI evaluation, we plan to survey a sample of the respondents to obtain empirical estimates for travel time adjustment factors.

If we cannot model the rationale for travel behavior, we bypass measuring impacts in their natural units and directly estimate the incremental consumer surplus change based on the travel behavior.

Figure 5-6 shows how the impact linkages are affected by the parallel approaches to internal benefits. The user impacts and impact valuation on the left refer to travel time savings. The lack of impacts and valuation on the right indicate the direct link from travel behavior change to the benefit.

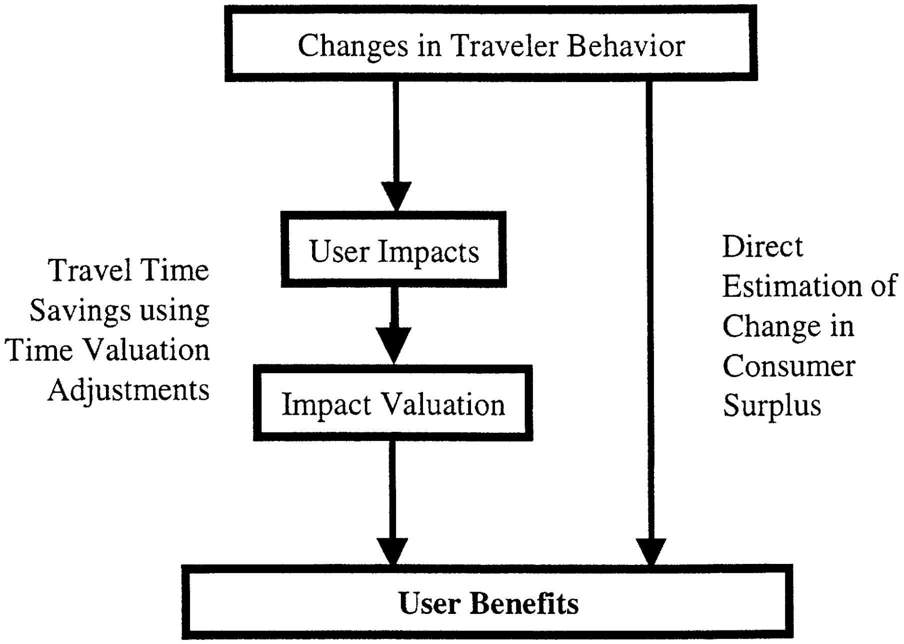


Figure 5-6. Parallel Approaches to Evaluating Internal Benefits of ATIS

In Chapter 6, we examine each traveler behavior separately to assess the appropriate approach to internal benefits estimation for different trip scenarios, which we also define in the chapter.

Chapter 6. Trip Scenarios and Quantitative Evaluation of ATIS

At the conclusion of Chapter 3, we proposed an approach to developing the ATIS evaluation methodology based on modeling the impact linkages that lead from preconditions for ATIS deployment to quantifiable benefits. In Chapter 4 and Chapter 5, we developed methods for modeling the linkages between transportation system impacts and external and internal benefits. In this chapter, we integrate these system impacts and benefits linkages with the precursor stages in the linkages framework: user access and traveler behavior. To integrate these stages, we present a framework for organizing benefits based on the user access and traveler behavior elements surrounding a single trip. We introduce the concept of the *trip scenario* to specify how we model user access, traveler behavior, impacts, and benefits at the level of the individual trip. We combine the internal and external benefits concepts with the trip scenario structure to develop a series of impact models that evaluate benefits for each scenario.

In this chapter, we first define the trip scenario, which is comprised of elements of user access and traveler behavior. We enumerate a set of scenarios that encompass the unique combinations of user access and traveler behavior, based on the elements we use in the classification. The user access characteristics are the information type used and the modal orientation of the traveler.

Next, we model each trip scenario following the structure shown in Figure 6-1. For each trip scenario, we have trips that would have been taken without the additional ATIS information (the **Base** alternative) and affected trips resulting from ATIS usage (the **Project** alternative). The difference between these two, represented by the 'Δ' in the figure is the **Impact** of that trip scenario. Because of the relationship between these three (**Project – Base = Impacts**), we only need to model two of them to define all three. The last step, valuation, requires valuation parameters such as the value of travel time or automobile social costs to estimate net benefits.

Our approach is to define the trips that would have been taken without ATIS, and then define the impacts on those trips when ATIS leads to a change of behavior defined within a trip scenario. To accomplish this, we first define a set of baseline trip characteristics, valuation parameters, and a notational system needed to represent impacts for all the trip scenarios. After that, we present the impact models specific to each ATIS trip scenario.

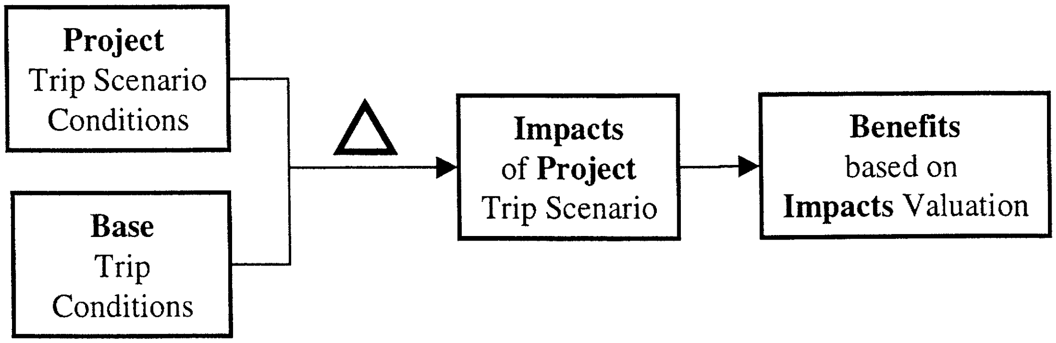


Figure 6-1. Structure for Evaluating Impacts and Benefits from Trip Scenarios

This chapter is organized according as follows. In Section 6.1, we define the trip scenarios. In Section 6.2 we present the general data needs for evaluation: baseline trip characteristics, the general format of the impact data from which we estimate benefits, and the parameters needed for valuation. In Section 6.3 we present the distinct impact models for each trip scenario.

The models presented in this chapter are the basis for the spreadsheet tool that is presented in Chapter 7.

6.1 Defining Trip Scenarios

The ATIS trip scenario is the situation where the traveler accesses ATIS, and then responds to the information by exhibiting an observable change in behavior. Therefore, one aspect of the trip scenario is the actual change in behavior. However, there are other elements to that scenario, and these elements are components of user access. If these other elements are discovered to be important to the modeling the impacts of trip scenarios, then we can append the trip scenarios that we define here.

In Figure 6-2, we show how the trip scenario fits within the impact linkages framework. User access and traveler behavior are the two components of the impacts stream that define the trip scenario. Modal orientation and information type are the two elements of user access which we use in modeling the impacts of each behavior change. As a result, we have three elements defining each trip scenario.

In the next three sections we cover each element of the trip scenario in greater detail, and explain how each element is needed to define the impact models of the trip scenario.

6.1.1 Changes in Traveler Behavior

The traveler behavior change is at the core of the scenario. It represents the action taken by the user in response to the information presented by the ATIS. The action may have consequences (impacts) which lead to benefits. The nature of the behavior will naturally affect the nature of the impacts and benefits.

We model eight actions or responses by travelers using ATIS: (1) change mode, (2) add a trip, (3) delete a trip, (4) change destination, (5) change route, (6) change departure time, (7) increase confidence, and (8) no change/no value. We treat the first seven of these behaviors in defining trip scenarios. The *no change/no value* behavior discontinues the impact linkages such that we do not observe benefits. If we find in the future that there are other behavioral responses to ATIS, we can investigate rationale for that behavior and append the trip scenarios enumerated in this section.

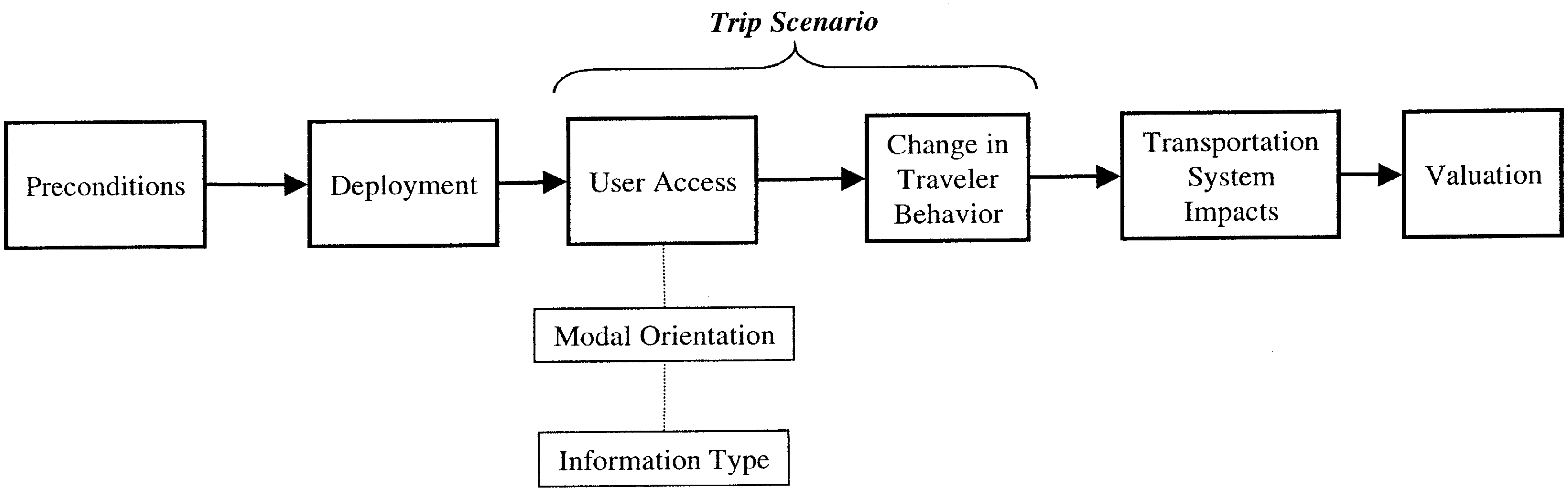


Figure 6-2. Defining Trip Scenarios within the Impact Linkages Framework

It is also possible that some travel behaviors cannot be uniquely defined by just one of these behaviors. We make the simplification that each user can exhibit only one behavior at time. For example, a user may change both mode and departure time, but when we ask the user to categorize their action they say only that they switched modes. In this case, the trip is classified as a mode switch and the departure time change is averaged into the impacts for the mode switch. Another common example is "trip chaining", where the traveler may change both route and destination. Trip chaining may also be classified as an added trip. In any case, we expect to learn about traveler behavior by direct observation via user surveys, so the traveler's answer to the question of what action was actually taken will determine how some of these ambiguous behaviors are categorized. We expect the impacts of trip chaining to be averaged into the impacts for whatever category trip chaining is attributed to by the user.

Traveler behavior directly affects the nature of the impacts. Obviously, both the user and system impacts and benefits for a mode change are different from a changed route, increased confidence, or any of the other behaviors. That is why traveler behaviors need to be part of our trip scenarios—they affect how we model the impacts and benefits of a particular ATIS-affected trip.

6.1.2 Modal Orientation of the Traveler

The modal orientation is important, since the impacts and benefits of any travel behavior are also going to be different depending on the mode options that the traveler has. We classify users according to these three modal orientations: (1) captive to auto, (2) captive to transit, or (3) modally flexible.

If a traveler is captive to a certain mode, such as the automobile, then all trip changes assume automobile use. The differentiation is important because changes in transit trips do not have the same external costs as changes in automobile trips. In the analysis, we choose not to quantify external costs of transit trips, because of the low magnitude and fixed nature of the costs (see Section 4.1).

If the traveler is modally flexible, then that person may exhibit the "change mode" behavior listed above. Mode change is defined after-the-fact on the basis of a traveler selecting a different mode as a result of using ATIS than the one that would have been selected in the absence of ATIS. By this definition, all flexible users derive value from the ATIS based on the actual mode change; none are simply more confident in their previous choice. For example, a traveler who has not made a modal decision uses an ATIS and chooses transit. By surveying the traveler, we determine that this person would have made the trip anyway, and would have chosen transit on the basis of information obtained from published schedules. The traveler, in the context of this model, is a transit user, even though he/she could theoretically have chosen auto for this trip. We differentiate between the impacts of the auto-to-transit switch and the transit-to-auto switch in the change mode behavior change scenarios.

As stated above, the modal orientation affects the impacts due to the scenario because we value changes in transit and auto use differently. Therefore, we need to distinguish modal orientation in our trip scenarios.

6.1.3 Information Type

The information usage also affects the impacts and benefits of traveler behavior. The information usage is based on the source of the ATIS information used. The source can be either static or dynamic, and a single ATIS application may contain one or both of these. Static information is predictable information, that may be stored on a device, such as a CD-ROM. It may include data such as expected travel times during different times of the week or scheduled transit service. Dynamic information is information that is updated to reflect current system conditions based on data received and disseminated via transportation system monitors. The ATIS device receives this information via link-up with an external information source. Dynamic information may either confirm predicted traffic or transit travel conditions, or provide information about unpredicted incidents and delays. We choose to differentiate between these two because the rationale for traveler behavior can differ based on the information, and the resulting impacts for both the user and the system are different depending on whether static or dynamic information is used.

Static information is generally used by the traveler to gain knowledge about their trip options, both in terms of possible means of travel (e.g. route, mode) and the value of end-trip opportunities (e.g. shopping malls, tourist attractions). The impacts of static information, especially for the user, are difficult to model based on travel time impacts and generally require direct estimation of changes in consumer surplus (see Chapter 5 for discussion of how we evaluate internal impacts and benefits). Dynamic information, on the other hand, provides the real-time status of the transportation system and is especially likely to lead to travel diversion if it conveys incident-related delay or congestion. Dynamic information can have one of two consequences for a trip:

(1) It can lead to the user physically altering the trip if it shows information about an incident that is causing excessive congestion. By physically altering the trip, we mean changing route, changing destination, changing mode, changing departure time, or not taking the trip at all. As a result, the impacts of the change will have benefits to the user and a change in system externalities, as the share of trips under congestion is affected by these altered trips.

(2) It can lead to the same trip occurring under conditions of *serenity*. This is modeled by an improved (i.e. lower) value of time cost to the user because they have been relieved of some of the stress normally associated with their trip. In this case the user does not physically alter travel, but nonetheless values the information because it has improved their confidence.

Of course, there is a third consequence, where for whatever reason the user does not value the information. No additional impacts or benefits occur in this situation.

At this stage, we have argued that trip scenarios are likely to have different impacts depending on the observed travel behavior change, the modal orientation of the user, and whether the information leading to the behavior change was static or dynamic.

6.1.4 Summary of the Trip Scenario Models

Figure 6-3 shows the structure of the trip scenario models based on the categorizations for mode and usage discussed in this section.

In the figure, we distinguish between the mode captive scenarios and the flexible scenarios. The top structure in the figure represents the structure for the six mode captive traveler behavior changes. The modal orientation of these users is strictly captive to auto or transit. The scenarios in both figures are further defined by the type of information used—static or dynamic. For each of the six behaviors, we have two modes and two information types, resulting in 24 trip scenarios. The bottom structure represents the special case of the *Change Mode* behavior. Users who change mode are classified as *flexible* in terms of their modal orientation, and we distinguish between the two directions of mode switch. For the change mode behavior, we have two additional trip scenarios.

In total, we have 26 trip scenarios. In the next two sections, we show how these trip scenarios are used to quantitatively estimate benefits of ATIS. For each scenario, we address the internal and external impacts and benefits that result, so that we can have up to 52 benefits models.

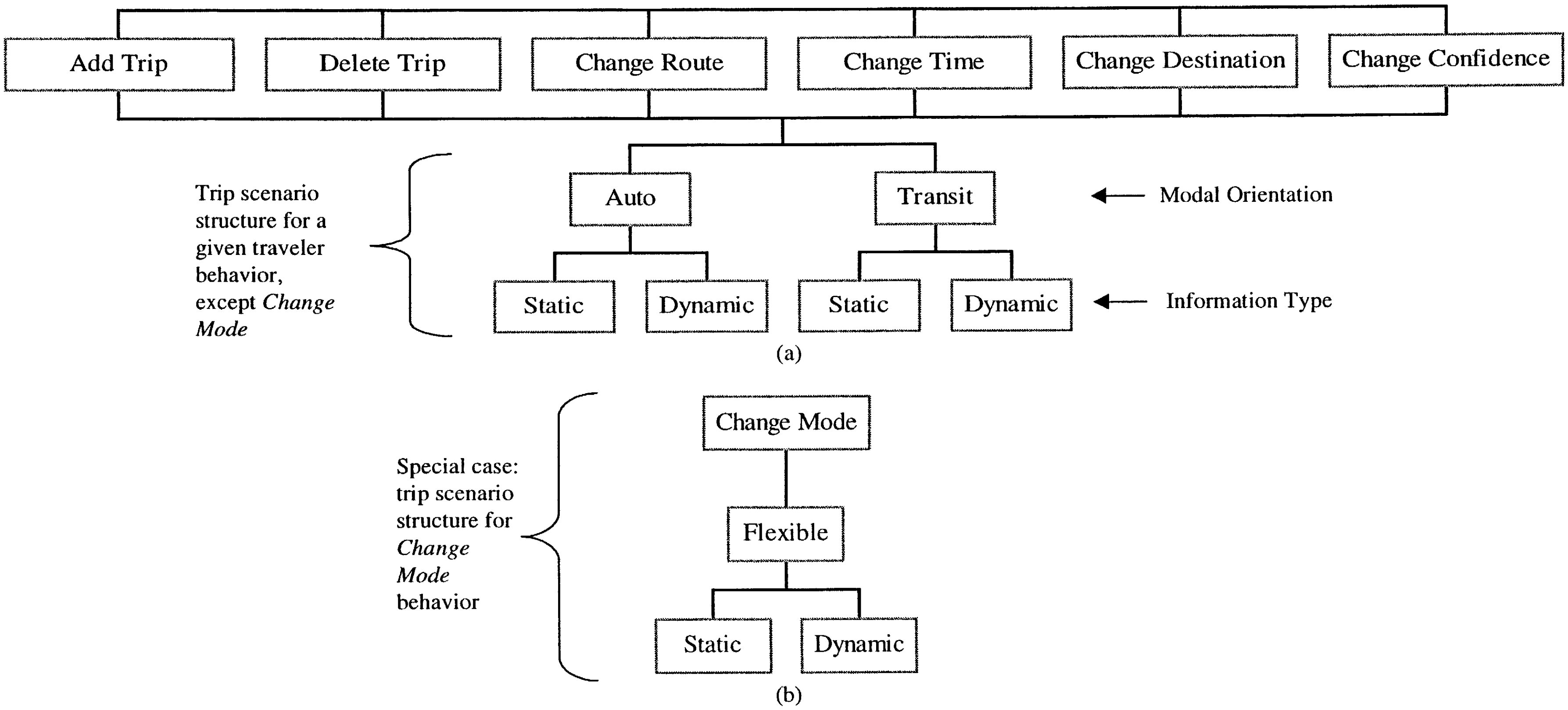


Figure 6-3. Trip Scenario Structure: Change in Traveler Behavior, Modal Orientation, and Information Type
(a) General case: Trip scenario structure for traveler behaviors, except the *Change Mode* case
(b) Special case: Trip scenario structure for *Change Mode* behavior

6.2 Data Framework for Trip Scenario Models

In this section, we present the data organization framework for trip scenario analysis. For all trip scenarios, we need to know baseline trip characteristics and impact data. The impact data is in natural units, so we also need travel time and automobile social cost parameters for impact valuation. This section is organized into three subsections presenting the data needs in these three areas:

1. Parameter Data. These are the value of time and automobile social cost parameters used in the analysis.
2. Baseline Trip Data. These are characteristics of the trips that would have occurred in the absence of ATIS. The characteristics include natural unit measurements of trip time or trip length as well as the relationship to corresponding time valuation parameters.
3. Impact Data. These are the trip-level impact changes that result from ATIS use and behavior change.

The frameworks presented in this data are symbolic in nature, but sample values are presented where necessary to enrich the understanding of the concepts.

6.2.1 Parameter Data

In Table 6-1 we present the value of time parameters and give some sample values. These value of time parameters are estimated based on relative differences in value of time for related travel conditions. They are all negative, because they represent hourly costs from travel. Instead of giving base travel time values and the adjustment factors such as those given by Lee and Pickrell (1997), we present actual values for each of the value of time parameters. As we discuss here, the importance lies in the differences among the parameters for related travel conditions.

Value of Time Parameter	Variable Name Convention	Sample Values* (dollars/hr)
Auto		
In-vehicle	V_{IV}	$ - 7.00
In-vehicle, congested	$V_{IV,C}$	$ - 8.00
In-vehicle, serene	$V_{IV,S}$	$ - 6.00
Transit		
In-transit, seated	V_{IT}	$ - 9.00
In-transit, standing	$V_{IT,ST}$	$ - 12.00
In-transit, seated, Serene	$V_{IT,S}$	$ - 8.00
In-transit, standing, Serene	$V_{IT,STS}$	$ - 11.00
Wait time	V_W	$ - 10.00
Wait time, serene	$V_{W,S}$	$ - 9.00
Schedule delay	V_{SD}	$ - 4.00
Trip Planning	V_P	$ - 5.00

Table 6-1. Value of Time Parameters: Variable Names and Sample Values

We explain the rationale for the values show in this figure as follows. (Note that when we compare values, we are comparing magnitudes.)

- Among the three in-vehicle value of time parameters, observe that congested travel is more expensive than average in-vehicle travel time, whereas *serene* travel is less expensive. Serene travel is based on the condition where the traveler is more certain or confident as a result of ATIS information. The difference between the highest and lowest value is $2.00. The difference may be more or less than that, but at this point we can only estimate the magnitude of the difference.
- Among the transit parameters, we value standing at a higher rate than sitting. For transit wait times, we identify a lower waiting rate during serenity. On average, note that transit wait time has a greater disutility than the in-transit seated time.

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* These sample values are hypothetical estimates, and they are not based on any existing empirical research. Future research, including that planned for the MMDI, should try to experimentally obtain likely values for these parameters.

- Trip planning and schedule delay times have lower value since they do not involve actually being "en route". Trip planning occurs before a trip, and schedule delay may occur before or after. Schedule delay is partially usable time since the traveler could be at home or at the office, for example, doing other things while the trip is being delayed for whatever reason.

Next, we have the automobile social costs. These are based on values estimated from the literature, as examined in Chapter 4. The variable name and sample values are given in Table 6-2.

Automobile Social Cost Parameters (values given in $/VMT)	Variable Name	Sample Value
External cost of automobile use in "freeflow" conditions	ϕ	$-0.03
Marginal external cost of automobile use under "peak" congestion	π	$-0.52

Table 6-2. Automobile Social Cost: Variable Name and Sample Values

The values shown are negative because they represent costs. We distinguish the automobile social costs for freeflow versus congested conditions. For freeflow conditions, the costs are due to accidents and pollution from emissions. For congested conditions, these same environmental effects are greater, and an additional cost due to imposed time delay is included. The values are based on the analysis presented in Chapter 4.

6.2.2 Baseline Trip Data

Baseline trip information is average trip information that is generally available from local or nationally available data. It includes information about average trip mileage, average travel time, share of trips or VMT's under congestion, etc.

We define two kinds of baseline trips: *Normal* and *incident-affected.* The trips are different due to the traffic conditions under which they occur:

1. *Normal* traffic conditions. For automobile travel, a certain share of the trips may occur under congestion due to predictable, recurring congestion. The travel times are based on normal, expected travel times on the auto or transit routes.
2. *Incident-affected* traffic conditions. These are that conditions were unpredictable, and result in unforeseen delay due to incidents on the roadway. The delay may be a consequence of lane closures, weather conditions, accidents, or the start of road construction. For automobile travel during these conditions, the probability of trips occurring under congestion is considerably higher than that of those that would have occurred under congestion during normal conditions. For both automobile and transit travel, we expect the travel times to be higher under these conditions.

In Table 6-3, we list the baseline trip characteristics along with the variable names and corresponding value of time parameters. Observe that in the baseline case, we maintain that the average trip length for automobile trips, X, does not change from the normal case to the incident case. If the impact model suggests otherwise, and impact parameter to represent ΔX is used. The travel time characteristics have different variable names in the two cases because the values are expected to change in the incident case, and the share of trips under congestion conditions is also expected to change.

Trip Characteristics	*Normal Trip*		*Incident-Affected Trip*	
	Natural Units	Value of Time	Natural Units	Value of Time
Transit				
In-transit time (min)	T_{IT}	V_{IT} or $V_{IT,ST}$	$T_{IT,I}$	V_{IT} or $V_{IT,ST}$
Wait time (min)	T_W	V_W	$T_{W,I}$	V_W
Auto				
In-vehicle time (min)	T_{IV}	V_{IV}	$T_{IV,I}$	$V_{IV,C}$
Average distance (miles)	X	-	X	-
% trips under congested conditions	p_n	-	p_I	-

Table 6-3. Baseline Trip Characteristics for *Normal* and *Incident-Affected* Trips

The next step after identifying the baseline trip characteristics and parameters is to define how we identify the impacts. The next section shows the framework for impact data collection and organization.

6.2.3 Impact Data

Finally, we identify impacts for each trip scenario. The impacts and corresponding symbols are listed in Table 6-4 (for auto) and Table 6-5 (for transit). The cells in the table correspond to the data items needed to estimate benefits based on the methods outlined in the previous two chapters. We briefly review the methodology for estimating internal and external benefits:

- Internal benefits may be estimated via either a direct estimation of the change in Consumer Surplus (CS) or a progressive model of travel time savings. For the latter case, the internal benefits models presented here may include changes in travel time (including in-transit or in-vehicle time, wait time, and schedule delay) and changes in the value of time (VOT) depending on the nature of the travel time (congested versus uncongested, waiting versus in-transit, etc.) In Table 6-4, a particular behavior change scenario will either contain a value in the "Change in consumer surplus" cell or some set of set of travel time changes in the travel time, wait time, and schedule delay cells. The "new" trip VOT parameters are listed on the right. These parameters are used when dynamic information leads to the new trip occurring under "serene" circumstances.
- Externalities are estimated for changes in automobile use. The changes considered include changes in vehicle-miles traveled and changes in the travel conditions. The travel conditions may have different congestion characteristics, and therefore have different social costs associated with them. In Table 6-5, we show a "placeholder" for social costs from transit use as well, but we are choosing not to quantify these at this time.

Each trip scenario may include values for one or many of these impacts, based on how we choose to model the rationale for traveler behavior change. In the next section we use the baseline and impact data structures presented here in benefits estimation models for each trip scenario.

Benefits Category	Impact Description	Variable Name	New VOT
Internal Benefits: Direct estimation of change in Consumer Surplus Method	Change in consumer surplus ($)	ΔCS	-
Internal Benefits: Travel Time Savings Method	Change in travel time (minutes) Schedule delay (minutes)	ΔT_{IV} T_{SD}	$V_{IV,S}$ V_{SD}
Externalities	Change in auto VMT (miles) Change in %trip under congestion	ΔX Δp	- -

Table 6-4. Impact Data Elements for Automobile Trips

Benefits Category	Impact Description	Variable Name	New VOT
Internal Benefits: Direct estimation of change in Consumer Surplus Method	Change in consumer surplus ($)	ΔCS	-
Internal Benefits: Travel Time Savings Method	Change in travel time (minutes) Change in wait time (minutes) Schedule delay (minutes)	ΔT_{IT} ΔT_W T_{SD}	$V_{IT,S}$ $V_{IT,STS}$ $V_{W,S}$ V_{SD}
Externalities	Change in transit social costs	(not used)	-

Table 6-5. Impact Data Elements for Transit Trips

6.3 Impact Model Equations for Trip Scenarios

In this section, we present the models we use to estimate benefits from trip scenarios using the data items in the structures presented in Section 6.2. For each scenario, we consider the rationale for changes in travel behavior, and how this relates to likely impacts. Based on the scenario definitions shown in Figure 6-3, we have a total of 26 (6 behaviors × 2 modes × 2 usage types + 2 "change mode" models) scenarios that we model separately in considering the impacts and benefits from behavior changes. We include all seven travel behaviors, static and dynamic usage, and both captive and flexible modal orientations for auto and transit. In doing so, we are assuming that the ATIS would be comprehensive in terms of providing both static and dynamic information and both transit and auto information. The models that we explain in this section are used in the spreadsheet tool presented in Chapter 7.

The chapter is organized by behavior change and usage type. The two modes are explained in the same section in order to facilitate efficiency in explaining each scenario. For each scenario, we present examples of how this scenario could occur and the models for internal and external impacts and benefits.

The models for all the scenarios are summarized in the Appendix, in Table A- 2..

6.3.1.1 Change Mode

The change mode behavior results in the user switching modes from transit to auto or auto to transit. It implies that the user was flexible in determining travel mode, the information presented in the ATIS service influenced this decision, and the user would *not* have switched in the absence of ATIS. These travelers are classified as *flexible* users, but the modal orientation distinction is made in the models based on the direction of the mode switch.

Change Mode In Response to Static Information

Examples of how this scenario could occur:

- Transit schedules or transit trip planning available through ATIS suggest that the transit option is more difficult than originally thought. The traveler decides to drive or take a cab.

- Transit trip planning or schedule information suggest the system's schedule corresponds better than expected with a person's travel schedule, leading the user to forgo driving.
- Automobile trip planning or route guidance lead the user to drive instead of use transit by decreasing the stress or uncertainty related to driving to the destination.
- Automobile trip planning features lead the user to decide that driving to the destination will be too complex or difficult, so transit is preferred.

We use direct estimation of change in consumer surplus to estimate the internal benefits. We choose not to model the traveler's rationale for mode change via travel time savings. There are elements of convenience and cost to the user that limit the ability to capture the internal benefits as a function of only travel time. Therefore, we account for this internal benefit via direct estimation of the change in consumer surplus for all the "change mode" behaviors. The internal benefits are defined as

$$IB_{\Delta\text{mode, flex, static}} = \Delta CS_{\Delta\text{mode, auto, static}}$$

The result of this behavior change is the addition or deletion of an "average" automobile trip according to the baseline trip characteristics. We estimate external costs for this trip as the weighted average of the two cases as

$$EX_{\Delta\text{mode, flex, static}} = (\%\text{to auto})(\Delta X)(\phi + p_n\pi) + (\%\text{to transit})(\Delta X)(\phi + p_n\pi)$$

Observe that for the transit to auto switch, $\Delta X=X$ (the average baseline trip length); and for the auto to transit switch, $\Delta X= -X$.

Change Mode In Response to Dynamic Information

Examples of how this scenario could occur:

- Dynamic transit information may show that the transit service is either running behind schedule or experiencing a disruption in service, leading the user to drive or take a taxi.
- Dynamic traffic information suggests that conditions are less congested than expected, making an automobile trip more feasible than expected.

- Dynamic traffic information shows incident-related congestion that leads the user to switch to transit instead of driving or taking a taxi.

We use direct estimation of change in consumer surplus to estimate the internal benefits, following the same argument as that given for the change mode in response to static case. The benefits are defined as

$$IB_{\Delta\text{mode, flex, dynamic}} = \Delta CS_{\Delta\text{mode, flex, dynamic}}$$

The result of this behavior change is the addition of a normal automobile trip or deletion of an "incident-affected" automobile trip. For the new trip, we assume that it takes place under better than baseline conditions. For the auto to transit switch, the trip that would have been taken without ATIS would have had a congestion probability "p_i", following the baseline trip notation. For the transit to auto switch, the congestion probability is "$p_i + \Delta p$". "Δp" will be negative to show that the new automobile trip occurs under better than baseline conditions. If the new trip occurs under normal conditions, then Δp is simply "$p_n - p_i$". We estimate external costs for this trip as the weighted average of the two change mode cases as

$$EX_{\Delta\text{mode, flex, dynamic}} = (\%\text{to auto})(X)(\phi + (p_i + \Delta p)\,\pi) + (\%\text{to transit})(-X)(\phi + p_i\pi)$$

6.3.1.2 Add Trip

ATIS may result in trips being taken that would not have been taken otherwise due to increased reliability or confidence based on the new information. Either auto or transit trips can be added, and it is assumed that in the absence of ATIS the user would not have taken the trip.

<u>Add Trip In Response to Static Information</u>

Examples of how this scenario could occur:

- Automobile trip planning or route guidance features lead the user to consider a trip that would otherwise have been considered too difficult or onerous to take.

- Transit trip planning leads the user to consider a transit trip that would otherwise have been considered too time-consuming or complicated.

We use direct estimation of the change in consumer surplus to estimate the internal benefits. We cannot model the rationale for adding a new trip via travel time savings. We would require the value of the end-trip opportunity, which we choose not to estimate. Therefore, we account for this internal benefit via direct estimation of the change in consumer surplus for all the "add trip" behaviors. The internal benefits are defined as

$$IB_{+\text{ trip, auto/transit, static}} = \Delta CS_{+\text{ trip, auto/transit, static}}$$

The result of this behavior is the addition of a normal auto or transit trip. We do not quantify the benefit of the transit trip. We estimate the external cost from the new auto trip as

$$EX_{+\text{ trip, auto, static}} = \Delta X(\phi + p_n\pi)$$

Add Trip In Response to Dynamic Information

Examples of how this scenario could occur:

- Dynamic traffic information may show that driving conditions are normal, decreasing the risk of a trip to the traveler or decreasing the stress that may have been associated with the trip due to uncertainty about traffic conditions.
- Dynamic transit schedule information suggests the system's schedule corresponds better than expected with a person's travel schedule, leading the user to make a trip that would have otherwise not been taken. The information may also decrease the stress that may have been associated with the trip due to uncertainty about transit schedule adherence.

We use direct estimation of the change in consumer surplus to estimate the internal benefits, following the same argument about added trips as given above in the static case. The internal benefits are defined as

$$IB_{+\text{ trip, auto/transit, dynamic}} = \Delta CS_{+\text{ trip, auto/transit, dynamic}}$$

The result of this behavior is the addition of a normal auto or transit trip. We choose not quantify the benefit of the transit trip. For the new auto trip, we expect that the trip occurs under normal or better than normal conditions, so that $\Delta p = p_i - p_n$. However, we allow Δp to remain a variable as we did in the Change Mode-to Transit-Dynamic case. We estimate the external costs of the new auto trip as

$$EX_{+\text{ trip, auto, dynamic}} = \Delta X(\phi + (p_i+\Delta p)\pi)$$

6.3.1.3 Delete Trip

ATIS may result in trips not being taken that would have been taken otherwise due to information suggesting that a trip was more onerous than originally thought due to complexity or an abnormal incident. Either auto or transit trips can be deleted, and it is assumed that in the absence of ATIS the user would have taken the trip.

Delete Trip In Response to Static Information

Examples of how this scenario could occur:

- Automobile trip planning from static maps lead the user to believe that the trip is more complicated or longer than expected.
- Transit trip planning based on schedules leads the user to determine that a transit trip is too onerous.

Internal benefits are modeled similarly across all delete trip scenarios. This decision is too complex to replicate via travel time savings, since the trade-off between the benefits of the foregone trip and the travel costs are too complex to quantify. We use direct estimation of the change in consumer surplus to estimate the internal benefit as

$$IB_{-\text{ trip, auto/transit, static}} = \Delta CS_{-\text{ trip, auto/transit, static}}$$

We model the externalities of the foregone automobile trip. Because this decision is based on static information, we assume the foregone trip would have occurred under "normal" trip conditions. We choose not to consider the social costs of the deleted transit trip. The deleted automobile trip's externality is estimated as

$$EX_{\text{- trip, auto, static}} = \Delta X(\phi + p_n\pi)$$

where $\Delta X = -X$ for this situation.

Delete Trip In Response to Dynamic Information

Examples of how this scenario could occur:

- Dynamic traffic information may show that driving conditions are worse than expected (incident-affected) causing the driver to forgo the trip.
- Dynamic transit schedule information suggests the system is behind schedule or experiencing a service breakdown, leading the user to forgo a trip.

Following the same argument as in the static case above, we use direct estimation of the change in consumer surplus to estimate the internal benefit as

$$IB_{\text{- trip, auto/transit, dynamic}} = \Delta CS_{\text{- trip, auto/transit, dynamic}}$$

We value the externalities of the foregone automobile trips based on the characteristics of incident-affected trips, because with the use of dynamic information we assume special conditions led to the trip being deleted. As usual, we choose not to consider the social costs of the deleted transit trip. The deleted automobile trip's externality is estimated as

$$EX_{\text{- trip, auto, dynamic}} = \Delta X(\phi + p_i\pi)$$

6.3.1.4 Change Destination

ATIS may lead users to alter the destination of their trip by providing information on alternate destinations that the user would otherwise have not come to know of in the absence of ATIS. The user may change destination due to a more valuable end-trip opportunity, a less costly travel plan, or both.

Change Destination In Response to Static Information

Examples of how this scenario could occur:

- Traveler may learn from static transit schedule, road maps, or route planning that the average travel time is longer than suggested and chooses an alternate destination.
- Traveler may learn that an alternate destination provides a similar or more valuable end-trip opportunity. For example another automated teller machine may be nearer than the one that the traveler originally intended to go to.

The internal benefits of changing destination based on static information are too complex to model as a travel time savings, because the value of the end-trip opportunity may or may not be as much as that of the originally intended destination. The user trades off the change in value of the end-trip opportunity with the change in travel costs. Since the decision is based on static information, we expect that the value of the end-trip opportunity is more important in the decision than the travel cost itself. We use direct estimation of the change in consumer surplus to estimate the internal benefit as

$$IB_{\Delta\text{ dest, auto/transit, static}} = \Delta CS_{\Delta\text{ dest, auto/transit, static}}$$

We have no a priori reason to expect the trip characteristics to change, since we have proposed that this decision has more to do with the value of the end-trip opportunity than the travel cost or length. If we do find that a change in the trip length is significant, we would estimate the benefit as

$$EX_{\Delta\text{ dest, auto, static}} = \Delta X(\phi + p_n\pi)$$

Change Destination In Response to Dynamic Information

Examples of how this scenario could occur:

- Incident congestion reported via the ATIS leads the user to choose an alternate destination that provides the same benefits but has a different travel time.

- Dynamic information about unexpected delays in the transit service may lead the user to select an alternate destination that fulfills the same needs.

In the static change destination scenario, we suggested that the motivation for the change was the value of the end-trip opportunity for the user. In the dynamic scenario, we propose that the user chooses another destination based solely on travel costs. The new trip occurs under normal conditions, whereas the previously intended trip would have occurred under incident-affected conditions. We estimate ΔT_{IV}, ΔT_{IT}, and ΔT_W accordingly, by taking the difference between the normal and incident trips. The travel time savings estimation for the auto scenario is

$$IB_{\Delta\text{ dest, auto, dynamic}} = T_{IV,I}(V_{IV,S} - V_{IV,C}) + \Delta T_{IV}\, V_{IV,S}$$

where $\Delta T_{IV} = T_{IV} - T_{IV,I}$. The new trip and the difference in travel time are valued at "serene" rates ($V_{IV,S}$). The travel time to the destination that the travelers would have gone to is valued at the congested rate ($V_{IV,C}$). (Value of time parameters are listed in Table 6-1.) The travel time savings estimation for the transit scenario is

$$IB_{\Delta\text{ dest, transit, dynamic}} = T_{IT,I}(V_{IT,S} - V_{IT}) + \Delta T_{IT}\,(V_{IT,S}) + T_{W,I}(V_{W,S} - V_W) + \Delta T_W\,(V_{W,S})$$

where $\Delta T_{IT} = T_{IT} - T_{IT,I}$ and $\Delta T_W = T_W - T_{W,I}$. The new trip and the differences in transit and wait times are valued at "serene" rates.

For automobile trips, we assume that the new trips occur in slightly better than average conditions, whereas the original trips would have occurred under incident-affected conditions. The externality for the automobile trips is

$$EX_{\Delta\text{ dest, auto, dynamic}} = (X)(\Delta p)(\pi) + \Delta X\,(\phi + (p_i + \Delta p)(\pi))$$

The trip is based on Equation 5-4, and the intuition for each term is as follows:

- $(X)(\Delta p)(\pi)$ represents the change in external costs for the base VMT's in the trip.
- $\Delta X\,(\phi + (p_i + \Delta p)(\pi))$ represents the social cost of additional VMT's. If we estimate $\Delta X=0$, there is no additional cost.

We could use a sub-model such as $\Delta p = (p_n - p_i)\times(1.1)$ to estimate that the new trips occur under conditions that are an additional 10% better than normal conditions.

6.3.1.5 Change Route

ATIS may lead users to change their route by providing them information about a faster route that they would not have known of without ATIS or by informing them of unforeseen circumstances causing delay along their planned route, leading them to take another route based on their own judgment.

Change Route In Response to Static Information

Examples of how this scenario could occur:

- ATIS route planner may provide the user with a shorter route than the one that would have been taken or provide information that prevents the user from making wrong turns and getting lost.
- Static transit schedules show a shorter route than originally planned by the traveler.

For both auto and transit, we expect that the route change was made based improved travel conditions, marked by lower travel time. The travel time savings is based on valuing the decreased travel time (in-vehicle, in-transit, or waiting) at the normal rates, so that the model

$$IB_{\Delta \text{ route, auto, static}} = \Delta T_{IV}\,(V_{IV})$$

and the travel time savings model for the transit scenario is

$$IB_{\Delta \text{ route, transit, static}} = \Delta T_{IT}\,(V_{IT}) + \Delta T_{W}\,(V_{W})$$

For automobile trips, we assume that the change route behavior results in some change in the trips under congestion, but we have no a priori intuition as to the change in VMT's. For the externality, we simply value the change in costs due to fewer trips occurring under congested conditions as

$$EX_{\Delta\text{ route, auto, static}} = (X)(\Delta p)(\pi) + \Delta X\ (\phi + (p_n+\Delta p)(\pi))$$

For this situation, it is likely that $\Delta X = 0$.

Change Route In Response to Dynamic Information

Examples of how this scenario could occur:

- ATIS provides the traveler with information about unforeseen delays or incident-related congestion on their route, and user chooses another route. The new route may or may not have been prescribed by the ATIS.
- Transit system breakdown or delay information is provided via ATIS, leading the user to take another transit route.

In the case of dynamic information, we expect that the basis for the route change is to avoid incident-related delay along the normal route. The base case trip is the incident-affected trip, with its higher travel times and higher share of congested trips for both commuters and tourists. As a result of ATIS, the traveler chooses a trip that decreases travel cost. We expect that this travel cost relates to congestion, and the travelers alter their trip in a way that does not affect overall travel time but does decrease the stress associated with travel. For the auto trips, we estimate that the travel time does not change but the share of trips under congestion does. As a result, the VOT can be valued at serene rates on the new trip versus the higher rates that would have been incurred in the absence of ATIS. We estimate the benefit for auto trips as

$$IB_{\Delta\text{ route, auto, dynamic}} = T_{IV,I}(V_{IV,S} - V_{IV,C}) + \Delta T_{IV,}\ (V_{IV,S})$$

The base auto trip would have had a longer travel time and a higher VOT. For the new trip, we may choose to assume that $\Delta T_{IV} = 0$. For the transit trip changes, we suggest that the new trip might have an even longer in-transit time, but a shorter wait time. The benefit for the transit trip is similarly estimated as

$$IB_{\Delta\text{ route, transit, dynamic}} = T_{IT,I}(V_{IT,S} - V_{IT}) + \Delta T_{IT}\ (V_{IT,S}) + T_{W,I}(V_{W,S} - V_W) + \Delta T_W\ (V_{W,S})$$

The in-transit VOT for normal and serene conditions may be either seated or standing. When we present how this model is implemented in the spreadsheet tool in the next chapter, we define the seated or standing rate according to the market segments.

We estimate that the new automobile route might be longer by a few VMT's, but the share of trips under congestion is better than normal conditions.

$$EX_{\Delta \text{ route, auto, dynamic}} = (X)(\Delta p)(\pi) + \Delta X\ (\phi + (p_i + \Delta p)\pi)$$

We can estimate Δp to be better by 10% or some other value. For example, if $(p_n - p_i) \times 1.1$, then the new trips are a 10% improvement over normal trips. This "improvement adjustment" is a variable in the spreadsheet tool we create for the next chapter.

6.3.1.6 Change Departure Time

ATIS may provide travelers with information that allows them to adjust their departure time to minimize travel time, minimize wait time, or avoid congestion. The users can trade-off schedule delay with changes in the travel time costs of the trip.

Change Departure Time In Response to Static Information

Examples of how this scenario could occur:

- ATIS may provide better route and time information that allows the user to arrange time more effectively. The traveler may leave earlier since the trip time can be estimated with more certainty. Information about recurring congestion patterns may provide greater certainty.
- The transit user may get better information from a trip planner or static schedule and adjust departure time to minimize wait time.

For both cases, we assume the user trades off travel time with schedule delay. Schedule delay is valued at a lower rate than travel time, since it is partially usable time spent at their origin. For the auto case, we deduct travel time and add schedule delay time, so that the benefits are estimated as

$$IB_{\Delta \text{ departure time, auto, static}} = \Delta T_{IV}(V_{IV,S}) + T_{SD}(V_{SD})$$

For the transit case, we assume that the schedule delay reduces wait time, but not in-transit time. We estimate the benefits as

$$IB_{\Delta \text{ departure time, transit, static}} = \Delta T_W(V_{W,S}) + T_{SD}(V_{SD})$$

The schedule delay used in this example could refer to additional time spent at either the origin or destination. The same benefits estimation applies, since the natural units of schedule delay do not have a sign—schedule delay is always considered a cost.

We do not have any a priori reasoning to consider a change in trip length for automobile trips, but we do expect that a slightly lower share of trips occur under congested conditions. Therefore, we estimate the externality as

$$EX_{\Delta \text{ departure time, auto, static}} = (X)(\Delta p)(\pi)$$

Change Departure Time In Response to Dynamic Information

Examples of how this scenario could occur

- ATIS provides information about unforeseen congestion, and the traveler is able to depart from home or work earlier or later than planned. The information allows the user to avoid delay or undesirable driving conditions at the cost of shifting his/her schedule.
- ATIS provides user with the actual arrival time of a bus or train that has been delayed and leads the user to delay his/her trip to minimize wait time.

Dynamic information allows the user to avoid unnecessary wait, but requires shifting the user's schedule (forwards or backwards) at some cost. The new travel time (both in-transit time and wait time) is valued at serene rates. We estimate the user benefits following the same method as that used for the static case. Because of the higher travel times under incident conditions, we may estimate a higher schedule delay than in the static case, and an equivalent greater reduction in either in-vehicle time or wait time. We value the entire new trip at serene rates, and count the benefit from the congested rates. The benefits for automobile trips for this scenario are

$$IB_{\Delta \text{ departure time, auto, dynamic}} = T_{IV,I}(V_{IV,S} - V_{IV,C}) + \Delta T_{IV}(V_{IV,S}) + T_{SD}(V_{SD})$$

For transit trips, the benefits are estimated as

$$IB_{\Delta \text{ departure time, transit, dynamic}} = T_{IT,I}(V_{IT,S} - V_{IT}) + T_{W,I}(V_{W,S} - V_W) + \Delta T_W(V_{W,S}) + T_{SD}(V_{SD})$$

We do not have any a priori reasoning to consider a change in trip length for automobile trips, but we do expect that a slightly lower share of trips occur under congested conditions. We may choose to assume a reduction that is 10% better than normal conditions, as we suggested in the "Change Route" case above. The externality is estimated as

$$EX_{\Delta \text{ departure time, auto, dynamic}} = (X)(\Delta p)(\pi)$$

6.3.1.7 Increased Confidence

Although increasing confidence does not represent a physical change in behavior, there is a benefit to the user of knowing the information and having more certainty about the trip being taken. These scenarios are modeled to capture the general decrease in the price of travel that may relate only to the disutility of the travel time. There are no system impacts, and hence no external benefits, due to increased confidence.

Increased Confidence In Response to Static Information

Examples of how this scenario could occur:

- Traveler confirms that the planned route is the recommended route using a trip planning feature.
- Traveler confirms that the route and schedule are as expected.
- Traveler uses ATIS to find route, and follows route as given.

We assume no changes in travel time impacts, so we do not show the impacts table. In this situation, the traveler is consulting ATIS in order to plan a trip. We directly estimate change in consumer surplus for the internal benefits:

$$IB_{\Delta \text{ confidence, auto/transit, static}} = \Delta CS_{\Delta \text{ confidence, auto/transit, static}}$$

We do not have an externality in this case, since the user has not physically altered the trip, and we assume that the trip would have been made in the absence of ATIS.

Increased Confidence In Response to Dynamic Information

Examples of how this scenario could occur:

- Traveler confirms that the planned route has no incidents or unusual congestion. Automobile trip continues as planned, under serene conditions.
- Traveler finds out that there is an incident or congestion, but continues with the trip as originally planned. The travel occurs under serene conditions.
- Traveler confirms that the transit schedule is as expected and no incidents or delays are reported. Trip continues as planned, but under serene conditions.
- Traveler learns of an incident or delay in the transit service, but continues with the trip as planned. The travel occurs under serene conditions.

We actually have two situations here. In one case, the dynamic information simply informs the traveler that their normal trip is unaffected. In another case, the dynamic information tells the traveler that the trip is affected by an incident, and there will be some delay. The traveler takes the trip as planned, with or without an incident. In either case, we estimate the benefit by taking the difference between valuing the trip time at serene rates and the base rates. The base characteristics for travel time and value of time are different for incident conditions versus normal conditions, so the benefit will be different in each case. We estimate the internal benefit as a weighted average of the probability that the increase confidence is due to taking a normal trip versus taking an incident-affected trip for auto as

$$IB_{\Delta\ \text{confidence, auto, dynamic}} = (\%\text{normal})\ (T_{IV}\ (V_{IV,S} - V_{IV}) + (\%\text{incident})(T_{IV,I}(V_{IV,S} - V_{IV,C}))$$

and for transit as

$$IB_{\Delta \text{ confidence, transit, dynamic}} = (\%\text{normal})(T_{IT,I}(V_{IT,S} - V_{IT}) + T_{W,I}(V_{W,S} - V_W) + (\%\text{incident})(T_{IT}(V_{IT,S} - V_{IT}) + T_W(V_{W,S} - V_W))$$

In the next chapter, we present how the methods shown in this chapter are implemented in the form of a spreadsheet tool that can be used to estimate benefits for an entire project, considering different project-level scenarios for markets, baseline trips, valuation parameters, etc. The benefits estimation in the spreadsheet tool is based on the methodology we used in this chapter.

Chapter 7. A Spreadsheet Tool for Evaluating Project Benefits of ATIS

In this chapter, the frameworks, theory, and methods presented in this thesis are incorporated into a spreadsheet tool which estimates annual benefits for an ATIS project. The spreadsheet tool models the impact linkages between user access, traveler behavior, system impacts, and benefits. The core of the tool are the trip scenario models developed in Chapter 6, but for project evaluation, we introduce another dimension—market segmentation. The purpose of defining market segments in a benefit-cost evaluation is to "divide travelers into subgroups whose behavior is homogeneous within each subgroup but different from one subgroup to another" (Lee & Lappin, 1997). These subgroups, while not required for benefit-cost analysis, are useful for providing more depth to the evaluation and analysis. We explain why in this chapter.

In presenting the layout of the spreadsheet, we present the series of linked modules that comprise the spreadsheet, and show the extensions used to implement these methods for project evaluation. The spreadsheet modules include hypothetical data to demonstrate how the spreadsheet is used. The spreadsheet modules can be divided into two types: inputs and outputs. The discussion in this chapter is organized along that differentiation as well. For a general demonstration, we base this ATIS project evaluation on the Fastline *Embarc* handheld personal computer application discussed in Section 2.1.2, but we also show how the spreadsheet tool can be used with little or no additional modification to evaluate other ATIS projects.

The chapter is organized as follows. In Section 7.1 we show a design for market segmentation of ATIS use. In Section 7.2 we present the data input modules of the spreadsheet. In Section 7.3 we present the organization of the major outputs of the spreadsheet—the summary of benefits. In Section 7.4 we discuss how this spreadsheet tool can be implemented, i.e. our strategy for collecting the data needed to estimate benefits. In Section 7.5 we show how this spreadsheet is adaptable to different ATIS projects. In Section 7.6 we show how the analytical results of this spreadsheet can be adapted for prospective evaluation of planned ATIS projects at non-MMDI sites.

7.1 ATIS Use and Market Segmentation

As we stated above, the purpose of defining market segments in a benefit-cost evaluation is to divide travelers into subgroups whose behavior is homogeneous within each subgroup but different from one subgroup to another (Lee & Lappin, 1997). The core market segmentation problem, then, is "to determine what attributes of the travel or the traveler will allow for greater accuracy in predicting travel choices than treating all travelers as identical." In addition to the prediction of traveler behavior in response to ATIS, market segments also allow us to differentiate the magnitude of impacts. A market segmentation for ATIS has been proposed by Lee and Lappin (1997), and we present their ideas and append them with additional thoughts on how market segmentation for ATIS projects may be designed.

For ATIS, we can look at the market segments by considering three characteristics: trip purpose, trip flexibility, and familiarity with the area (Lee & Lappin, 1997). In this thesis, we append this set with the additional characteristic of the likelihood of peak period travel. These four characteristics are shown in Table 7-1. The interaction between trip purpose, familiarity, flexibility, and peak travel offers an intuitive set of characteristics that could be used to explain systematic differences among traveler behavior and subsequent impacts.

Given the typology shown in the table, we choose five mutually exclusive, collectively exhaustive market segments: (1) commute/school, (2) personal/shopping, (3) recreation/tourist, (4) business/commercial-familiar, and (5) business/commercial-unfamiliar. These segments are a combination of trip purpose and familiarity. Time flexibility and peak period travel are unique for each of these five trip purpose-familiarity combinations, so we do not need to define the grouping any further.

TRIP PURPOSE	FAMILIARITY WITH AREA	TIME FLEXIBILITY	PEAK PERIOD TRAVEL
Commute/School	High	Constrained	High
Personal/Shopping	Generally high	Less constrained	Low/Medium
Recreation/Tourist	Generally low	Much less constrained	Low
Business/Commercial	High or Low	Constrained	High

Table 7-1. Typology of Market Segments by Trip Purpose, Demographics, and Trip Characteristics
(Modified from Lee & Lappin, 1997)

The implications of these market segments can be defined in two ways:

1. We assign users to one of these five groups. This is the traditional interpretation of a market segment.
2. We classify trips into one of these five groups. A single user may use the ATIS for some or all of these five trip types.

Under the first definition, market segments affect the likelihood of travel behavior and the impact of the scenarios. For example, changing destination might be less likely an option for commuters than for tourists. The impacts of changes to commute trips, which we expect to take place during peak travel times, may be very different than changes to personal/shopping trips, which take place during weekdays and weekends at various times. The familiarity and flexibility of commuters is likely to be different from that of tourists. The problem with classifying users into a particular market segment is that we limit travel behavior by the characteristics of a market segment. In practice, a commuter, for example, may use the ATIS on weekends for recreational trips, thereby exhibiting behavior not typical of the assigned market segment.

A better way is the classification under the second definition, where we do not classify users. We classify trips, and we propose that a user may make trips that fall into any of these five categories. This is a more realistic interpretation, since we expect users to consult ATIS services for trips that range in purpose, familiarity, flexibility, and peak travel. We also expect to be able to rationalize that certain ATIS services will be used predominantly for one of these trip types.

We may find that other socioeconomic or demographic variables also affect the response and impacts due to ATIS. For example, origin-destination characteristics may be very significant. Survey data or traffic simulation may reveal systematic differences in traveler behavior and impacts based on these characteristics.

Market segments add value to the project evaluation by allowing us to differentiate among the following:

(1) Magnitude of impacts. The impacts of behavior changes by some market segments may be substantially different than those for other market segments. For example, a commuter using ATIS to avoid unexpected incident-induced congestion creates a different level of externalities than a tourist using ATIS to avoid that same congestion. This is because the commuter's trip was likely to have occurred under some recurrent congestion even in the absence of the unexpected incident since that trip normally occurs during peak times, whereas the tourist trip is more likely to have occurred under freeflow conditions. Other impacts, such as the change in consumer surplus or travel time savings, are likely to be different since the value of time and the value of end-trip opportunities is likely to be different for different market segments, particularly with respect to work/business versus personal/recreational trips.

(2) Distribution of travel behaviors. Certain trip market segments are less likely to exhibit behavior changes such as changing destination, adding a trip, or deleting a trip than other market segments due to limitations in trip flexibility. The business and work related trips, for example, are likely to have much less flexibility than the personal or recreation trips.

(3) Distribution of modal orientation. This effect is similar to the travel behavior effect from market segments, as certain trip market segments will not have flexibility to change modes, thereby limiting them to the predominantly captive modal orientations.

(4) Distribution of information usage. Certain market segments, such as commuters, are likely to use ATIS almost exclusively for dynamic information, whereas tourists who are unfamiliar with a region will use it predominantly for learning about a region via static information.

These market segments are included in the spreadsheet tool, and we will see how each of the four above consequences are represented in the analysis.

7.2 Spreadsheet Data Input Modules

In this section, we present the data input modules in the spreadsheet. The data inputs are broken down into five major module types:

1. Project Characteristics
2. User Access
3. Distribution of Trip Scenarios
4. General Valuation Parameters
5. Baseline Characteristics and Trip Scenarios

The first three modules (Project Characteristics, User Access, Distribution of Trip Scenarios) are used in series to determine the share of each trip scenario. The approach of these three modules is to use an estimate of the total number of daily uses or "hits", and break that quantity down by modal orientation, information type, market segment, and change in traveler behavior.

The second two modules are a direct implementation of the impact models presented in Sections 6.2 and 6.3. The only difference is that we allow for different values by market segment.

Each module is comprised of one or more worksheets. The worksheets are shown as exhibits along with the discussion in each section. In the worksheets, shaded cells represent data that is for input by the spreadsheet user. All other cells contain automatically calculated values based on these inputs. The spreadsheet also contains array names which are used to facilitate equations and referencing throughout the tool. These appear in the exhibits in small type, and may be sometimes obstructed because they are not integral to the discussion.

7.2.1 Project Characteristics

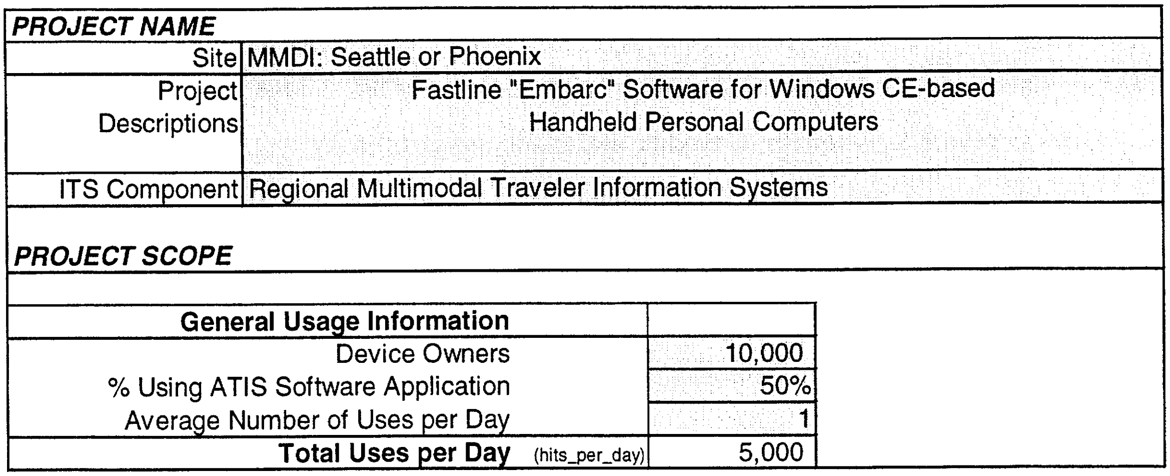
In the project characteristics module, we input general data about the level of market penetration and usage for the ATIS project.

Exhibit 7-1 shows the project characteristics module with descriptions and usage information for the Fastline HPC project, an ATIS application used in MMDI projects in both Seattle and Phoenix. The project is described in Section 2.1.2.

The "Project Name" area contains basic identifying information used to designate the project, the site, and the ITS component being evaluated.

The "Project Scope" area requires data inputs on the number of device (HPC) owners, the fraction of owners likely to be using the Fastline software, and the average number of times per day they use the device. Multiplying these three inputs, the worksheet estimates the total number of uses or "hits" per day.

The numbers show in this exhibit are hypothetical; they are for demonstration purposes only. While we try to be reasonable in presenting these hypothetical figures, they are not based on any empirically measured data. We input 10,000 for the number of HPC owners in a metropolitan area (either Seattle or Phoenix). We input 50% for the number of HPC who will actually download and use the software. The last input is the daily usage per HPC owner. We input one use per day. The product of these three values is a hypothetical value for the number of hits per day, which is shown in Exhibit 7-1 as 5,000.



PROJECT NAME	
Site	MMDI: Seattle or Phoenix
Project Descriptions	Fastline "Embarc" Software for Windows CE-based Handheld Personal Computers
ITS Component	Regional Multimodal Traveler Information Systems
PROJECT SCOPE	

General Usage Information	
Device Owners	10,000
% Using ATIS Software Application	50%
Average Number of Uses per Day	1
Total Uses per Day (hits_per_day)	5,000

Exhibit 7-1. Project Characteristics Module

7.2.2 User Access

In this module, we enter data about the users and the type of information they access in order to estimate the distribution of daily uses by market segment, modal orientation, and information type. The user access model is shown in Exhibit 7-2.

The "Modal Orientation of Users" section gives the likelihood that an ATIS user is transit captive, automobile captive, or modally flexible. Our hypothetical distribution allots 75% of all usage to automobile users.

The "Market Segments and Modal Orientation" section gives the breakdown of market segments by each of the three modal orientations. The market segments describe the trips that the ATIS is used for—not the characteristics of the users. The five segments are:

1. Recreational/Tourist (abbreviated 'Rec/Tour' in spreadsheet cells). This market segment is characterized by high trip flexibility and low user familiarity with the area.
2. Business-Familiar (abbreviated 'Bus-Fam' in spreadsheet cells). This market segment is characterized by low trip flexibility and high user familiarity.

3. Business-Unfamiliar (abbreviated 'Bus-Unfam' in spreadsheet cells). This market segment is characterized by low trip flexibility and low user familiarity.
4. Commuter (abbreviated 'Comm' in spreadsheet cells). This market segment is characterized by low trip flexibility and high user familiarity.
5. Shopping/Personal (abbreviated 'Shop/Pers', 'S/P', or 'Shp/Psnl' in spreadsheet cells). This market segment is characterized by high flexibility and high familiarity.

Again, there is some rationale behind the hypothetical figures shown in Exhibit 7-2. We show that the majority of transit and auto users are consulting ATIS for commuting trips. For the transit users, we show that business trips comprise a smaller percentage of this use than other trips. For flexible users, we show that a small percentage of commute trips would have the opportunity to choose mode. We also show less modal flexibility for business trips than recreational/tourist or shopping/personal trips by allotting a smaller percentage of these market segments to the flexible mode group.

The final area for user access data inputs is "Market Segments by Mode and Type of Information Accessed". In this area, we input static information usage versus dynamic information usage. The general strategy behind the sample data values used is that when a familiar trip is being taken, the user will consult primarily dynamic information, but when an unfamiliar trip is being taken, the user will consult primarily static information.

The last section of this module, "Hits per Day for Each Type of Information (by mode and market segment)", shows calculated values based on previous inputs. To get the values for each cell in this table, we multiply the total number of daily uses from the first module by the inputs in each of the subsequent sections. For example, to get the total number of auto/commute/dynamic trip scenarios, we multiply the number of daily uses by the percentage of users who are automobile captive, the percentage of automobile users who are commuters, and the percentage of automobile/commuter users who use dynamic information. The results in this table, based on our hypothetical data, show that over 2100 of the 5000 daily hits (approximately 42%) can be attributed to automobile users consulting dynamic ATIS information for their commute trips.

USER ACCESS MODEL

Modal Orientation of Users

Transit	(perc_hits_trans_arr)	20%
Auto	(perc_hits_auto_arr)	75%
Flexible	(perc_hits_flex_arr)	5%

Market Segments and Modal Orientation

	Transit				
	Rec/Tour	Bus-Fam	Bus-Unfam	Commuter	Shop/Personal
(perc_hits_byuser_transit_arr)	20%	5%	5%	50%	20%
	Auto				
	Rec/Tour	Bus-Fam	Bus-Unfam	Commuter	Shop/Personal
(perc_hits_byuser_auto_arr)	10%	10%	10%	60%	10%
	Choice				
	Rec/Tour	Bus-Fam	Bus-Unfam	Commuter	Shop/Personal
(perc_hits_byuser_flex_arr)	25%	15%	15%	5%	40%

Market Segments by Mode and Type of Information Accessed

	Transit				
	Rec/Tour	Bus-Fam	Bus-Unfam	Commuter	Shop/Personal
Static tatic_share_ofhits_trans_arr)	60%	20%	80%	5%	20%
Dynamic amic_share_ofhits_trans_arr)	40%	80%	20%	95%	80%
TOTAL: all information	100%	100%	100%	100%	100%
	Auto				
	Rec/Tour	Bus-Fam	Bus-Unfam	Commuter	Shop/Personal
Static tatic_share_ofhits__auto_arr)	60%	20%	80%	5%	20%
Dynamic namic_share_ofhits_auto_arr)	40%	80%	20%	95%	80%
TOTAL: all information	100%	100%	100%	100%	100%
	Choice				
	Rec/Tour	Bus-Fam	Bus-Unfam	Commuter	Shop/Personal
Static (static_share_ofhits_flex_arr)	60%	20%	80%	5%	20%
Dynamic namic_share_ofhits_flex_arr)	40%	80%	20%	95%	80%
TOTAL: all information	100%	100%	100%	100%	100%

Hits per Day for Each Type of Information (by mode and market segment)

	Transit				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	Shop/Personal
Static l_hits_perday_stat_trans_arr)	120	10	40	25	40
Dynamic l_hits_perday_dyn_trans_arr)	80	40	10	475	160
	Auto				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	Shop/Personal
Static al_hits_perday_stat_auto_arr)	225	75	300	113	75
Dynamic al_hits_perday_dyn_auto_arr)	150	300	75	2138	300
	Choice				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	Shop/Personal
Static tal_hits_perday_stat_flex_arr)	38	8	30	1	20
Dynamic tal_hits_perday_dyn_flex_arr)	25	30	8	12	80

Exhibit 7-2. User Access Module

7.2.3 Distribution of Traveler Behavior in Response to ATIS

In this module, we add the dimension of changes in traveler behavior to the user access module estimates presented above to complete the trip scenario definition. The module is broken down into four sections. The first two sections are used to enter traveler behavior data, and the second two sections give the results of combining this data with the user access results.

Exhibit 7-3 and Exhibit 7-4 show the distribution of traveler behavior changes by mode and market segment for static and dynamic information, respectively. Our hypothetical values are based on two rules of thumb: (1) flexible users are more likely to alter behavior than non-flexible users, and (2) familiar users are less likely to derive as much value from static information.

The transit and auto distributions are shown to be equivalent in the static and dynamic case. The change mode behavior is the only action attributed to flexible users (see Section 6.1.2), so the cells in these areas are unshaded, meaning that they do not require user input.

The results of these inputs are shown in Exhibit 7-5 and Exhibit 7-6. They show the total number of hits per day for static and dynamic information use. The "No Value" hits are not included in these counts. These values are obtained by multiplying the results from the user access module by the behavior distributions entered in the travel behavior module. The greatest number of hits results from dynamic use by automobile commuter trips.

Primary Actions Resulting from Access to STATIC Information						
		Transit				
		Rec/Tour	Bus-Fam	Bus-Unfam	Commuter	S/P
Action		(perc_actions_byuser_trans_static_mat)				
(1)	Change Mode	0%	0%	0%	0%	0%
(2)	Add Trip	5%	0%	5%	0%	10%
(3)	Delete Trip	5%	0%	5%	0%	10%
(4)	Change Destination	15%	0%	0%	0%	15%
(5)	Change Route	20%	30%	20%	60%	10%
(6)	Change Departure Time	30%	45%	20%	30%	30%
(7)	Change in Confidence	20%	15%	45%	0%	15%
(8)	No Value	5%	10%	5%	10%	10%
	TOTAL: All Actions	100%	100%	100%	100%	100%
		Auto				
		Rec/Tour	Bus-Fam	Bus-Unfam	Commuter	S/P
Action		(perc_actions_byuser_auto_static_mat)				
(1)	Change Mode	0%	0%	0%	0%	0%
(2)	Add Trip	5%	0%	5%	0%	10%
(3)	Delete Trip	5%	0%	5%	0%	10%
(4)	Change Destination	15%	0%	0%	0%	15%
(5)	Change Route	20%	30%	20%	60%	10%
(6)	Change Departure Time	30%	45%	20%	30%	30%
(7)	Change in Confidence	20%	15%	45%	0%	15%
(8)	No Value	5%	10%	5%	10%	10%
	TOTAL: All Actions	100%	100%	100%	100%	100%
		Choice				
		Rec/Tour	Bus-Fam	Bus-Unfam	Commuter	S/P
Action		(perc_actions_byuser_flex_static_mat)				
(1)	Change Mode	100%	100%	100%	100%	100%
(2)	Add Trip	0%	0%	0%	0%	0%
(3)	Delete Trip	0%	0%	0%	0%	0%
(4)	Change Destination	0%	0%	0%	0%	0%
(5)	Change Route	0%	0%	0%	0%	0%
(6)	Change Departure Time	0%	0%	0%	0%	0%
(7)	Change in Confidence	0%	0%	0%	0%	0%
(8)	No Value	0%	0%	0%	0%	0%
	TOTAL: All Actions	100%	100%	100%	100%	100%

Exhibit 7-3. Traveler Behavior Module: Distribution of Actions in Response to Static Information

Primary Actions Resulting from Access to DYNAMIC Information

		Transit				
		Rec/Tour	Bus-Fam	Bus-Unfam	Commuter	S/P
Action		(perc_actions_byuser_trans_dyn_mat)				
(1)	Change Mode	0%	0%	0%	0%	0%
(2)	Add Trip	5%	5%	5%	0%	5%
(3)	Delete Trip	5%	5%	5%	5%	5%
(4)	Change Destination	10%	0%	0%	0%	10%
(5)	Change Route	20%	20%	20%	20%	20%
(6)	Change Departure Time	40%	30%	30%	30%	30%
(7)	Change in Confidence	15%	35%	35%	40%	25%
(8)	No Value	5%	5%	5%	5%	5%
	TOTAL: All Actions	100%	100%	100%	100%	100%

		Auto				
		Rec/Tour	Bus-Fam	Bus-Unfam	Commuter	S/P
Action		(perc_actions_byuser_auto_dyn_mat)				
(1)	Change Mode	0%	0%	0%	0%	0%
(2)	Add Trip	5%	5%	5%	0%	5%
(3)	Delete Trip	5%	5%	5%	5%	5%
(4)	Change Destination	10%	0%	0%	0%	10%
(5)	Change Route	20%	20%	20%	20%	20%
(6)	Change Departure Time	40%	30%	30%	30%	30%
(7)	Change in Confidence	15%	35%	35%	40%	25%
(8)	No Value	5%	5%	5%	5%	5%
	TOTAL: All Actions	100%	100%	100%	100%	100%

		Choice				
		Rec/Tour	Bus-Fam	Bus-Unfam	Commuter	S/P
Action		(perc_actions_byuser_flex_dyn_mat)				
(1)	Change Mode	100%	100%	100%	100%	100%
(2)	Add Trip	0%	0%	0%	0%	0%
(3)	Delete Trip	0%	0%	0%	0%	0%
(4)	Change Destination	0%	0%	0%	0%	0%
(5)	Change Route	0%	0%	0%	0%	0%
(6)	Change Departure Time	0%	0%	0%	0%	0%
(7)	Change in Confidence	0%	0%	0%	0%	0%
(8)	No Value	0%	0%	0%	0%	0%
	TOTAL: All Actions	100%	100%	100%	100%	100%

Exhibit 7-4. Traveler Behavior Module: Distribution of Actions in Response to Dynamic Information

Total Hits/Day by Action Resulting from Static Information					
	Transit				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Action	(hits_perday_all_actions_static_trans_mat)				
Change Mode	0	0	0	0	0
Add Trip	6	0	2	0	4
Delete Trip	6	0	2	0	4
Change Destination	18	0	0	0	6
Change Route	24	3	8	15	4
Change Departure Time	36	5	8	8	12
Change in Confidence	24	2	18	0	6
TOTAL	114	9	38	23	36
	Auto				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Action	(hits_perday_all_actions_static_auto_mat)				
Change Mode	0	0	0	0	0
Add Trip	11	0	15	0	8
Delete Trip	11	0	15	0	8
Change Destination	34	0	0	0	11
Change Route	45	23	60	68	8
Change Departure Time	68	34	60	34	23
Change in Confidence	45	11	135	0	11
TOTAL	214	68	285	101	68
	Choice				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Action	(hits_perday_all_actions_static_flex_mat)				
Change Mode	38	8	30	1	20
Add Trip	0	0	0	0	0
Delete Trip	0	0	0	0	0
Change Destination	0	0	0	0	0
Change Route	0	0	0	0	0
Change Departure Time	0	0	0	0	0
Change in Confidence	0	0	0	0	0
TOTAL	38	8	30	1	20
Action	Total Hits/Day All Actions				
Change Mode	96				
Add Trip	46				
Delete Trip	46				
Change Destination	69				
Change Route	257				
Change Departure Time	286				
Change in Confidence	252				
TOTAL	1,050				

Exhibit 7-5. Hits per Day by Mode, Market Segment, and Traveler Behavior for Static Information Usage

Total Hits/Day by Action Resulting from Dynamic Information

	Transit				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Action	(hits_perday_all_actions_dyn_trans_mat)				
Change Mode	0	0	0	0	0
Add Trip	4	2	1	0	8
Delete Trip	4	2	1	24	8
Change Destination	8	0	0	0	16
Change Route	16	8	2	95	32
Change Departure Time	32	12	3	143	48
Change in Confidence	12	14	4	190	40
TOTAL	76	38	10	451	152

	Auto				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Action	(hits_perday_all_actions_dyn_auto_mat)				
Change Mode	0	0	0	0	0
Add Trip	8	15	4	0	15
Delete Trip	8	15	4	107	15
Change Destination	15	0	0	0	30
Change Route	30	60	15	428	60
Change Departure Time	60	90	23	641	90
Change in Confidence	23	105	26	855	75
TOTAL	143	285	71	2,031	285

	Choice				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Action	(hits_perday_all_actions_dyn_flex_mat)				
Change Mode	25	30	8	12	80
Add Trip	0	0	0	0	0
Delete Trip	0	0	0	0	0
Change Destination	0	0	0	0	0
Change Route	0	0	0	0	0
Change Departure Time	0	0	0	0	0
Change in Confidence	0	0	0	0	0
TOTAL	25	30	8	12	80

Action	Total Hits/Day All Actions
Change Mode	154
Add Trip	56
Delete Trip	186
Change Destination	69
Change Route	746
Change Departure Time	1,141
Change in Confidence	1,343
TOTAL	3,696

Exhibit 7-6. Hits per Day by Mode, Market Segment, and Traveler Behavior for Static Information Usage

7.2.4 Parameters Used for Valuation

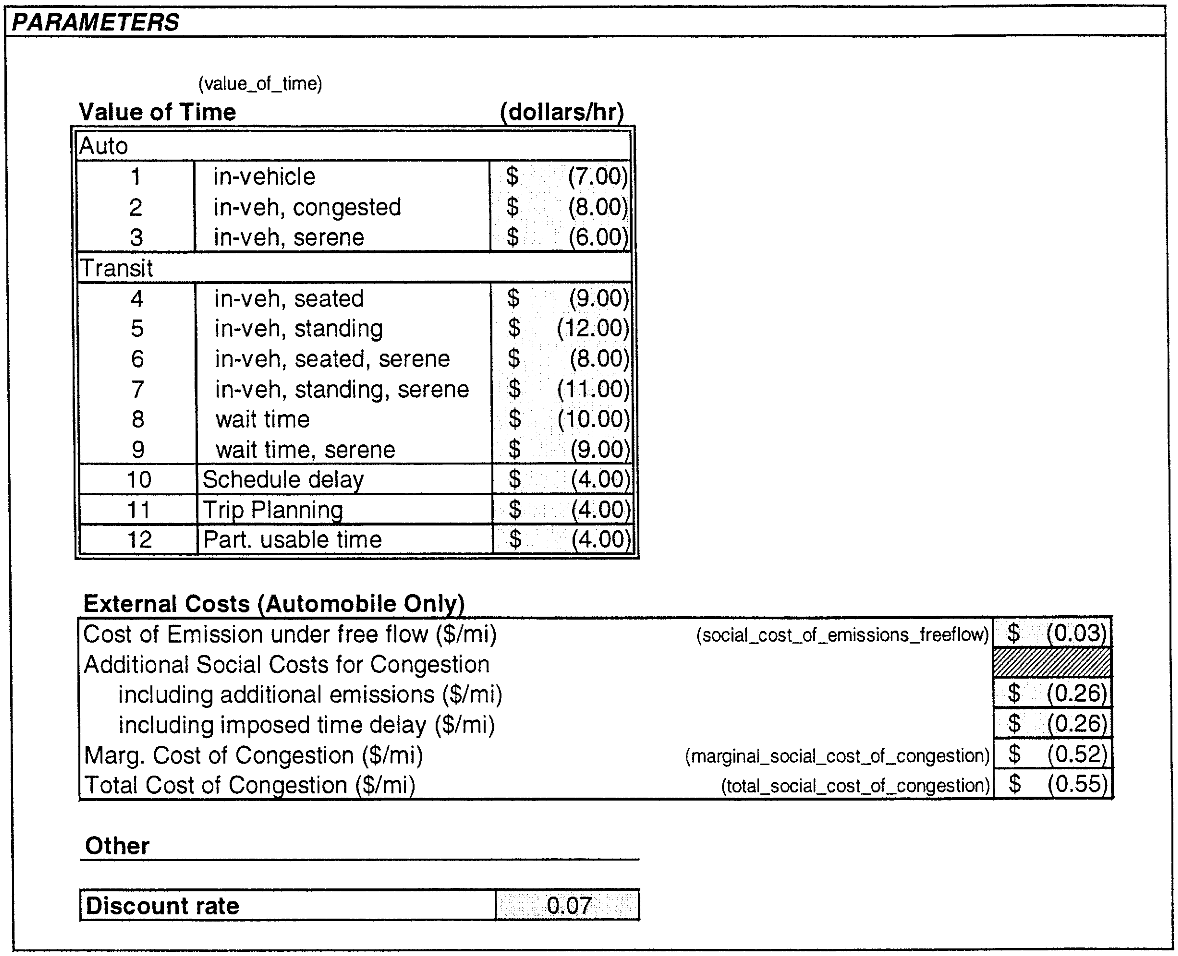
The ATIS evaluation makes use of three kinds of valuation parameters:

1. the value of time for different activities
2. the social costs of automobile use
3. the internal rate of return used to discount future benefits to the current year

These are entered in the parameter inputs module, shown in Exhibit 7-7. All of the value of time (VOT) and automobile social cost parameters are negative, since they represent costs. By entering them as negative numbers in this module, we avoid the use of negative signs in all future equations.

This module is also useful because we can use it to test the sensitivity of the results to these parameters. For example, we may want to consider different values for the marginal social cost of congestion. The value of time table is a "lookup" table. In proceeding modules, a code is entered for the value of time parameter corresponding to the left-most column of the Value of Time table. All changes to value of time parameters can be made in this table, so that we can easily test results sensitivity to these as well.

The values shown in the exhibit correspond to those show in previous chapters (see for example Section 6.2.1).



PARAMETERS

(value_of_time)

Value of Time **(dollars/hr)**

Auto		
1	in-vehicle	$ (7.00)
2	in-veh, congested	$ (8.00)
3	in-veh, serene	$ (6.00)
Transit		
4	in-veh, seated	$ (9.00)
5	in-veh, standing	$ (12.00)
6	in-veh, seated, serene	$ (8.00)
7	in-veh, standing, serene	$ (11.00)
8	wait time	$ (10.00)
9	wait time, serene	$ (9.00)
10	Schedule delay	$ (4.00)
11	Trip Planning	$ (4.00)
12	Part. usable time	$ (4.00)

External Costs (Automobile Only)

Cost of Emission under free flow ($/mi)	(social_cost_of_emissions_freeflow)	$ (0.03)
Additional Social Costs for Congestion		▨
including additional emissions ($/mi)		$ (0.26)
including imposed time delay ($/mi)		$ (0.26)
Marg. Cost of Congestion ($/mi)	(marginal_social_cost_of_congestion)	$ (0.52)
Total Cost of Congestion ($/mi)	(total_social_cost_of_congestion)	$ (0.55)

Other

Discount rate	0.07

Exhibit 7-7. Parameter Inputs Module

7.2.5 Trip Scenarios

The trip scenarios module includes information about baseline trips and the impacts and benefits that result from changes in traveler behavior. This is the core of the benefits evaluation spreadsheet, and this is where the decisions are made about how to estimate benefits for different scenarios. The methodology behind the trip scenarios, baseline data, and impacts is discussed in 6.2, where we present the rationale for each of the benefits estimation models. This section, therefore, will not be as in-depth as 6.2, and we refer the reader to that chapter for an in-depth discussion of each trip scenario and the benefit-cost analysis framework. However, because we have introduced quantitative data in these modules, we do give some insight in subsequent subsections to complement discussions of prior chapters. The baseline trip characteristics and impact data are allowed to differ by market segment.

7.2.5.1 Static Trip Scenario Modules

Exhibit 7-8 and Exhibit 7-9 show the baseline trip data and trip scenario modules for estimating benefits from changes in behavior due to static information use.

To explain how this module works, we summarize the inputs and outputs in these two exhibits:

Exhibit 7-8. Baseline Characteristics for Normal Trips (page 139)

There are three categories of information in this module, and each is entered separately for each market segment:

i. Trip characteristics
ii. Value Of Time (VOT) parameters
iii. Planning time savings estimation

The trip characteristics for automobile and transit trips are listed separately. The commute trip characteristics for both transit and auto are from the *1990 Nationwide Personal Transportation Survey* (Hu and Young,1993). Note that:

- the transit trip characteristics consist of travel (in-transit) times and wait times for average trips in each market segment. In general, we show commute trips to be the longest and shopping/personal trips to be the shortest. We show longer wait times when the market segment implies unfamiliarity with the region (recreational/tourist and business-unfamiliar). We also show that transit trips for commuting are standing trips, whereas all others are seated trips.

- the automobile trip characteristics consist of travel time, average distance, and the likelihood of the trip taking place under congested conditions. All travel times are shown as 15-20 minutes in length, and we show longer trip lengths for commuter trips and recreational trips. Commuter trips are the most congested because they occur during peak times. Business trips also have a high probability of occurring during congested conditions since normal business hours and peak travel periods overlap as well. Shopping/personal and recreational/tourist trips are the most likely to occur during off-peak times on off-peak routes. The module calculates the social cost per VMT (vehicle-mile traveled) for the trip based on the congestion characteristics entered in the trip characteristics table.

The value of time parameters are assigned in the middle section using the table lookup functions. The results of the table lookup are shown in the table below, entitled "Value of Time (normal trips)". The assignments are made based on the portion of the trip being valued. This includes in-transit and wait times for transit trips, in-vehicle travel time for automobile trips, and schedule delay for both transit and automobile trips. Note that for schedule delay, we assign a lower magnitude for value of time to business and commuter trips than to personal or recreational trips with the expectation that since the delay may involve staying at place-of-work or home longer it is more usable than the schedule delay time for non-business trips.

The last section presents planning time savings values used for both static and dynamic hits. We show a time *savings* for recreational/tourist, shopping/personal, and business-unfamiliar trips, and a time *cost* for commuters and business-familiar users who may not have consulted an information source otherwise.

Exhibit 7-9. Static Trip Scenarios Module (beginning page 140)

The static trip scenarios module is where impacts for trip changes based on static information are entered. We examine the rationale for estimating the benefits in each scenario in Section 6.3. The equations for estimating internal and external benefits are embedded in the spreadsheet cells which estimate benefits. The equations correspond to those presented in Section 6.3 and listed in the Appendix (Table A- 2). The impacts can have a different magnitude for each market segment.

For the hypothetical data presented, we show a higher consumer surplus change for business and commute trips, since the value of that time is expected to be slightly greater than that for recreational or personal time (see Section 5.1.2).

Average (Base Case) Trip Characteristics for Normal Trips						
		Natural Units				
		Rec/Tour	Bus-Fam	Bus-Unf	Comm	Shp/Psnl
Transit						
Travel time (min)	(avg_tt_transit_arr)	30	30	30	40	25
Wait time (min)	(avg_wt_transit_arr)	15	10	15	10	10
Auto						
Travel time (min)	(avg_tt_auto_arr)	20	20	20	20	15
Average distance (miles)	(avg_VMT_auto_arr)	11	6	6	11	6
% trips under congested condition	(avg_perc_trips_congested_arr)	20%	60%	60%	80%	20%
Social cost VMT for avg trip ($)	(avg_social_cost_VMT_arr)	$ (0.13)	$ (0.34)	$ (0.34)	$ (0.45)	$ (0.13)
		Value of Time				
		(Enter Code from table above)				
Transit		Rec/Tour	Bus-Fam	Bus-Unf	Comm	Shp/Psnl
Travel time (min)		4	4	4	5	4
Wait time (min)		8	8	8	8	8
Schedule Delay (min)		10	12	12	12	10
Auto						
Travel time (min)		1	1	1	1	1
Schedule Delay (min)		10	12	12	12	10
Value of Time (normal trips)						
		Rec/Tour	Bus-Fam	Bus-Unf	Comm	Shp/Psnl
Transit		($/hr)	($/hr)	($/hr)	($/hr)	($/hr)
Travel time	(avg_value_tt_trans_arr)	$ (9.00)	$ (9.00)	$ (9.00)	$ (12.00)	$ (9.00)
Wait time	(avg_value_wt_trans_arr)	$ (10.00)	$ (10.00)	$ (10.00)	$ (10.00)	$ (10.00)
Schedule Delay	(avg_value_sd_trans_arr)	$ (4.00)	$ (2.00)	$ (2.00)	$ (2.00)	$ (4.00)
Auto						
Travel time (uncongested)	(avg_value_tt_auto_arr)	$ (7.00)	$ (7.00)	$ (7.00)	$ (7.00)	$ (7.00)
Travel time (congested)	(cong_value_tt_auto_arr)	$ (8.00)	$ (8.00)	$ (8.00)	$ (8.00)	$ (8.00)
Schedule Delay	(avg_value_sd_auto_arr)	$ (4.00)	$ (2.00)	$ (2.00)	$ (2.00)	$ (4.00)

Planning Time Savings (all hits, static and dynamic)						
		Natural Units				
Additional planning time (negative implies savings)		Rec/Tour	Bus-Fam	Bus-Unf	Comm	Shp/Psnl
per hit (min)	(planning_time_savings_arr)	-2	1	-2	1	-1
		Value of Time				
	Enter code from table above	11	11	11	11	11
Value of Planning Time	(value_plan_time)	$ (4.00)	$ (4.00)	$ (4.00)	$ (4.00)	$ (4.00)

Exhibit 7-8. Baseline Characteristics for Normal Trips

STATIC TRIP SCENARIOS

Change Mode

		Rec/Tour	Bus-Fam	Bus-Unf	Commuter	S/P
% choosing transit	(perc_ch_mode_totrans_static_arr)	40%	40%	40%	40%	40%
Change in consumer surplus ($)	(ch_CS_ch_mode_totrans_static_arr)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(ch_VMT_ch_mode_totrans_static_arr)	-11.00	-6.00	-6.00	-11.00	-6.00
Change in %trips under congestion		0%	0%	0%	0%	0%
% choosing auto	(perc_ch_mode_toauto_static_arr)	60%	60%	60%	60%	60%
Change in consumer surplus ($)	(ch_CS_ch_mode_toauto_static_arr)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(ch_VMT_ch_mode_toauto_static_arr)	11.00	6.00	6.00	11.00	6.00
Change in %trips under congestion		0%	0%	0%	0%	0%
Internal/User Benefits	(ib_cm_stat_flex_trip)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Externality	(ex_cm_stat_flex_trip)	$ (0.29)	$ (0.41)	$ (0.41)	$ (0.98)	$ (0.16)

Add Trip

		Rec/Tour	Bus-Fam	Bus-Unf	Commuter	S/P
Transit						
Change in consumer surplus ($)	(ch_CS_add_trip_trans_static_arr)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(not used)	0.00	0.00	0.00	0.00	0.00
Internal/User Benefits	(ib_add_stat_trans_trip)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Externality	(ex_add_stat_trans_trip)	$ -	$ -	$ -	$ -	$ -
Auto	(perc_add_trip_auto_static)					
Change in consumer surplus ($)	(ch_CS_add_trip_auto_static_arr)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(ch_VMT_add_trip_auto_static_arr)	11.00	6.00	6.00	11.00	6.00
Change in %trips under congestion		0%	0%	0%	0%	0%
Internal/User Benefits	(ib_add_stat_auto_trip)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Externality	(ex_add_stat_auto_trip)	$ (1.47)	$ (2.05)	$ (2.05)	$ (4.91)	$ (0.80)

Delete Trip

		Rec/Tour	Bus-Fam	Bus-Unf	Commuter	S/P
Transit						
Change in consumer surplus ($)	(ch_CS_elim_trip_trans_static_arr)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(not used)	0.00	0.00	0.00	0.00	0.00
Internal/User Benefits	(ib_del_stat_trans_trip)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Externality	(ex_del_stat_trans_trip)	$ -	$ -	$ -	$ -	$ -
Auto						
Change in consumer surplus ($)	(ch_CS_elim_trip_auto_static_arr)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(ch_VMT_del_trip_auto_static_arr)	-11.00	-6.00	-6.00	-11.00	-6.00
Change in %trips under congestio	(not used)	0%	0%	0%	0%	0%
Internal/User Benefits	(ib_del_stat_auto_trip)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Externality	(ex_del_stat_auto_trip)	$ 1.47	$ 2.05	$ 2.05	$ 4.91	$ 0.80

Exhibit 7-9. Static Trip Scenarios Module
(Part 1 of 3)

STATIC TRIP SCENARIOS (continued)

Change Destination

		Rec/Tour	Bus-Fam	Bus-Unf	Comm.	Shp/Psnl
Transit						
Change in consumer surplus ($)	(ch_CS_ch_dest_trans_static_arr)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(not used)	0.00	0.00	0.00	0.00	0.00
Internal/User Benefits	(ib_cd_stat_trans_trip)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Externality	(ex_cd_stat_trans_trip)	$ -	$ -	$ -	$ -	$ -
Auto						
Change in consumer surplus ($)	(ch_CS_ch_dest_auto_static_arr)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)		0.00	0.00	0.00	0.00	0.00
Change in %trips under congestion		0%	0%	0%	0%	0%
Internal/User Benefits	(ib_cd_stat_auto_trip)	$ 1.00	$ 2.00	$ 2.00	$ 2.00	$ 1.00
Externality	(ex_cd_stat_auto_trip)	$ -	$ -	$ -	$ -	$ -

Change Route

		Rec/Tour	Bus-Fam	Bus-Unf	Comm.	Shp/Psnl
Transit						
Change in travel time (min)	(ch_TT_ch_route_trans_static_arr)	-5.00	-5.00	-5.00	-5.00	-5.00
Change in wait time (min)	(ch_WT_ch_route_trans_static_arr)	-5.00	-5.00	-5.00	-5.00	-5.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(not used)	0.00	0.00	0.00	0.00	0.00
Internal/User Benefits	(ib_cr_stat_trans_trip)	$ 1.58	$ 1.58	$ 1.58	$ 1.83	$ 1.58
Externality	(ex_cr_stat_trans_trip)	$ -	$ -	$ -	$ -	$ -
Auto						
Change in travel time (min)	(ch_TT_ch_route_auto_static_arr)	-5.00	-5.00	-5.00	0.00	-5.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(ch_VMT_ch_route_auto_static_arr)	0.00	-0.50	0.00	0.00	0.00
Change in %trips under cong.	(ch_perc_trips_congd_ch_route_static_arr)	-2%	-5%	-10%	-10%	-10%
Internal/User Benefits	(ib_cr_stat_auto_trip)	$ 1.58	$ 1.58	$ 1.58	$ 1.83	$ 1.58
Externality	(ex_cr_stat_auto_trip)	$ 0.11	$ 0.31	$ 0.31	$ 0.57	$ 0.31

Exhibit 7-9. Static Trip Scenarios Module (continued)

(Part 2 of 3)

STATIC TRIP SCENARIOS (continued)

Change Departure Time

		Rec/Tour	Bus-Fam	Bus-Unf	Comm.	Shp/Psnl
Transit						
Change in travel time (min)	(ch_TT_ch_dept_trans_static_arr)	0.00	0.00	0.00	0.00	0.00
Change in wait time (min)	(ch_WT_ch_dept_trans_static_arr)	-10.00	-5.00	-5.00	-5.00	-5.00
Schedule delay (min)	(trip_delay_ch_dept_trans_static_arr)	10.00	5.00	5.00	5.00	5.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(not used)	0.00	0.00	0.00	0.00	0.00
Internal/User Benefits	(ib_ct_stat_trans_trip)	$ 1.00	$ 0.67	$ 0.67	$ 0.67	$ 0.50
Externality	(ex_ct_stat_trans_trip)	$ -	$ -	$ -	$ -	$ -
Auto						
Change in travel time (min)	(ch_TT_ch_dept_auto_static_arr)	-10.00	-5.00	-10.00	-5.00	-5.00
Schedule delay (min)	(trip_delay_ch_dept_auto_static_arr)	10.00	5.00	10.00	5.00	5.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)		0.00	0.00	0.00	0.00	0.00
Change in %trip under cong	(ch_perc_trips_congd_ch_dept_static_arr)	-10%	-20%	-20%	-20%	-20%
Internal/User Benefits	(ib_ct_stat_auto_trip)	$ 1.00	$ 0.67	$ 1.33	$ 0.67	$ 0.50
Externality	(ex_ct_stat_auto_trip)	$ 0.57	$ 0.62	$ 0.62	$ 1.14	$ 0.62

Change Confidence

		Rec/Tour	Bus-Fam	Bus-Unf	Comm.	Shp/Psnl
Transit: Change in consumer surplus ($)						
	(ch_CS_ch_satisfaction_trans_static_arr)	$ 0.50	$ 0.25	$ 0.50	$ 0.25	$ 0.25
Internal/User Benefits	(ib_cc_stat_trans_trip)	$ 0.50	$ 0.25	$ 0.50	$ 0.25	$ 0.25
Auto: Change in consumer surplus ($)						
	(ch_CS_ch_satisfaction_auto_static_arr)	$ 0.50	$ 0.25	$ 0.50	$ 0.25	$ 0.25
Internal/User Benefits	(ib_cc_stat_auto_trip)	$ 0.50	$ 0.25	$ 0.50	$ 0.25	$ 0.25

Exhibit 7-9. Static Trip Scenarios Module (continued)

(Part 3 of 3)

7.2.5.2 Dynamic Trip Scenario Modules

The dynamic trip scenario modules follow the same format as the static modules, with a few more inputs because of the greater complexity of the situation. Exhibit 7-10 shows the baseline trip characteristics for incident-affected trips, and Exhibit 7-11 shows the dynamic trip scenarios.

To explain how this module works, we summarize the inputs and outputs in these two exhibits:

Exhibit 7-10. Baseline Characteristics for Incident-Affected Trips (page 145)

There are two categories of inputs in this module:

i. Trip characteristics
ii. Value Of Time (VOT) parameters for incident-affected trips

The trip characteristics are similar to those for normal trips, with travel times, trip lengths, and congestion likelihood entered in the shaded cells. In the data shown, we show five minute increases in transit times and wait times, and ten minute increases in automobile travel time for all market segments.

In the value of time section, we distinguish between baseline values and new, serene values. The incident-affected VOT's for transit trips are the same as those for the normal transit trips. For automobile trips, we show a higher VOT due to unforeseen congestion which may cause stress or uncertainty in the user. In the presence of ATIS-based knowledge, we value the "new" trips at serene rates. By "new" we refer to the trip with ATIS as opposed to that which would have taken place without ATIS. For automobile trips, these rates are $2.00 less than the congested rates; for transit trips they are $1.00 less than the average in-transit and wait time rates. The method for entering value of time data is to input the appropriate code corresponding to the Value of Time table in the Parameters module. The module displays the actual values based on the code inputs.

Exhibit 7-11. Dynamic Trip Scenarios Module (page 146)

The dynamic trip scenarios module is where impacts for trip changes based on dynamic information are entered. The tables in this module are discussed in detail on a scenario-by-scenario basis in Section 6.3, where we present impact models for each scenario. The equations for internal and external benefits estimation are embedded within each scenario table. Most of the impacts and benefits are calculated based on differences between normal and incident-affected travel conditions, except for the "Change Route" and "Change Departure Time" scenarios, which require user estimation of trip length, travel time, and congestion likelihood. In several of the scenarios, we introduce an impact called "Congestion improvement over normal conditions" to represent a change in the probability of congested travel relative to normal conditions. For example, for commute trips, $p_n = 80\%$ and $p_i = 100\%$. A new trip chosen by the user under dynamic conditions may occur with p_n instead of p_i to avoid incident-affected travel. In that case, $\Delta p = p_n - p_i$. The congestion improvement value is used to adjust Δp by an additional percentage. For example, $\Delta p = (p_n - p_i)\times(1.1)$ means that the improvement was an additional 10% beyond the "normal trip" rate of congestion. This factor is used in the "Change Destination", "Change Route", and "Change Departure Time" scenarios. The formula used in the spreadsheet is safeguarded so that the new congestion likelihood value does not fall below zero. If it does, then p_n is used.

Average (Base Case) Trip Characteristics for Incident-Affected Trips						
		Natural Units				
		Rec/Tour	Bus-Fam	Bus-Unf	Comm	Shp/Psnl
Transit						
Travel time (min)	(avg_tt_under_incident_trans_arr)	35	35	35	45	30
Wait time (min)	(avg_wt_under_incident_arr)	20	15	20	15	15
Auto						
Travel time (min)	(avg_tt_under_incident_auto_arr)	30	30	30	30	25
Average distance (miles)	(same as base for static cases)	11.00	6.00	6.00	11.00	6.00
% trips under congestion	(avg_perc_trips_congested_under_incident_arr)	80%	80%	80%	100%	80%
Social cost VMT for avg trip ($)	(avg_social_cost_VMT_under_incident_arr)	$ (0.45)	$ (0.45)	$ (0.45)	$ (0.55)	$ (0.45)
		Value of Time (Enter Code from table above)				
Transit		Rec/Tour	Bus-Fam	Bus-Unf	Comm	Shp/Psnl
Travel time (min)	(avg_tt_under_incident_trans_arr)	4	4	4	5	4
Wait time (min)	(avg_wt_under_incident_arr)	8	8	8	8	8
Auto						
Travel time (min)	(avg_tt_under_incident_auto_arr)	2	2	2	2	2
Value of Time (average trip under incident conditions)						
		Rec/Tour	Bus-Fam	Bus-Unf	Comm	Shp/Psnl
Transit		($/hr)	($/hr)	($/hr)	($/hr)	($/hr)
In-transit VOT	(avg_value_tt_trans_arr)	$ (9.00)	$ (9.00)	$ (9.00)	$ (12.00)	$ (9.00)
Wait time VOT	(avg_value_wt_trans_arr)	$ (10.00)	$ (10.00)	$ (10.00)	$ (10.00)	$ (10.00)
Auto						
In-vehicle congested VOT	(avg_value_tt_under_incident_auto_arr)	$ (8.00)	$ (8.00)	$ (8.00)	$ (8.00)	$ (8.00)
"New" Value of Time (assuming real time information --> serene)						
		(Enter Code from table above)				
Transit		Rec/Tour	Bus-Fam	Bus-Unf	Comm	Shp/Psnl
Travel time (min)		6	6	6	7	6
Wait time (min)		9	9	9	9	9
Auto						
Travel time (min)		3	3	3	3	3
		Rec/Tour	Bus-Fam	Bus-Unf	Comm	Shp/Psnl
Transit		($/hr)	($/hr)	($/hr)	($/hr)	($/hr)
In-transit VOT (serene)	(value_tt_trans_serene_arr)	$ (8.00)	$ (8.00)	$ (8.00)	$ (11.00)	$ (8.00)
Wait time VOT (serene)	(value_wt_trans_serene_arr)	$ (9.00)	$ (9.00)	$ (9.00)	$ (9.00)	$ (9.00)
Auto						
In-vehicle VOT (serene)	(value_tt_auto_serene_arr)	$ (6.00)	$ (6.00)	$ (6.00)	$ (6.00)	$ (6.00)

Exhibit 7-10. Baseline Characteristics for Incident-Affected Trips

DYNAMIC TRIP SCENARIOS

Change Mode (Dynamic)

	Rec/Tour	Bus-Fam	Bus-Unf	Commuter	S/P
% choosing transit (perc_ch_mode_totrans_dynamic_arr)	60%	60%	60%	60%	60%
Change in consumer surplus ($)(ch_CS_ch_mode_totrans_dynamic_arr)	$ 2.00	$ 3.00	$ 3.00	$ 3.00	$ 2.00
Change in other social cost ($) (not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi) (ch_VMT_ch_mode_totrans_dynamic_arr)	-11.00	-6.00	-6.00	-11.00	-6.00
Change in %trips under congestio (same as avg with incident)	0%	0%	0%	0%	0%
% choosing auto (perc_ch_mode_toauto_dynamic_arr)	40%	40%	40%	40%	40%
Change in consumer surplus ($)(ch_CS_ch_mode_toauto_dynamic_arr)	$ 2.00	$ 3.00	$ 3.00	$ 3.00	$ 2.00
Change in other social cost ($) (not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi) (ch_VMT_ch_mode_toauto_dynamic_arr)	11.00	6.00	6.00	11.00	6.00
Change in %trips under congestio (ch_%trips_congd_ch_mode_toauto_dynamic_arr)	-60%	-20%	-20%	-20%	-60%
Internal/User Benefits (ib_cm_dyn_flex_trip)	$ 2.00	$ 3.00	$ 3.00	$ 3.00	$ 2.00
Externality (ex_cm_dyn_flex_trip)	$ 2.35	$ 0.78	$ 0.78	$ 1.67	$ 1.28

Add Trip (Dynamic)

	Add a Trip				
	Rec/Tour	Bus-Fam	Bus-Unf	Commuter	S/P
Transit					
Change in consumer surplus ($) (ch_CS_add_trip_trans_dynamic_arr)	$ 2.00	$ 3.00	$ 3.00	$ 2.00	$ 2.00
Change in other social cost ($) (not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi) (not used)	0.00	0.00	0.00	0.00	0.00
Internal/User Benefits (ib_add_dyn_trans_trip)	$ 2.00	$ 3.00	$ 3.00	$ 2.00	$ 2.00
Externality (ex_add_dyn_trans_trip)	$ -	$ -	$ -	$ -	$ -
Auto					
Change in consumer surplus ($) (ch_CS_add_trip_auto_dynamic_arr)	$ 2.00	$ 3.00	$ 3.00	$ 2.00	$ 2.00
Change in other social cost ($) (not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi) (ch_VMT_add_trip_auto_dynamic_arr)	11.00	6.00	6.00	11.00	6.00
Change in %trips under congestio (ch_%trips_congd_add_trip_auto_dynamic_arr)	-60%	-20%	-20%	-20%	-60%
Internal/User Benefits (ib_add_dyn_auto_trip)	$ 2.00	$ 3.00	$ 3.00	$ 2.00	$ 2.00
Externality (ex_add_dyn_auto_trip)	$ (1.47)	$ (2.05)	$ (2.05)	$ (4.91)	$ (0.80)

Delete Trip (Dynamic)

	Eliminate a Trip				
	Rec/Tour	Bus-Fam	Bus-Unf	Commuter	S/P
Transit					
Change in consumer surplus ($) (ch_CS_elim_trip_trans_dynamic_arr)	$ 2.00	$ 3.00	$ 3.00	$ 2.00	$ 2.00
Change in other social cost ($) (not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi) (not used)	0.00	0.00	0.00	0.00	0.00
Internal/User Benefits (ib_del_dyn_trans_trip)	$ 2.00	$ 3.00	$ 3.00	$ 2.00	$ 2.00
Externality (ex_del_dyn_trans_trip)	$ -	$ -	$ -	$ -	$ -
Auto					
Change in consumer surplus ($) (ch_CS_elim_trip_auto_dynamic_arr)	$ 2.00	$ 3.00	$ 3.00	$ 2.00	$ 2.00
Change in other social cost ($) (not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi) (ch_VMT_elim_trip_auto_dynamic_arr)	-11.00	-6.00	-6.00	-11.00	-6.00
Change in %trips under congestio (assume no change)	0%	0%	0%	0%	0%
Internal/User Benefits (ib_del_dyn_auto_trip)	$ 2.00	$ 3.00	$ 3.00	$ 2.00	$ 2.00
Externality (ex_del_dyn_auto_trip)	$ 4.91	$ 2.68	$ 2.68	$ 6.05	$ 2.68

Exhibit 7-11. Dynamic Trip Scenarios Module
(Part 1 of 3)

DYNAMIC TRIP SCENARIOS (continued)

Change Destination (Dynamic)

		Rec/Tour	Bus-Fam	Bus-Unf	Commuter	Shp/Psnl
Transit						
Change in travel time (min)	(ch_TT_ch_dest_trans_dynamic_arr)	-5.00	-5.00	-5.00	-5.00	-5.00
Change in wait time (min)	(ch_WT_ch_dest_trans_dynamic_arr)	-5.00	-5.00	-5.00	-5.00	-5.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(not used)	0.00	0.00	0.00	0.00	0.00
New in-transit VOT ($/hour)	(value_tt_trans_serene_arr)	$ (8.00)	$ (8.00)	$ (8.00)	$ (8.00)	$ (8.00)
New wait time VOT ($/hour)	(value_wt_trans_serene_arr)	$ (9.00)	$ (9.00)	$ (9.00)	$ (9.00)	$ (9.00)
Internal/User Benefits	(ib_cd_dyn_trans_trip)	$ 2.33	$ 2.25	$ 2.33	$ 2.67	$ 2.17
Externality	(ex_cd_dyn_trans_trip)	$ -	$ -	$ -	$ -	$ -
Auto						
Change in travel time (min)	(ch_TT_ch_dest_auto_dynamic_arr)	-10.00	-10.00	-10.00	-10.00	-10.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(ch_VMT_ch_dest_auto_dynamic_arr)	0.00	0.00	0.00	0.00	0.00
Congestion improvement over n	(cong_imp_ch_dest_auto_dynamic_arr)	10%	10%	10%	10%	10%
Change in %trips under cong	(ch_perc_trips_congd_ch_dest_dynamic_arr)	-66%	-22%	-22%	-22%	-66%
New in-vehicle VOT ($/hour)	(value_tt_auto_serene_arr)	$ (6.00)	$ (6.00)	$ (6.00)	$ (6.00)	$ (6.00)
Internal/User Benefits	(ib_cd_dyn_auto_trip)	$ 2.00	$ 2.00	$ 2.00	$ 2.00	$ 1.83
Externality	(ex_cd_dyn_auto_trip)	$ 3.78	$ 0.69	$ 0.69	$ 1.26	$ 2.06

Change Route (Dynamic)

		Rec/Tour	Bus-Fam	Bus-Unf	Commuter	Shp/Psnl
Transit						
Change in travel time (min)	(ch_TT_ch_route_trans_dynamic_arr)	5.00	5.00	0.00	5.00	0.00
Change in wait time (min)	(ch_WT_ch_route_trans_dynamic_arr)	-5.00	-5.00	0.00	-5.00	0.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(not used)	0.00	0.00	0.00	0.00	0.00
New in-transit VOT ($/hour)	(value_tt_trans_serene_arr)	$ (8.00)	$ (8.00)	$ (8.00)	$ (11.00)	$ (8.00)
New wait time VOT ($/hour)	(value_wt_trans_serene_arr)	$ (9.00)	$ (9.00)	$ (9.00)	$ (9.00)	$ (9.00)
Internal/User Benefits	(ib_cr_dyn_trans_trip)	$ 1.00	$ 0.92	$ 0.92	$ 0.83	$ 0.75
Externality	(ex_cr_dyn_trans_trip)	$ -	$ -	$ -	$ -	$ -
Auto						
Change in travel time (min)	(ch_TT_ch_route_auto_dynamic_arr)	-10.00	0.00	0.00	5.00	0.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(ch_VMT_ch_route_auto_dynamic_arr)	2.00	2.00	2.00	2.00	1.00
Congestion improvement over n	(cong_imp_ch_route_auto_dynamic_arr)	10%	10%	10%	10%	10%
Change in %trips under cong	(ch_perc_trips_congd_ch_route_dynamic_arr)	-66%	-22%	-22%	-22%	-66%
New in-vehicle VOT ($/hour)	(value_tt_auto_serene_arr)	$ (6.00)	$ (6.00)	$ (6.00)	$ (6.00)	$ (6.00)
Internal/User Benefits	(ib_cr_dyn_auto_trip)	$ 2.00	$ 1.00	$ 1.00	$ 0.50	$ 0.83
Externality	(ex_cr_dyn_auto_trip)	$ 3.57	$ 0.02	$ 0.02	$ 0.39	$ 1.96

Exhibit 7-11. Dynamic Trip Scenarios Module (continued)
(Part 2 of 3)

DYNAMIC TRIP SCENARIOS (continued)

Change Departure Time (Dynamic)

		Rec/Tour	Bus-Fam	Bus-Unf	Commuter	Shp/Psnl
Transit						
Change in travel time (min)	(ch_TT_ch_dept_trans_dynamic_arr)	0.00	0.00	0.00	0.00	0.00
Change in wait time (min)	(ch_WT_ch_dept_trans_dynamic_arr)	-15.00	-5.00	-10.00	-10.00	-10.00
Schedule delay (min)	(trip_delay_ch_dept_trans_dynamic_arr)	15.00	5.00	10.00	10.00	10.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(not used)	0.00	0.00	0.00	0.00	0.00
New in-transit VOT ($/hour)	(value_tt_trans_serene_arr)	$ (8.00)	$ (8.00)	$ (8.00)	$ (11.00)	$ (8.00)
New wait time VOT ($/hour)	(value_wt_trans_serene_arr)	$ (9.00)	$ (9.00)	$ (9.00)	$ (9.00)	$ (9.00)
Schedule delay VOT ($/hour)	(avg_value_sd_trans_arr)	$ (4.00)	$ (2.00)	$ (2.00)	$ (2.00)	$ (4.00)
Internal/User Benefits	(ib_ct_dyn_trans_trip)	$ 2.17	$ 1.42	$ 2.08	$ 2.17	$ 1.58
Externality	(ex_ct_dyn_trans_trip)	$ -	$ -	$ -	$ -	$ -
Auto						
Change in travel time (min)	(ch_TT_ch_dept_auto_dynamic_arr)	-10.00	-10.00	-10.00	-10.00	-10.00
Schedule delay (min)	(trip_delay_ch_dept_auto_dynamic_arr)	10.00	10.00	10.00	10.00	10.00
Change in other social cost ($)	(not used)	$ -	$ -	$ -	$ -	$ -
Change in VMT (mi)	(not used)	0.00	0.00	0.00	0.00	0.00
Congestion improvement over n	(cong_imp_ch_dept_auto_dynamic_arr)	10%	10%	10%	10%	10%
Change in %trips under cong	(ch_perc_trips_congd_ch_dept_dynamic_arr)	-66%	-22%	-22%	-22%	-66%
New in-vehicle VOT ($/hour)	(value_tt_auto_serene_arr)	$ (6.00)	$ (6.00)	$ (6.00)	$ (6.00)	$ (6.00)
Schedule delay (min)	(avg_value_sd_auto_arr)	$ (4.00)	$ (2.00)	$ (2.00)	$ (2.00)	$ (4.00)
Internal/User Benefits	(ib_ct_dyn_auto_trip)	$ 1.33	$ 1.67	$ 1.67	$ 1.67	$ 1.17
Externality	(ex_ct_dyn_auto_trip)	$ 3.78	$ 0.69	$ 0.69	$ 1.26	$ 2.06

Change Confidence (Dynamic)

		Rec/Tour	Bus-Fam	Bus-Unf	Commuter	Shp/Psnl
Transit						
%Incident-affected trips	(perc_trips_incident_ch_conf_trans_arr)	20%	20%	20%	20%	20%
%Normal trips	(perc_trips_normal_ch_conf_trans_arr)	80%	80%	80%	80%	80%
New in-transit VOT ($/hour)	(value_tt_trans_serene_arr)	$ (8.00)	$ (8.00)	$ (8.00)	$ (11.00)	$ (8.00)
New wait time VOT ($/hour)	(value_wt_trans_serene_arr)	$ (9.00)	$ (9.00)	$ (9.00)	$ (9.00)	$ (9.00)
Internal/User Benefits	(ib_cc_dyn_trans_trip)	$ 0.78	$ 0.70	$ 0.78	$ 0.87	$ 0.62
Auto						
%Incident-Affected Trips	(perc_trips_incident_ch_conf_auto_arr)	20%	20%	20%	20%	20%
%Normal trips	(perc_trips_normal_ch_conf_auto_arr)	80%	80%	80%	80%	80%
New in-vehicle VOT ($/hour)	(value_tt_auto_serene_arr)	$ (6.00)	$ (6.00)	$ (6.00)	$ (6.00)	$ (6.00)
Internal/User Benefits	(ib_cc_dyn_auto_trip)	$ 0.25	$ 0.25	$ 0.25	$ 0.25	$ 0.21

Exhibit 7-11. Dynamic Trip Scenarios Module (continued)
(Part 3 of 3)

7.3 Spreadsheet Outputs: Summary of Benefits

The result of all the inputs is a listing of benefits for the ATIS project. The benefits are listed by trip scenario and market segment.

We examine the benefits from three perspectives:

1. Scenario-specific benefits
2. Annual aggregated benefits
3. Project lifecycle benefits

7.3.1 Summary of Scenario-Specific Benefits

The scenario-specific benefits are the "per trip" benefits. They are estimated and displayed in the trip scenario modules, but we also summarize them in spreadsheet. These modules are shown in the following exhibits (pages 150 through 153):

- Exhibit 7-12. Summary of Internal Benefits per Hit for Static Trip Scenarios
- Exhibit 7-13. Summary of Externalities per Hit for Static Trip Scenarios
- Exhibit 7-14. Summary of Internal Benefits per Hit for Dynamic Trip Scenarios
- Exhibit 7-15. Summary of Externalities per Hit for Dynamic Trip Scenarios

These summaries are based on hypothetical data, but they will be useful for observing the range of internal and external benefits and assessing the reasonableness of the results when actual data is used. For example, in comparing the values in Exhibit 7-12 and Exhibit 7-14 we show that internal benefits are up to $2.00 for static hits and $3.00 for dynamic hits. The highest internal benefits are those that resulted from direct inputs of changes in consumer surplus. Comparing the values Exhibit 7-13 and Exhibit 7-15, we see that the externalities shown are higher for dynamic hits than static hits, and the highest and lowest externalities occur for added and deleted trips.

INTERNAL BENEFITS PER HIT: Static Information

INTERNAL BENEFITS ($/hit)	**Transit**				
(CS, direct or through time)	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
	(avg_planning_benefits_perhit_trans_arr)				
Planning Time Benefits (apply to all hits)	0.13	-0.07	0.13	-0.07	0.07
	(avg_internal_benefits_perhit_byaction_static_trans_mat)				
Change Mode	▨	▨	▨	▨	▨
Add Trip	1.00	2.00	2.00	2.00	1.00
Delete Trip	1.00	2.00	2.00	2.00	1.00
Change Destination	1.00	2.00	2.00	2.00	1.00
Change Route	1.58	1.58	1.58	1.83	1.58
Change Departure Time	1.00	0.67	0.67	0.67	0.50
Change in Confidence	0.50	0.25	0.50	0.25	0.25
INTERNAL BENEFITS ($/hit)	**Auto**				
(CS, direct or through time)	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
	(avg_planning_benefits_perhit_auto_arr)				
Planning Time Benefits (apply to all hits)	0.13	-0.07	0.13	-0.07	0.07
	(avg_internal_benefits_perhit_byaction_static_auto_mat)				
Change Mode	▨	▨	▨	▨	▨
Add Trip	1.00	2.00	2.00	2.00	1.00
Delete Trip	1.00	2.00	2.00	2.00	1.00
Change Destination	1.00	2.00	2.00	2.00	1.00
Change Route	1.58	1.58	1.58	1.83	1.58
Change Departure Time	1.00	0.67	1.33	0.67	0.50
Change in Confidence	0.50	0.25	0.50	0.25	0.25
INTERNAL BENEFITS ($/hit)	**Choice**				
(CS, direct or through time)	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
	(avg_planning_benefits_perhit_flex_arr)				
Planning Time Benefits (apply to all hits)	0.13	-0.07	0.13	-0.07	0.07
	(avg_internal_benefits_perhit_byaction_static_flex_mat)				
Change Mode	1.00	2.00	2.00	2.00	1.00
Add Trip	▨	▨	▨	▨	▨
Delete Trip	▨	▨	▨	▨	▨
Change Destination	▨	▨	▨	▨	▨
Change Route	▨	▨	▨	▨	▨
Change Departure Time	▨	▨	▨	▨	▨
Change in Confidence	▨	▨	▨	▨	▨

Exhibit 7-12. Summary of Internal Benefits per Hit for Static Trip Scenarios

EXTERNALITIES PER HIT: Static Information

EXTERNALITIES ($/hit)	**Transit**				
(cong., emis., other social cost)	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
	(avg_external_benefits_perhit_byaction_static_trans_mat)				
Change Mode					
Add Trip	0.00	0.00	0.00	0.00	0.00
Delete Trip	0.00	0.00	0.00	0.00	0.00
Change Destination	0.00	0.00	0.00	0.00	0.00
Change Route	0.00	0.00	0.00	0.00	0.00
Change Departure Time	0.00	0.00	0.00	0.00	0.00
Change in Confidence					

EXTERNALITIES ($/hit)	**Auto**				
(cong., emis., other social cost)	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
	(avg_external_benefits_perhit_byaction_static_auto_mat)				
Change Mode					
Add Trip	-1.47	-2.05	-2.05	-4.91	-0.80
Delete Trip	1.47	2.05	2.05	4.91	0.80
Change Destination	0.00	0.00	0.00	0.00	0.00
Change Route	0.11	0.31	0.31	0.57	0.31
Change Departure Time	0.57	0.62	0.62	1.14	0.62
Change in Confidence					

EXTERNALITIES ($/hit)	**Choice**				
(cong., emis., other social cost)	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
	(avg_external_benefits_perhit_byaction_static_flex_mat)				
Change Mode	-0.29	-0.41	-0.41	-0.98	-0.16
Add Trip					
Delete Trip					
Change Destination					
Change Route					
Change Departure Time					
Change in Confidence					

Exhibit 7-13. Summary of Externalities per Hit for Static Trip Scenarios

INTERNAL BENEFITS PER HIT: Dynamic Information

INTERNAL BENEFITS ($/hit) (CS, direct or through time)	**Transit**				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
	(avg_internal_benefits_perhit_byaction_dynamic_trans_mat)				
Change Mode	▨	▨	▨	▨	▨
Add Trip	2.00	3.00	3.00	2.00	2.00
Delete Trip	2.00	3.00	3.00	2.00	2.00
Change Destination	2.33	2.25	2.33	2.67	2.17
Change Route	1.00	0.92	0.92	0.83	0.75
Change Departure Time	2.17	1.42	2.08	2.17	1.58
Change in Confidence	0.78	0.70	0.78	0.87	0.62

INTERNAL BENEFITS ($/hit) (CS, direct or through time)	**Auto**				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
	(avg_internal_benefits_perhit_byaction_dynamic_auto_mat)				
Change Mode	▨	▨	▨	▨	▨
Add Trip	2.00	3.00	3.00	2.00	2.00
Delete Trip	2.00	3.00	3.00	2.00	2.00
Change Destination	2.00	2.00	2.00	2.00	1.83
Change Route	2.00	1.00	1.00	0.50	0.83
Change Departure Time	1.33	1.67	1.67	1.67	1.17
Change in Confidence	0.25	0.25	0.25	0.25	0.21

INTERNAL BENEFITS ($/hit) (CS, direct or through time)	**Choice**				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
	(avg_internal_benefits_perhit_byaction_dynamic_flex_mat)				
Change Mode	2.00	3.00	3.00	3.00	2.00
Add Trip	▨	▨	▨	▨	▨
Delete Trip	▨	▨	▨	▨	▨
Change Destination	▨	▨	▨	▨	▨
Change Route	▨	▨	▨	▨	▨
Change Departure Time	▨	▨	▨	▨	▨
Change in Confidence	▨	▨	▨	▨	▨

Exhibit 7-14. Summary of Internal Benefits per Hit for Dynamic Trip Scenarios

EXTERNALITIES PER HIT: Dynamic Information

EXTERNAL BENEFITS ($/hit) (cong., emis., other social cost)	**Transit**				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
	(avg_external_benefits_perhit_byaction_dynamic_trans_mat)				
Change Mode					
Add Trip	0.00	0.00	0.00	0.00	0.00
Delete Trip	0.00	0.00	0.00	0.00	0.00
Change Destination	0.00	0.00	0.00	0.00	0.00
Change Route	0.00	0.00	0.00	0.00	0.00
Change Departure Time	0.00	0.00	0.00	0.00	0.00
Change in Confidence					

EXTERNAL BENEFITS ($/hit) (cong., emis., other social cost)	**Auto**				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
	(avg_external_benefits_perhit_byaction_dynamic_auto_mat)				
Change Mode					
Add Trip	-1.47	-2.05	-2.05	-4.91	-0.80
Delete Trip	4.91	2.68	2.68	6.05	2.68
Change Destination	3.78	0.69	0.69	1.26	2.06
Change Route	3.57	0.02	0.02	0.39	1.96
Change Departure Time	3.78	0.69	0.69	1.26	2.06
Change in Confidence					

EXTERNAL BENEFITS ($/hit) (cong., emis., other social cost)	**Choice**				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
	(avg_external_benefits_perhit_byaction_dynamic_flex_mat)				
Change Mode	2.35	0.78	0.78	1.67	1.28
Add Trip					
Delete Trip					
Change Destination					
Change Route					
Change Departure Time					
Change in Confidence					

Exhibit 7-15. Summary of Externalities per Hit for Dynamic Trip Scenarios

7.3.2 Summary of Annual Aggregated Benefits

The annual benefits are based on the average daily use rate multiplied by 365, and are summarized in the following exhibits (pages 156 through 158):

- Exhibit 7-16. Summary of Annual Internal Benefits by Mode, Market Segment, and Action for Static and Dynamic Usage
- Exhibit 7-17. Summary of Annual External Benefits by Mode, Market Segment, and Action for Static and Dynamic Usage
- Exhibit 7-18. Summary of Net Benefits (Internal and External) by Mode, Market Segment, and Action for Static and Dynamic Usage

We summarize these results across mode, market segment, and action in an abbreviated summary in Table 7-2:

Total Benefits Summary from Example Analysis			
	Static	Dynamic	Total
Internal	$ 446,282	$ 1,401,643	$ 1,847,925
External	$ 69,850	$ 996,110	$ 1,065,960
Total	$ 516,132	$ 2,397,753	$ 2,913,885

Table 7-2. Abbreviated Summary of Annual Benefits from Example Project Analysis

These results are obviously biased due to the inputs we used. For example, we attributed most ATIS use to automobile commuters using dynamic information. As a result, $1.2 million in net benefits is due to this category, which accounts for over 40% of the total project benefits. In addition, we observe that the external benefits from static use are considerably lower than internal benefits. This is due our hypothetical data being based on the assumption that the static information does not lead to as much avoidance of congestion as dynamic information does. For dynamic information, the external benefits are shown to be on the same order of magnitude as internal benefits.

The sensitivity of the results to consumer surplus estimates, impact estimates, and automobile social cost parameter estimates would have to be more closely considered in an actual ATIS projects evaluation.

Another perspective for evaluating the magnitude of these benefits estimates is to look at the annual benefits for a single user of ATIS. Since many consumer acceptance studies examine willingness-to-pay for a service on a monthly or annual basis, this provides a comparable measure. Based on the estimates in the example presented in this chapter, the annual internal benefits for a single user of an ATIS service similar to that of the HPC application is $480, and the external benefits are $103. Previous ATIS studies have suggested willingness-to-pay on the order of $5 to $10 per month for call-in traveler information services (Charles River Associates Incorporated, 1996), and $5 per day or $28 per week for rental or up to $1,000 for ownership of in-vehicle navigation systems (Inman *et al.* 1995). The HPC device is similar in functionality to the in-vehicle navigation system, in terms of the rental rates for these systems. Our hypothetical data, therefore, may not be too far from these empirical estimates.

Annual Internal Benefits from all Actions ($) - STATIC

	Transit				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Action					
Change Mode	$ -	$ -	$ -	$ -	$ -
Add Trip	$ 2,482	$ -	$ 1,557	$ -	$ 1,557
Delete Trip	$ 2,482	$ -	$ 1,557	$ -	$ 1,557
Change Destination	$ 7,446	$ -	$ -	$ -	$ 2,336
Change Route	$ 15,038	$ 1,661	$ 5,013	$ 9,673	$ 2,409
Change Departure Time	$ 14,892	$ 986	$ 2,336	$ 1,643	$ 2,482
Change in Confidence	$ 5,548	$ 100	$ 4,161	$ -	$ 694
TOTAL	$ 47,888	$ 2,747	$ 14,624	$ 11,315	$ 11,035

	Auto				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Action					
Change Mode	$ -	$ -	$ -	$ -	$ -
Add Trip	$ 4,654	$ -	$ 11,680	$ -	$ 2,920
Delete Trip	$ 4,654	$ -	$ 11,680	$ -	$ 2,920
Change Destination	$ 13,961	$ -	$ -	$ -	$ 4,380
Change Route	$ 28,196	$ 12,456	$ 37,595	$ 43,526	$ 4,517
Change Departure Time	$ 27,923	$ 7,391	$ 32,120	$ 7,391	$ 4,654
Change in Confidence	$ 10,403	$ 753	$ 31,208	$ -	$ 1,300
TOTAL	$ 89,790	$ 20,600	$ 124,283	$ 50,918	$ 20,691

	Choice				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Action					
Change Mode	$ 15,513	$ 5,293	$ 23,360	$ 441	$ 7,787
Add Trip	$ -	$ -	$ -	$ -	$ -
Delete Trip	$ -	$ -	$ -	$ -	$ -
Change Destination	$ -	$ -	$ -	$ -	$ -
Change Route	$ -	$ -	$ -	$ -	$ -
Change Departure Time	$ -	$ -	$ -	$ -	$ -
Change in Confidence	$ -	$ -	$ -	$ -	$ -
TOTAL	$ 15,513	$ 5,293	$ 23,360	$ 441	$ 7,787

Action	Total Hits/Day All Actions
Change Mode	$ 52,393
Add Trip	$ 24,850
Delete Trip	$ 24,850
Change Destination	$ 28,123
Change Route	$ 160,083
Change Departure Time	$ 101,817
Change in Confidence	$ 54,166
TOTAL	$ 446,282

Annual Internal Benefits from all Actions ($) - DYNAMIC

	Transit				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Action					
Change Mode	$ -	$ -	$ -	$ -	$ -
Add Trip	$ 3,115	$ 2,141	$ 572	$ -	$ 6,035
Delete Trip	$ 3,115	$ 2,141	$ 572	$ 16,760	$ 6,035
Change Destination	$ 7,203	$ -	$ -	$ -	$ 13,043
Change Route	$ 6,619	$ 2,482	$ 767	$ 26,584	$ 9,539
Change Departure Time	$ 26,864	$ 5,913	$ 2,427	$ 109,226	$ 28,908
Change in Confidence	$ 4,015	$ 3,236	$ 1,171	$ 55,480	$ 9,977
TOTAL	$ 50,930	$ 15,914	$ 5,508	$ 208,050	$ 73,535

	Auto				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Action					
Change Mode	$ -	$ -	$ -	$ -	$ -
Add Trip	$ 5,840	$ 16,060	$ 4,289	$ -	$ 11,315
Delete Trip	$ 5,840	$ 16,060	$ 4,289	$ 75,418	$ 11,315
Change Destination	$ 11,680	$ -	$ -	$ -	$ 20,805
Change Route	$ 23,360	$ 20,440	$ 6,205	$ 67,616	$ 19,710
Change Departure Time	$ 32,120	$ 52,560	$ 14,783	$ 374,490	$ 40,515
Change in Confidence	$ 3,176	$ 7,154	$ 3,705	$ 58,254	$ 7,483
TOTAL	$ 82,016	$ 112,274	$ 33,270	$ 575,778	$ 111,143

	Choice				
	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Action					
Change Mode	$ 19,467	$ 32,120	$ 8,578	$ 12,714	$ 60,347
Add Trip	$ -	$ -	$ -	$ -	$ -
Delete Trip	$ -	$ -	$ -	$ -	$ -
Change Destination	$ -	$ -	$ -	$ -	$ -
Change Route	$ -	$ -	$ -	$ -	$ -
Change Departure Time	$ -	$ -	$ -	$ -	$ -
Change in Confidence	$ -	$ -	$ -	$ -	$ -
TOTAL	$ 19,467	$ 32,120	$ 8,578	$ 12,714	$ 60,347

Action	Total Hits/Day All Actions
Change Mode	$ 133,225
Add Trip	$ 49,366
Delete Trip	$ 141,544
Change Destination	$ 52,730
Change Route	$ 183,321
Change Departure Time	$ 687,806
Change in Confidence	$ 153,650
TOTAL	$ 1,401,643

Exhibit 7-16. Summary of Annual Internal Benefits by Mode, Market Segment, and Action for Static and Dynamic Usage

Annual Externalities from all Actions ($) - STATIC

	Transit				
Action	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Change Mode	$ -	$ -	$ -	$ -	$ -
Add Trip	$ -	$ -	$ -	$ -	$ -
Delete Trip	$ -	$ -	$ -	$ -	$ -
Change Destination	$ -	$ -	$ -	$ -	$ -
Change Route	$ -	$ -	$ -	$ -	$ -
Change Departure Time	$ -	$ -	$ -	$ -	$ -
Change in Confidence	$ -	$ -	$ -	$ -	$ -
TOTAL	$ -	$ -	$ -	$ -	$ -

	Auto				
Action	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Change Mode	$ -	$ -	$ -	$ -	$ -
Add Trip	$ (6,053)	$ -	$ (11,235)	$ -	$ (2,201)
Delete Trip	$ 6,053	$ -	$ 11,235	$ -	$ 2,201
Change Destination	$ -	$ -	$ -	$ -	$ -
Change Route	$ 1,879	$ 2,579	$ 6,833	$ 14,093	$ 854
Change Departure Time	$ 14,093	$ 7,687	$ 13,666	$ 14,093	$ 5,125
Change in Confidence	$ -	$ -	$ -	$ -	$ -
TOTAL	$ 15,972	$ 10,266	$ 20,498	$ 28,185	$ 5,979

	Choice				
Action	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Change Mode	$ (4,035)	$ (1,123)	$ (4,494)	$ (224)	$ (1,174)
Add Trip	$ -	$ -	$ -	$ -	$ -
Delete Trip	$ -	$ -	$ -	$ -	$ -
Change Destination	$ -	$ -	$ -	$ -	$ -
Change Route	$ -	$ -	$ -	$ -	$ -
Change Departure Time	$ -	$ -	$ -	$ -	$ -
Change in Confidence	$ -	$ -	$ -	$ -	$ -
TOTAL	$ (4,035)	$ (1,123)	$ (4,494)	$ (224)	$ (1,174)

Action	Total Hits/Day All Actions
Change Mode	$ (11,050)
Add Trip	$ (19,488)
Delete Trip	$ 19,488
Change Destination	$ -
Change Route	$ 26,237
Change Departure Time	$ 54,662
Change in Confidence	$ -
TOTAL	$ 69,850

Annual Externalities from all Actions ($) - DYNAMIC

	Transit				
Action	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Change Mode	$ -	$ -	$ -	$ -	$ -
Add Trip	$ -	$ -	$ -	$ -	$ -
Delete Trip	$ -	$ -	$ -	$ -	$ -
Change Destination	$ -	$ -	$ -	$ -	$ -
Change Route	$ -	$ -	$ -	$ -	$ -
Change Departure Time	$ -	$ -	$ -	$ -	$ -
Change in Confidence	$ -	$ -	$ -	$ -	$ -
TOTAL	$ -	$ -	$ -	$ -	$ -

	Auto				
Action	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Change Mode	$ -	$ -	$ -	$ -	$ -
Add Trip	$ (4,035)	$ (11,235)	$ (2,809)	$ -	$ (4,402)
Delete Trip	$ 13,430	$ 14,651	$ 3,663	$ 236,007	$ 14,651
Change Destination	$ 20,669	$ -	$ -	$ -	$ 22,548
Change Route	$ 39,087	$ 508	$ 127	$ 60,418	$ 42,845
Change Departure Time	$ 82,677	$ 22,548	$ 5,637	$ 294,536	$ 67,645
Change in Confidence	$ -	$ -	$ -	$ -	$ -
TOTAL	$ 151,828	$ 26,473	$ 6,618	$ 590,961	$ 143,287

	Choice				
Action	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Change Mode	$ 21,480	$ 8,594	$ 2,148	$ 7,228	$ 37,493
Add Trip	$ -	$ -	$ -	$ -	$ -
Delete Trip	$ -	$ -	$ -	$ -	$ -
Change Destination	$ -	$ -	$ -	$ -	$ -
Change Route	$ -	$ -	$ -	$ -	$ -
Change Departure Time	$ -	$ -	$ -	$ -	$ -
Change in Confidence	$ -	$ -	$ -	$ -	$ -
TOTAL	$ 21,480	$ 8,594	$ 2,148	$ 7,228	$ 37,493

Action	Total Hits/Day All Actions
Change Mode	$ 76,943
Add Trip	$ (22,480)
Delete Trip	$ 282,402
Change Destination	$ 43,217
Change Route	$ 142,985
Change Departure Time	$ 473,043
Change in Confidence	$ -
TOTAL	$ 996,110

Exhibit 7-17. Summary of Annual External Benefits by Mode, Market Segment, and Action for Static and Dynamic Usage

Annual Net Benefits from all Actions ($) - STATIC

	Transit				
Action	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Change Mode	$ -	$ -	$ -	$ -	$ -
Add Trip	$ 2,482	$ -	$ 1,557	$ -	$ 1,557
Delete Trip	$ 2,482	$ -	$ 1,557	$ -	$ 1,557
Change Destination	$ 7,446	$ -	$ -	$ -	$ 2,336
Change Route	$ 15,038	$ 1,661	$ 5,013	$ 9,673	$ 2,409
Change Departure Time	$ 14,892	$ 986	$ 2,336	$ 1,643	$ 2,482
Change in Confidence	$ 5,548	$ 100	$ 4,161	$ -	$ 694
TOTAL	$ 47,888	$ 2,747	$ 14,624	$ 11,315	$ 11,035

	Auto				
Action	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Change Mode	$ -	$ -	$ -	$ -	$ -
Add Trip	$ (1,399)	$ -	$ 445	$ -	$ 719
Delete Trip	$ 10,706	$ -	$ 22,915	$ -	$ 5,121
Change Destination	$ 13,961	$ -	$ -	$ -	$ 4,380
Change Route	$ 30,075	$ 15,034	$ 44,428	$ 57,619	$ 5,371
Change Departure Time	$ 42,015	$ 15,078	$ 45,786	$ 21,484	$ 9,778
Change in Confidence	$ 10,403	$ 753	$ 31,208	$ -	$ 1,300
TOTAL	$ 105,762	$ 30,865	$ 144,781	$ 79,103	$ 26,670

	Choice				
Action	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Change Mode	$ 11,477	$ 4,169	$ 18,866	$ 217	$ 6,613
Add Trip	$ -	$ -	$ -	$ -	$ -
Delete Trip	$ -	$ -	$ -	$ -	$ -
Change Destination	$ -	$ -	$ -	$ -	$ -
Change Route	$ -	$ -	$ -	$ -	$ -
Change Departure Time	$ -	$ -	$ -	$ -	$ -
Change in Confidence	$ -	$ -	$ -	$ -	$ -
TOTAL	$ 11,477	$ 4,169	$ 18,866	$ 217	$ 6,613

Action	Total Hits/Day All Actions
Change Mode	$ 41,343
Add Trip	$ 5,362
Delete Trip	$ 44,339
Change Destination	$ 28,123
Change Route	$ 186,320
Change Departure Time	$ 156,479
Change in Confidence	$ 54,166
TOTAL	$ 516,132

Annual Net Benefits from all Actions ($) - DYNAMIC

	Transit				
Action	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Change Mode	$ -	$ -	$ -	$ -	$ -
Add Trip	$ 3,115	$ 2,141	$ 572	$ -	$ 6,035
Delete Trip	$ 3,115	$ 2,141	$ 572	$ 16,760	$ 6,035
Change Destination	$ 7,203	$ -	$ -	$ -	$ 13,043
Change Route	$ 6,619	$ 2,482	$ 767	$ 26,584	$ 9,539
Change Departure Time	$ 26,864	$ 5,913	$ 2,427	$ 109,226	$ 28,908
Change in Confidence	$ 4,015	$ 3,236	$ 1,171	$ 55,480	$ 9,977
TOTAL	$ 50,930	$ 15,914	$ 5,508	$ 208,050	$ 73,535

	Auto				
Action	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Change Mode	$ -	$ -	$ -	$ -	$ -
Add Trip	$ 1,805	$ 4,825	$ 1,480	$ -	$ 6,913
Delete Trip	$ 19,270	$ 30,711	$ 7,952	$ 311,425	$ 25,966
Change Destination	$ 32,349	$ -	$ -	$ -	$ 43,353
Change Route	$ 62,447	$ 20,948	$ 6,332	$ 128,034	$ 62,555
Change Departure Time	$ 114,797	$ 75,108	$ 20,420	$ 669,026	$ 108,160
Change in Confidence	$ 3,176	$ 7,154	$ 3,705	$ 58,254	$ 7,483
TOTAL	$ 233,844	$ 138,747	$ 39,888	$ 1,166,739	$ 254,430

	Choice				
Action	Rec/Tour	Bus-Fam	Bus-Unf	Comm	S/P
Change Mode	$ 40,947	$ 40,714	$ 10,726	$ 19,942	$ 97,839
Add Trip	$ -	$ -	$ -	$ -	$ -
Delete Trip	$ -	$ -	$ -	$ -	$ -
Change Destination	$ -	$ -	$ -	$ -	$ -
Change Route	$ -	$ -	$ -	$ -	$ -
Change Departure Time	$ -	$ -	$ -	$ -	$ -
Change in Confidence	$ -	$ -	$ -	$ -	$ -
TOTAL	$ 40,947	$ 40,714	$ 10,726	$ 19,942	$ 97,839

Action	Total Hits/Day All Actions
Change Mode	$ 210,168
Add Trip	$ 26,886
Delete Trip	$ 423,946
Change Destination	$ 95,948
Change Route	$ 326,306
Change Departure Time	$ 1,160,849
Change in Confidence	$ 153,650
TOTAL	$ 2,397,753

Exhibit 7-18. Summary of Net Benefits (Internal and External) by Mode, Market Segment, and Action for Static and Dynamic Usage

7.3.3 Summary of Project Lifecycle Benefits

When evaluating a transportation project using benefit-cost analysis, the decision criteria is the net present value of benefits over the life of the project. To obtain this measure using this spreadsheet, we need to know three additional types of information:

i. Project life. We need to consider a finite time horizon for evaluating the project. For this example, we assume that the we are evaluating the project for a five-year horizon.

ii. Discount rate. This is an input in the Parameters module of the spreadsheet, and it is used to discount future benefits to the current year. For this example, we assume a 7% internal rate of return.

iii. Time-dependent variables. These are the inputs or parameters that change over the life of the project. The most obvious one is the number of users, which in the example we based on a combination of the number of HPC owners and the share of those who use the software. In this net present value benefits estimation, we will consider only the number of HPC owners. We assume a 25% growth rate in HPC owners over the five year horizon.

Based on these assumptions and using the hypothetical example from above, we get the following result:

Year	Number of HPC Owners	Number of Users	Actual Year Benefits
1	10,000	5,000	$ 2,913,885
2	12,500	6,250	$ 3,642,356
3	15,625	7,813	$ 4,552,945
4	19,531	9,766	$ 5,691,109
5	24,414	12,207	$ 7,113,959
Net present value of benefits:			$ 19,035,066

Table 7-3. Net Present Value of Benefits for Sample ATIS Project (Discount Rate=7%) (does not include ATIS infrastructure and operating costs)

There are other factors that are not considered by this analysis that are worth mentioning:

- This result is incomplete without consideration of the cost-side of the benefit-cost analysis, which was not included here.
- The rate of daily ATIS use and the share of HPC owners who use the ATIS is likely to change over the project life being considered.
- The availability of other ATIS services may affect the use of the HPC software for traveler information.
- The internal benefits may increase over time. For example, as travelers become accustomed to using ATIS and come to plan their travel schedules based on the reliability of the information, they may value the information more than they can now.
- The externalities may change. For example, the imposed time delay costs may increase as traffic volumes increase.
- Impacts of use will change. If market penetration of ATIS increases such that a large enough percentage of drivers alter behavior in response to incidents, the incremental benefit to the user for altering behavior may be diluted because of increased travel times due to congestion on alternate routes.

We can use scenario models built into the spreadsheet software to estimate benefits under various project scenarios. The same tools can also be used to test the sensitivity of results to other input parameters.

In the next section, we examine methods for actually collecting the data needed as inputs to this spreadsheet tool.

7.4 Implementing the ATIS Benefits Evaluation Tool: Data Collection Strategy

The spreadsheet tool we have presented captures, organizes, and analyzes data to estimate benefits from ATIS use. As we have seen, the analysis requires many data inputs. The inputs are not easily observable, and they cannot be obtained from just one source. We approach this issue by describing relevant sources for the data inputs, and then summarizing the data inputs for the spreadsheet analysis and linking them to a potential data source. We present both ideal and alternate sources for the data.

7.4.1 Data Collection Sources

We examine five potential sources and, where applicable, related methodologies for capturing the data needed for input to the benefits evaluation spreadsheet described in this chapter: The five sources are we consider are:

1. Customer satisfaction research
2. Traffic simulation
3. Transportation statistics (local or national)
4. Automatically collected data
5. Economics literature

The contribution of this thesis is not to advance the methodology of the fields of customer satisfaction research or traffic simulation, but rather to suggest how the results of these analyses can be used in concert with the benefits framework we present here to help us gain more knowledge about the potential for ATIS benefits.

7.4.1.1 Customer Satisfaction Studies

Customer satisfaction research refers to a broad set of methodologies that rely on traveler surveys and econometric evaluation of collected data to gain insights into the user experience with ATIS. These studies are potentially useful for providing values for data inputs related to the user experience with ATIS. These inputs include:

- Extent of use (number of hits per day)
- User characteristics (market segments, modal orientation)
- Changes in travel behavior
- Change in consumer surplus values for certain travel behaviors
- Travel time values under different conditions

Customer satisfaction subsumes three concepts to aid in its evaluation analyses: customers' revealed preferences, customers' stated preferences, and willingness to pay for ITS products and services.

Revealed preference methods rely on direct observation or user surveys to estimate user experiences with ATIS. These methods are most useful for answering the question "How did travelers respond to ATIS?" By learning about the characteristics of the travelers, the context (trip type, mode, usage) in which they used the ATIS, and the behavioral changes that result, we can directly gain the data needed to fill in the user access and traveler behavior inputs for the spreadsheet model.

The next use of customer satisfaction studies, which requires greater econometric analysis and more sophisticated survey design, is to determine the value of the information to the user. The value can be determined by measurement of Willingness-To-Pay(WTP). WTP measured via revealed preference methods involves directly asking the consumer to monetize the benefits or reveal the price they would pay for the service. Brand (1998) warns that this type of purchase behavior modeling may seriously underestimate the value of ATIS because of the immaturity of the ATIS market. In the past, the ATIS market's potential growth has been suppressed due to the lack of information infrastructure to provide depth of information and to the lack of knowledge on behalf of the travelers as to the potential value ATIS services may hold for them. The MMDI offers the opportunity to reduce these factors by providing services in an environment rich in both ITS infrastructure itself and ITS marketing that better informs the public of benefits.

An alternative to revealed preference methods for user benefits derivation is stated preference analysis. The difference between revealed and stated preference is that in revealed preference we measure value from actual changes in behavior and in stated preference we infer value by survey and analysis. A common stated preference method is the tradeoff survey. Survey respondents are asked to trade off satisfaction with ATIS attributes against various levels of dollar expenditures. This type of analysis is comparable to a simulation environment, where consumers choose among hypothetical alternatives.

The willingness-to-pay results, whether measured via stated or revealed preference surveys, are the best sources of obtaining information about such useful data as changes in consumer surplus or travel time valuation in an information-rich environment. By directly measuring value, these methods do not rely on specification of the travel utility function, which as we discussed in Chapter 5 is very complex and comprised of a number of hard to observe factors.

7.4.1.2 Traffic Simulation Studies

Traffic simulation is the ideal source for providing data on the travel-related characteristics of behavior change from ATIS. The data inputs in the spreadsheet that could come from this source include:

- Baseline trip characteristics under normal and incident conditions
- Changes in travel time (in-vehicle, in-transit, wait)
- Changes in trip length
- Changes in the probability of congested trips

By using sophisticated models of traffic flow, network path dynamics, and driver response, traffic simulation for a metropolitan area can provide us with data that is representative of average impacts for a particular city or region. Data is available at the origin-destination level as well as the regional level. If systematic differences exist among origin-destination (O-D) pairs, we may choose to modify the user access module to represent some segmentation by O-D pair.

7.4.1.3 Transportation Statistics (Local or National)

Surveys conducted by national and local government agencies to assess trends in transportation are useful for providing information about baseline trip characteristics.

Some of the data inputs obtainable from these sources include:

- Average trip length by trip purpose
- Average travel time by trip purpose and mode
- Distribution of trips by mode

In comparison to traffic simulation data, this data may be adequate for our studies because the increased precision of traffic simulation may be unnecessary based on the uncertainty of the automobile social cost parameters.

7.4.1.4 Automatically Collected Data

This is usage data collected by software used to provide ATIS. This can include web site usage data, number of messages sent to pagers or fax machines, number of incoming phone calls, number of user accesses at kiosks, or travel diaries built into in-vehicle navigation devices or HPC software. This data provides us with the necessary inputs for the project description and user access modules. For example, in the HPC study above, we needed to know number of uses per day. This is the type of information we can best collect via electronic or automatic means. Alternatively, revealed preference surveys can provide this information. If automatically collected data is available, we should compare it to the data obtained from consumer surveys. The automatically collected data may include hits that resulted in unreported (by the user via revealed preference) use of the ATIS.

7.4.1.5 Economics Literature

Economics literature includes value-of-time and automobile social cost studies references in previous chapters.

The U. S. Department of Transportation provides guidance on the use of value of time parameters for transportation benefit-cost studies (Office of the Secretary of Transportation, 1997). However, in the analysis, we require a more sophisticated and broader set of parameters to assess travel time savings based on changes in the travel conditions. Lee and Pickrell (1997) provide estimates of factors that can be used to determine changes in the value of time under different scenarios.

For the automobile social cost parameters, we rely on the work of Anderson and Mohring (1997) and Delucchi (1997) to derive *per VMT* costs of motor-vehicle use under freeflow and congested conditions.

7.4.2 Summary of Data Inputs and Sources

Table 7-4 summarizes the data collection strategy by spreadsheet module. We give a primary data source and, where applicable, a secondary data source. We have suggested this strategy for collecting data in the MMDI evaluation.

7.5 Adapting the Spreadsheet Model for Different MMDI ATIS Projects

We used the example of the handheld personal computer in showing how the spreadsheet tool and the framework can be used to estimate benefits based on information about the users and usage statistics. Ascertaining project scope and user access is different for other ATIS projects. The major differences seem to be in how we model the user access or estimate the number of uses. In this section, we consider the other categories of ATIS technologies currently under development or consideration in the MMDI and beyond.

Spreadsheet Module and Data Types	Primary Data Source	Secondary Data Source
Project Scope		
Device Owners	ATIS Service Provider	
% Using ATIS Software Application	ATIS Service Provider	
Average Number of Uses per Day	Automatically Collected Data	Customer Satisfaction Studies
User Access		
Modal Orientation of Users	Customer Satisfaction Studies	
Market Segments and Modal Orientation	Customer Satisfaction Studies	
Market Segments by Mode and Type of Information Accessed	Customer Satisfaction Studies	
Actions		
Traveler behavior by market segment, modal orientation, information use	Customer Satisfaction Studies	
Parameters		
Value of time	Economics Literature	
Automobile social costs	Economics Literature	
Discount rate	(assumed)	
Static Scenarios		
Trip characteristics under Average conditions	Traffic Simulation	Local Transportation Statistics
Mode Change to Auto vs. to Transit	Customer Satisfaction Studies	
Impact data for Change Route and Change Departure Time scenarios	Traffic Simulation	
Change in consumer surplus for change mode, add trip, delete trip, change destination and change confidence scenarios	Customer Satisfaction Studies	
Dynamic Scenarios		
Trip characteristics under Incident affected conditions	Traffic Simulation	Local Transportation Statistics
Mode Change to Auto vs. to Transit	Customer Satisfaction Studies	
Change in consumer surplus for change mode, add trip, and delete trip scenarios	Customer Satisfaction Studies	
Impact data for change destination, change route and change departure scenarios	Traffic Simulation	

Table 7-4. Data Collection Strategy by Spreadsheet Module

This section shows how we adapt the framework to other ATIS devices. Specifically, we look at changes in the user access and information use, since this may differ from one ATIS project to the next. The project information is based on descriptions for MMDI projects (Sitabkhan *et al.* 1997). A summary of MMDI projects is included in the Appendix (Table A- 3).

7.5.1 Personalized Messaging Services

We adapt the benefits evaluation framework for personalized messaging services by simplifying the level of detail required for data collection. Figure 7-1 shows these simplifications for personalized messaging services relative to the overall framework. We explain the rationale for these simplifications here.

For personalized messaging services, the main source of knowledge about the users is subscription, since that is the prerequisite of use. As a result, the user access would simply be the total number of subscribers, who can subsequently be broken down by modal orientation. This information can be determined during the subscription enrollment and registration process. For prospective projects, it can be determined based on the average modal distribution of trips in the area. Also, personalized messaging services provide information for commute-based trips only, and the information is always dynamic. In many cases, it is likely that only automobile users will be interested in the information, since transit delays are less common than road delays. This would simplify the level of information needed to evaluate benefits. The benefits evaluation process for personalized messaging services is essentially a subset of the framework for HPC's we have devised here. We can de-emphasize those elements related to static use, non-commute trips, and non-automobile use by placing "zeroes" in the appropriate cells in the spreadsheet where the share of static use, non-commute trips, or transit/flexible trips is allocated. These are in the User Access Module (see Section 7.2.2). If we have strong a priori justification as to the major source of benefits, we can also simplify the data collection process by focusing on those data that give us the most explanatory information about the likelihood of benefits.

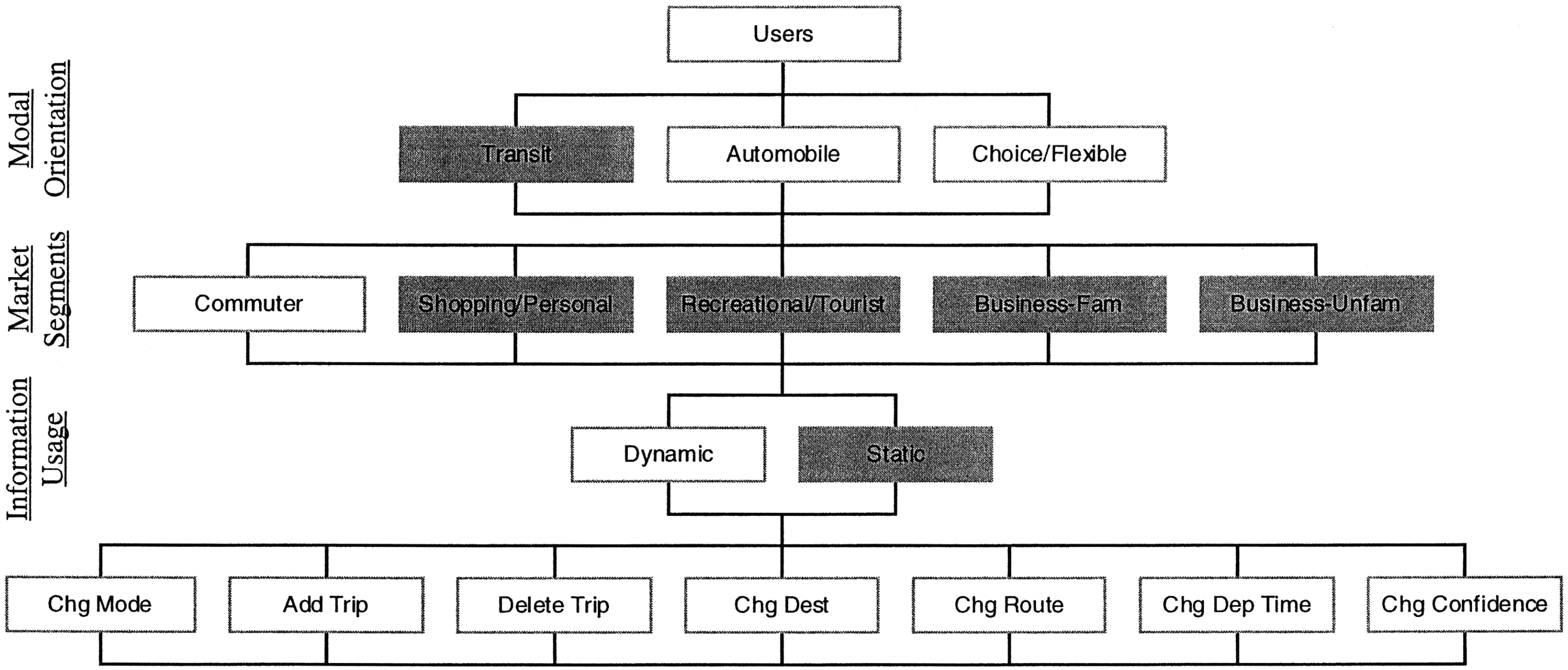


Figure 7-1. Simplifications of the ATIS Benefits Evaluation Framework for application to Personalized Messaging Services

7.5.2 Web Sites

Web sites are similar to handheld personal computers in terms of the potential breadth and depth of information they provide. We have no a priori justification for excluding any particular modal orientation or trip market segment, and the information usage (static or dynamic) is dependent on the nature of the web site. In most cases, web sites have both static and dynamic information on multiple modes.

The major difference is in modeling user access. For web sites, we may estimate the number of hits per day, and we may even be able to estimate (via automatically collected data) the distribution of hits throughout the day and the types of screens and information accessed in order to know about the set of trip scenarios being affected by the ATIS.

7.5.3 Kiosks

Kiosks are similar to websites and the HPC application in terms of information content and usage. The significant difference is the complexity of the user access model. Kiosks may have multiple locations, and the nature of the use at each location may differ. For example, a kiosk located at a transit center versus a kiosk located at a hotel may have different levels and types of use and lead to different benefits. Exhibit 7-19 shows how the user access model for kiosks can be constructed. For kiosks, we are interested in segmented the population by the location of the kiosk. This is important because kiosk projects involve free, publicly owned and operated services. We are interested in knowing how kiosk location affects the likelihood and nature of benefits.

The kiosk user access model in Exhibit 7-19 counts the number of kiosks and hits per day by location. It also has separate modal distributions by location. The market segments by mode are similar to those for the HPC model (see Exhibit 7-2), but we have additional lines in the table for each kiosk location. We could also structure the kiosk benefits summary to estimate benefits by kiosk location.

As an alternative to the more complex kiosk user access structure shown here, we could simply use a different spreadsheet for each set of kiosks, thereby eliminating the need for this complexity. However, if we want to consolidate the benefits summary for all projects in one table, we can do that using this structure. Our framework and the spreadsheet tool are flexible for either case.

7.5.4 In-Vehicle Navigation Systems

In-vehicle navigation systems (IVN's) are very similar in terms of functionality to the handheld personal computers. The additional advantage of IVN's is that many include audio route guidance in addition to the on-screen route guidance in the HPC application.

The IVN user access structure is similar to that of kiosks. The difference that instead of kiosk location, we have vehicle type. An IVN in a rental car, for example, may have different usage trends than one in a privately owned vehicle. As with the kiosk user access model, we have the option to either model each vehicle type in its own spreadsheet or have a user access model structured like the kiosk user access model shown in Exhibit 7-19. For the IVN's, this model would be modified so that instead of locations we list vehicle types.

7.5.5 Television (Broadcast and Cable)

For the television-based ATIS, the user access model is based on the number of households or travelers tuning in to either the broadcast or cable station. This may be determined by survey or television ratings. The next step is to estimate the modal orientation and market segmentation distributions of the travelers.

KIOSK USER ACCESS MODEL

Kiosk Location and Use

Kiosk Location	Number of Kiosks	Hits per Day per Kiosk	Total Hits per Location
Transit Centers	5	100	500
Public Buildings	6	100	600
Shopping Malls	8	100	800
Universities/Colleges	1	100	100
Airports	6	100	600
Hotels	9	100	900
Hospitals	1	100	100
Points of Interest	2	100	200
Employers	10	100	1000
Total	48	100	4,800

Percent of Hits by User for Each Location

Locations	**Transit** total share	**Auto** total share	**Choice** total share
Transit Centers	1.00	0.00	0.00
Public Buildings	0.45	0.50	0.05
Shopping Malls	0.50	0.50	0.00
Universities/Colleges	0.45	0.40	0.15
Airports	0.40	0.50	0.10
Hotels	0.30	0.65	0.05
Hospitals	0.50	0.50	0.00
Points of Interest	0.30	0.70	0.00
Employers	0.40	0.50	0.10

Percent of Hits by User for Each Location

	Transit or Auto Users						**Choice Users**				
Locations	Rec/Tour	Bus-Fam	Bus-Unfam	Commuter	S/P	**Locations**	Rec/Tour	Bus-Fam	Bus-Unfam	Commuter	S/P
Transit Centers	0.10	0.10	0.20	0.50	0.10	Transit Centers	0.25	0.25	0.25	0.00	0.25
Public Buildings	0.20	0.30	0.30	0.10	0.10	Public Buildings	0.20	0.30	0.30	0.10	0.10
Shopping Malls	0.20	0.00	0.00	0.00	0.80	Shopping Malls	0.20	0.00	0.00	0.00	0.80
Universities/Colleges	0.50	0.10	0.20	0.20	0.00	Universities/Colleges	0.50	0.10	0.20	0.20	0.00
Airports	0.25	0.25	0.25	0.00	0.25	Airports	0.25	0.25	0.25	0.00	0.25
Hotels	0.25	0.25	0.25	0.00	0.25	Hotels	0.25	0.25	0.25	0.00	0.25
Hospitals	0.00	0.25	0.25	0.00	0.50	Hospitals	0.00	0.25	0.25	0.00	0.50
Points of Interest	0.80	0.10	0.10	0.00	0.00	Points of Interest	0.80	0.10	0.10	0.00	0.00
Employers	0.00	0.25	0.25	0.25	0.25	Employers	0.00	0.25	0.25	0.25	0.25

Exhibit 7-19. Modifying the User Access Model for Kiosks

In Exhibit 7-20, we show how we need to modify only the terminology in the project characteristics module for the TV-based ATIS.

PROJECT NAME	
Site	Any MMDI Site
Project Descriptions	Cable or Broadcast TV ATIS
ITS Component	Regional Multimodal Traveler Information Systems
PROJECT SCOPE	

General Usage Information	
Population	10,000
% Tuning in to ATIS TV Channel	50%
Average Number of Hits per Day	1
Total Uses per Day (hits_per_day)	5,000

Exhibit 7-20. Modifying the Project Characteristics Module for Television-based ATIS

Instead of HPC owners, we have a broader measure, such as population for the metropolitan area. Instead of the share of HPC owners owning the ATIS application, we have the share of TV viewers tuning in to the ATIS channel. Finally, the average number of hits or users per day is the same type of measure, representing the average number of affected trips per user.

7.5.6 Telephone Call-In Services

Telephone call-in services may be transit or auto-based. We can track usage based on counts of incoming phone calls, and, based on the time period, we may have a higher percentage of commute-based trips being affected. The framework does not require modification, and the modes, market segments, and traveler behaviors that are considered non-applicable can be excluded as needed simply by placing zeroes in the appropriate cells.

7.5.7 Variable Message Signs

Of all the traveler information services, variable message-signs (VMS) are the most likely to have system impacts right away due to the immediate high market penetration. As a result, the framework is challenged because we model impact linkages at the trip level, instead of network impacts. Of course, there are other benefits of VMS which, like many ATIS benefits, cannot be evaluated on a systemic level. Increased confidence, considered a major source of user benefits, is better captured in the impact linkages framework. If we do choose to use this framework for VMS benefits evaluation, then we would need to know how many vehicles pass by the signs on a daily basis, and then estimate modal orientation, trip market segmentation, etc. as with other ATIS projects. The key difference is what we describe as a "hit". In this case, it is any vehicle driving by. Many will derive no value, others will exhibit one of the seven traveler behaviors we have in this framework.

The purpose of this section has been to show what kinds of changes would need to be made to the spreadsheet framework to evaluate other categories of ATIS projects, and the challenges they pose for additional data collection. Our conclusion is that we can evaluate all the existing ATIS projects with this framework and slight modifications to either the Project Characteristics or User Access modules. The framework is comprehensive in terms of behaviors, usage, modal orientation, and market segments as we know of them at this stage. In the next section, we consider how analyses based on this tool can be transferred for prospective evaluation.

7.6 Transferability for Prospective Evaluation

The key next step for ATIS evaluation is to follow through on benefit-cost analysis for the MMDI. This includes studying system impacts, customer satisfaction, and developing ATIS project cost models. These studies will provide the necessary inputs to the analytical tool developed in this thesis. After the MMDI study, the next set of challenges for ATIS benefits evaluation will be prospective project evaluation for projects in other cities, such as the 73 non-MMDI sites in the U.S.

Prospective evaluation means that the project is appraised prior to deployment. The Metropolitan Model Deployment Initiative (MMDI) is by nature a retrospective evaluation. Because of the conditions of this evaluation, there are opportunities to observe and collect information in a laboratory-type setting that would not be available when evaluating a planned project. As a result, there is a need to recognize the opportunities and limitations for transferring MMDI observations and experience to prospective evaluation of similar ATIS services elsewhere.

In developing the analytic tool for benefits evaluation, we included a broad set of inputs that are valuable to the analysis, and which allow us to transfer and apply the impacts and benefits from a retrospective evaluation for application to future or planned projects. Our analytic framework is useful because it is modular and can be adapted for different project contexts.

The inputs in our tool encompass changes in the distribution of market segments, modal orientation, information type used, magnitude of impacts, and deployment levels. In summary, our tool separates the frequency and distribution of trip scenarios from the impacts and benefits of each. As we move from retrospective to prospective evaluation, we need to account for changes in the frequency and distribution of trip scenarios and changes in the impacts related to each.

There are four major factors that determine the frequency and distribution of trip scenarios, and we list these here and discuss how each of them affects the likelihood of trip scenarios:

(1) Market Segments. Market segmentation, as we have defined them, is based on trip purpose, trip familiarity, trip flexibility, and likelihood of peak travel. We group the

outputs of our analysis by market segment, so we have a means of estimating benefits for different groups based on changes in these inputs. If market segments at a planned deployment are expected to differ from those at an MMDI project which we have analyzed using our tool, we can modify the distribution of the subgroups, and our analysis results will change to reflect the effect of the new distribution.

(2) Modal Orientation. At a new project, we may be able to predict *a priori* the share of auto, transit, and flexible trips. We could change these inputs in our user access model to correspond to the expected distribution at the new project.

(3) Information Type Used. If a proposed ATIS project is similar to an MMDI project but has different information, we can modify the information usage distribution. In our analysis, we have modeled static versus dynamic usage because of its impacts on the rationale for behavior change. In the future, we may also consider other elements of the information, and the changing traveler behaviors in response to them.

(4) Deployment Levels. The level of deployment is an explicit input in our model. We can modify this input along with the other inputs shown above in estimating the likely benefits of a future project.

As we stated above, the second set of inputs are the magnitudes of impacts from each trip scenario. These are separated from the frequency and distribution, so we can adjust these based on regional transportation data. Average trip lengths, trip times, and the share of trips under congestion may be different from one city to the next. We can adjust these values, and the benefits will be adjusted based on changes in these impacts. Our valuation parameters may be the same, or we may choose to modify them for the new city.

Finally, we have another category of information for transferability—the geographic characteristics of the region. By this we mean the transportation system characteristics, and how they may be similar from one city to the next. These are not explicitly included as inputs, but to the extent that the four cities in the MMDI (New York, Phoenix, San Antonio, Seattle) exemplify these differences, we can compare them to any of the 73 non-MMDI sites in the U.S. for which prospective evaluation is needed. Our transferability could be based on similarities between a non-MMDI site and one of the four MMDI cities, and we in the future a consistent strategy may developed for systematically relating other U.S. cities to one of the MMDI sites.

Benefits evaluation of ATIS is still in its early stages, and we are getting our first insights into full-scale deployment of integrated ITS. The lessons we learn through the MMDI and other retrospective evaluation efforts should aid in our long term ability to forecast benefits for new projects.

Chapter 8. Conclusions and Future Directions for ATIS Evaluation

In this chapter, we summarize the contributions of this thesis and present future directions for ATIS evaluation research.

8.1 Conclusions

Advanced Traveler Information Systems (ATIS) are a set of technologies that provide travelers with travel-related information that takes advantage of improvements in traffic sensing, information processing, system control, and modern communications media to provide personalized, reliable, and timely information to the service users. As ATIS projects are considered alongside other transportation investments, there is a need to be able to evaluate these projects in commensurate terms with other transportation investments. The original motivation for this research was the need for methods to evaluate ATIS benefits for projects in the Metropolitan Model Deployment Initiative (MMDI). The MMDI presents an invaluable opportunity to observe the impacts and benefits of ATIS in an ITS-rich environment. We expect the results of the MMDI evaluation study to make valuable, progressive contributions to our knowledge of ATIS. By applying a consistent evaluation framework across all of the MMDI ATIS projects, we will be able to compare projects and conduct analyses that will enhance our understanding of ATIS.

In this thesis, we have developed a framework and methods for evaluating the benefits of Advanced Traveler Information Systems (ATIS) in commensurate terms with other transportation project investments, based on the structure of a Benefit-Cost Analysis (BCA). A spreadsheet tool was developed. The tool implements these methods. We expect to use this tool to evaluate the benefits of MMDI ATIS projects.

Following is a summary of the main components of this thesis:

- First, we present a framework that shows the causal chain that results in the benefits that can be attributed to ATIS. This framework is a series of impact linkages showing the actions taken to deploy the ATIS, the effects of ATIS on traveler behavior, and the effects of traveler behavior that lead to benefits.
- Next, we develop methods for modeling the linkages between transportation system impacts and external and internal benefits. We present a framework for organizing benefits based on the user access and traveler behavior elements surrounding a single trip. We introduce the concept of the *trip scenario* to specify how we model user access, traveler behavior, impacts, and benefits at the level of the individual trip. We combine the internal and external benefits concepts with the trip scenario structure to develop a series of impact models that evaluate benefits for each scenario.
- Finally, a spreadsheet tool implements the frameworks and methods developed in this thesis to estimate annual benefits for an ATIS project. The spreadsheet tool models the impact linkages between user access, traveler behavior, system impacts, and benefits. The core of the tool are the trip scenario models. The tool includes market segmentation for evaluating ATIS usage and benefits.

The work in this thesis provides an analytical framework for answering these key questions about the evaluation of an ATIS project:

(1) **Is a given project worthwhile?** This question can be answered based on whether or not the net present value of the project, taking into consideration all discounted benefits and costs, yields a positive value that stands up to a reasonable sensitivity analysis. The spreadsheet tool estimates the net present value of benefits (which do not include project costs), and is constructed to allow sensitivity analysis based on varying input data or parameters.

(2) **Which project alternative is best?** This question can be answered by comparing net present value of an ATIS project with other projects. This allows ATIS to be considered in parallel with other investment options.

(3) **How do the benefits to the user compare to the benefits (or costs) to the rest of society?** The spreadsheet tool separately models internal and external benefits for every trip scenario resulting from ATIS use, and organizes the output to facilitate analysis.

8.2 Future Research Directions

The next frontier for ATIS evaluation is based on the premise that, in the future, ATIS will have much greater levels of market penetration and increased technological sophistication, such that the impacts and benefits go beyond those included in our analysis. The analysis in this research is based on modeling linear impact linkages. In the future, these linkages may be insufficient in representing ATIS benefits and more sophisticated system modeling techniques will need to be incorporated into the benefits evaluation.

A long term goal of ATIS is deeper market penetration and both predictive and prescriptive information that will allow the technology to be used as a congestion management tool in addition to a source of basic traveler information. In this case, ATIS is part of a much broader system, incorporating other ITS, such as traffic management tools (e.g., signal setting, ramp metering). In this interconnected system, the models and algorithms that provide route guidance for ATIS and those that are used for traffic network management will be integrated such that are used in concert to maximize throughput and efficiency. The usefulness of both ATIS and advanced traffic management systems are enhanced by this integration.

The effects of the integrated system change the evaluation needs. There are at least two issues in benefits evaluation that are consequences of this integration and that are not included in the analysis presented in this thesis. First, the impacts, which we have assumed to be marginal, may be non-marginal. The use of constant parameters for valuing trip-level changes may no longer appropriate be in this case. Second, we have the potential for significant induced demand, which affects both ATIS-equipped and non-ATIS-equipped users. Each of these have consequences for estimating benefits. Future research on evaluation of ATIS should consider how these effects can be included in a benefit-cost evaluation structure.

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Appendix

Table A- 1. Mitretek Benefits Review (Mitretek, 1997)

Project or Study Name and/or Location	**Project Description**	**Class of Benefit**	**Key Findings**
Crash Reduction Benefits			
Ramp Rollover Warning System. Washington, D.C.	Advanced traffic information system to warn commercial vehicles and other heavy vehicles of a potentially dangerous highway situation	Measured	Since 1993 implementation, there have not been any rollover accidents at any of the three sites and average truck speed has been reduced by 11 kph.
TravTek, Orlando	In-vehicle navigation device	Anecdotal	Compared to control conditions of paper maps and road signals, use of both visual and voice displays yielded lower driver workloads in each category of stress, including time stress, visual effort, and psychological stress. Users perceived increased safety.
TravTek, Orlando	In-vehicle navigation device	Predicted (traffic simulation)	Overall reduction in crash risk of up to 4% for motorists using navigation devices. Overall network results showed a neutral to slight safety improvement when diversion occurred.
Fatality Reduction Benefits			
Oklahoma	GPS receiver in emergency helicopter	Anecdotal	Crash in Muskogee County, Oklahoma, resulted in the need for medical attention. Fog that contributed to the collision would have delayed emergency response, but a helicopter equipped with a GPS receiver was able to complete the rescue
Schaumburg, Illinois	Automatic-Vehicle Location (AVL) system installed by police department	Anecdotal	AVL system has enabled dispatch of backup to officers who failed to report location information and dispatch of assistance to an incapacitated officer

Time Benefits			
Information for Motorists (INFORM) program on Long Island, New York	Integrated corridor-management system using variable message signs, ramp metering, and signal coordination	Measured	Estimates of delay savings due to motorist information reach as high as 1900 vehicle-hours for a peak period incident and 300,000 vehicle-hours fin incident related delay annually
TravTek, Orlando	In-vehicle navigation device	Measured	For unfamiliar drivers, wrong turn probability decreased by 30% and travel time decreased by 20% relative to using paper maps, while travel planning time decreased by 80%.
ADVANCE, Chicago	Dynamic route guidance	Measured	Motorists could reduce travel time by 4% under normal or recurring conditions (problems of small sample size and high standard deviation).
Pathfinder, Los Angeles	In-vehicle navigation and motorist information	Measured	Fewer travelers failing to follow their desired route.
FleetMaster, Redondo Beach and Hermosa Beach, California	Fleet management system using GPS, realt-time system for AVL installed in police vehicles	Anecdotal	Anticipated that FleetMaster system will save 25% of the time required to provide police and emergency service response to crimes and traffic incidents.
Advanced Traveler Information Kiosks Project, Atlanta, Georgia	Information kiosks	Anecdotal	92% - 98% of participants found current information on accidents, alternate routes, road closures, and traffic congestion to be useful and desirable.
Stated preference survey in Marin County, California	Testing response to alternate route information presented to regular commuters	Anecdotal	69% of commuters said they would have diverted and saved an average of 17 minutes if presented with alternate routes and travel time estimates.
Netherlands	Traffic information provided to vehicles equipped with FM sideband data receivers	Anecdotal	40% increase in route diversions

Information for Motorists (INFORM) program on Long Island, New York	Integrated corridor-management system using variable message signs, ramp metering, and signal coordination	Anecdotal	Drivers will divert from 5% to 10% of the time when passive (no recommended actions) messages are displayed and twice that when messages include recommendation to divert. Drivers will start to divert several ramps prior to an incident, resulting in an increase in ramp usage of 40% - 70%.
Surveys in Seattle, Washington and Boston, Massachusetts	Travel information survey	Anecdotal	30%-40% of travelers frequently adjust travel patterns based on travel information. Of these, about 45% change route, 45% change departure time, and 5%-10% change mode.
Architecture Program (no location given)	Influence of in-vehicle traffic information on network	Predicted (traffic simulation)	On a network experiencing periodic saturation, with congestion causing increases of up to a factor of 3 from free flow travel time, drivers with in-vehicle traffic information experience an 8%-20% advantage in travel time. As the network becomes loaded, but before congestion significantly affects travel time, the advantage to drivers with in-vehicle information is smaller. For experienced commuters, the simulation predicts and aggregate travel time benefit of 7%-12%. Benefit to longer trips is more significant in both absolute and relative terms than benefit to shorter trips. A separate simulation study predicted that pre-trip information on roadway conditions could result in a system-wide delay reduction of 21% when a capacity reducing incident occurs, other travel options are present, and pre-trip information is universally available.
Simulations based on Detroit Metropolitan Area	Effects of pre-trip route selection under incident conditions	Predicted (traffic simulation)	90% of the benefit associated with en-route guidance could be obtained by receiving route travel time information before the start of a trip. For every 1.6 km of trip length, time saved for those equipped with pre-trip route selection increased by 12

			seconds.
Throughput Benefits			
TravTek, Orlando	Simulations on dynamic route guidance using data collected in the field operational test	Predicted (traffic simulation)	Using constant average trip duration as a surrogate for maintaining level of service, a market penetration of 30% for dynamic route guidance results in the ability to handle 10% additional demand
Customer Satisfaction Benefits			
Puget Sound Help Me (PuSHMe) Mayday System, Seattle/Puget Sound	In-vehicle mayday system allowing driver to immediately send a response center a notification and location of incidents along with the need for any assistance. Voice and without voice options.	Measured	95% of those drivers equipped with voice communications felt more secure, while 70% of those without said that they were more secure with the system installed
Genesis Project, Minneapolis	Incident information via alphanumeric pagers	Measured	65% reported using the service daily, 88% used at least weekly. Users discovered over 50% of incidents using the system, versus 15% discovery relying on radio and TV. 42% chose alternate routes when they became aware of an incident.
TravTek, Orlando	In-vehicle navigation device	Measured	38% of rental users found the device helpful in finding specific destinations in unfamiliar territory; 63% of local drivers found it useful as well.
Pathfinder, Los Angeles	In-vehicle navigation and motorist information	Measured	Users perceived their trips were less stressful and that they were saving time even in situations where the time savings were insignificant. 40% increase in route diversions.

Los Angeles Smart Traveler Project	Information kiosks	Anecdotal	Number of daily accesses ranged from 20 to 100 in a 20-hour day. Most frequent request was for a freeway map (83%). Over half of accesses included requests for transit information. Positive response from upper middle class users.
TravLink, Minneapolis	PC and video text terminals displaying transit route and schedule information, including real-time transit information; Downtown information kiosks	Anecdotal	In July 1995, users logged onto the PC system 1660 times, an average of slightly more than 1 access per participant per week. One third of the accesses requested bus schedule adherence; 31% examined bus schedules. Downtown kiosks offering similar information average a total of 71 accesses per day in test period, with real-time traffic data requested more frequently than bus schedule adherence.
Rochester-Genesee Regional Transportation Authority automated transit information system	Automated phone system	Anecdotal	80% increase in calling volume
New Jersey Transit automated transit information system	Automated phone system	Anecdotal	Reduced caller wait time from an average of 85 seconds to 27 seconds and reduced calling hang-up rate from 10% to 3% while total number of callers increased.
Boston SmarTraveler	Automated phone system	Anecdotal	138% increase in usage from 1994 to 1995, due partly to partnership with local cellular telephone service provider.
TravTek, Orlando	In-vehicle navigation device	Anecdotal	User perception of safer driving

Table A- 2. Summary of Internal and External Benefit Models by Scenario Used in Benefits Evaluation Spreadsheet

Change Mode	Internal Benefits	Externalities
Static-Flex	$IB_{\Delta mode,\ flex,\ static} = \Delta CS_{\Delta mode,\ auto,\ static}$	$EX_{\Delta mode,\ flex,\ static} =$ $(\%to\ auto)(\Delta X)(\phi + p_n \pi) + (\%to\ transit)(\Delta X)(\phi + p_n \pi)$
Dynamic-Flex	$IB_{\Delta mode,\ flex,\ dynamic} = \Delta CS_{\Delta mode,\ flex,\ dynamic}$	$EX_{\Delta mode,\ flex,\ dynamic} =$ $(\%to\ auto)(X)(\phi + (p_i + \Delta p)\pi) + (\%to\ transit)(-X)(\phi + p_i \pi)$
Add Trip	Internal Benefits	Externalities
Static-Auto	$IB_{+\ trip,\ auto,\ static} = \Delta CS_{+\ trip,\ auto,\ static}$	$EX_{+\ trip,\ auto,\ static} = \Delta X(\phi + p_n \pi)$
Static-Transit	$IB_{+\ trip,\ transit,\ static} = \Delta CS_{+\ trip,\ transit,\ static}$	▨
Dynamic-Auto	$IB_{+\ trip,\ auto,\ dynamic} = \Delta CS_{+\ trip,\ auto,\ dynamic}$	$EX_{+\ trip,\ auto,\ dynamic} = \Delta X(\phi + (p_i + \Delta p)\pi)$
Dynamic-Transit	$IB_{+\ trip,\ transit,\ dynamic} = \Delta CS_{+\ trip,\ transit,\ dynamic}$	▨
Delete Trip	Internal Benefits	Externalities
Static-Auto	$IB_{-\ trip,\ auto,\ static} = \Delta CS_{-\ trip,\ auto,\ static}$	$EX_{-\ trip,\ auto,\ static} = \Delta X(\phi + p_n \pi)$
Static-Transit	$IB_{-\ trip,\ transit,\ static} = \Delta CS_{-\ trip,\ transit,\ static}$	▨
Dynamic-Auto	$IB_{-\ trip,\ auto,\ dynamic} = \Delta CS_{-\ trip,\ auto,\ dynamic}$	$EX_{-\ trip,\ auto,\ dynamic} = \Delta X(\phi + p_i \pi)$
Dynamic-Transit	$IB_{-\ trip,\ transit,\ dynamic} = \Delta CS_{-\ trip,\ transit,\ dynamic}$	▨

Change Destination	Internal Benefits	Externalities
Static-Auto	$IB_{\Delta \text{ dest, auto, static}} = \Delta CS_{\Delta \text{ dest, auto, static}}$	$EX_{\Delta \text{ dest, auto, static}} = \Delta X(\phi + p_n\pi)$
Static-Transit	$IB_{\Delta \text{ dest, transit, static}} = \Delta CS_{\Delta \text{ dest, transit, static}}$	▨
Dynamic-Auto	$IB_{\Delta \text{ dest, auto, dynamic}} = T_{IV,I}(V_{IV,S} - V_{IV,C}) + \Delta T_{IV} V_{IV,S}$	$EX_{\Delta \text{ dest, auto, dynamic}} = (X)(\Delta p)(\pi) + \Delta X (\phi + (p_i + \Delta p)(\pi))$
Dynamic-Transit	$IB_{\Delta \text{ dest, transit, dynamic}} = T_{IT,I}(V_{IT,S} - V_{IT}) + \Delta T_{IT} (V_{IT,S}) + T_{W,I}(V_{W,S} - V_W) + \Delta T_W (V_{W,S})$	▨
Change Route	Internal Benefits	Externalities
Static-Auto	$IB_{\Delta \text{ route, auto, static}} = \Delta T_{IV} (V_{IV})$	$EX_{\Delta \text{ route, auto, static}} = (X)(\Delta p)(\pi) + \Delta X (\phi + (p_n + \Delta p)(\pi))$
Static-Transit	$IB_{\Delta \text{ route, transit, static}} = \Delta T_{IT} (V_{IT}) + \Delta T_W (V_W)$	▨
Dynamic-Auto	$IB_{\Delta \text{ route, auto, dynamic}} = T_{IV,I}(V_{IV,S} - V_{IV,C}) + \Delta T_{IV,} (V_{IV,S})$	$EX_{\Delta \text{ route, auto, dynamic}} = (X)(\Delta p)(\pi) + \Delta X (\phi + (p_i + \Delta p)\pi)$
Dynamic-Transit	$IB_{\Delta \text{ route, transit, dynamic}} = T_{IT,I}(V_{IT,S} - V_{IT}) + \Delta T_{IT} (V_{IT,S}) + T_{W,I}(V_{W,S} - V_W) + \Delta T_W (V_{W,S})$	▨

Change Departure Time	Internal Benefits	Externalities
Static-Auto	$IB_{\Delta \text{ departure time, auto, static}} = T_{IV}(V_{IV,S} - V_{IV}) + \Delta T_{IV}(V_{IV,S}) + T_{SD}(V_{SD})$	$EX_{\Delta \text{ departure time, auto, static}} = (X)(\Delta p)(\pi)$
Static-Transit	$IB_{\Delta \text{ departure time, transit, static}} = \Delta T_W(V_{W,S}) + T_{SD}(V_{SD})$	▨
Dynamic-Auto	$IB_{\Delta \text{ departure time, auto, dynamic}} = T_{IV,I}(V_{IV,S} - V_{IV,C}) + \Delta T_{IV}(V_{IV,S}) + T_{SD}(V_{SD})$	$EX_{\Delta \text{ departure time, auto, dynamic}} = (X)(\Delta p)(\pi)$
Dynamic-Transit	$IB_{\Delta \text{ departure time, transit, dynamic}} = T_{IT,I}(V_{IT,S} - V_{IT}) + T_{W,I}(V_{W,S} - V_W) + \Delta T_W(V_{W,S}) + T_{SD}(V_{SD})$	▨
Change Confidence	Internal Benefits	Externalities
Static-Auto	$IB_{\Delta \text{ confidence, auto, static}} = \Delta CS_{\Delta \text{ confidence, auto, static}}$	▨
Static-Transit	$IB_{\Delta \text{ confidence, transit, static}} = \Delta CS_{\Delta \text{ confidence, transit, static}}$	▨
Dynamic-Auto	$IB_{\Delta \text{ confidence, auto, dynamic}} = (\%\text{normal})(T_{IV}(V_{IV,S} - V_{IV}) + (\%\text{incident})(T_{IV,I}(V_{IV,S} - V_{IV,C}))$	▨
Dynamic-Transit	$IB_{\Delta \text{ confidence, transit, dynamic}} = (\%\text{normal})(T_{IT,I}(V_{IT,S} - V_{IT}) + T_{W,I}(V_{W,S} - V_W) + (\%\text{incident})(T_{IT}(V_{IT,S} - V_{IT}) + T_W(V_{W,S} - V_W))$	▨

Table A- 3. ATIS Projects in the MMDI

MMDI Project Number	Project Title	Device/Medium	Usage	Information Attributes
NY-1	Personalized Traveler Information	E-mail, fax, telephone, or pager	Pre-trip	Real-time highway/arterial traffic
			Pre-trip	Real-time transit
NY-2	Multimodal Call-In Traveler Information	Telephone	Pre-trip	Real-time highway/arterial traffic
			Pre-trip	Real-time transit
NY-3	Multimodal Traveler Web Site	URL	Pre-trip	Real-time highway/arterial traffic
			Pre-trip	Real-time transit
NY-4	Transit Trip Planner Web Site	URL	Pre-trip	Static transit
			Pre-trip	Real-time transit
NY-5	Call-In Transit Trip Planner	Phone	Pre-trip	Real-time transit
NY-6	Transcom "Satin" Kiosks	Kiosk	Pre-trip	Route Guidance - Static
			Pre-trip	Route Guidance - Dynamic
			Pre-trip	Real-time transit
			Pre-trip	Real-time highway/arterial traffic
PH-9	Cable Television	Cable Television	Pre-trip	Real-time highway/arterial traffic
PH-10	Information Kiosks	Kiosk	Pre-trip	Real-time highway/arterial traffic
			Pre-trip	Real-time transit
			Pre-trip	Static transit
			Pre-trip	Other travel related information
PH-12	Fastline Handheld Personal Computer	PCD/Internet	Pre-trip	Route Guidance
			En route	Route Guidance
			Both	Real-time highway/arterial traffic
			Pre-trip	Static transit
			Both	Other travel related information

MMDI Project Number	Project Title	Device/Medium	Usage	Information Attributes
PH-13	Personalized Messaging Services	Pager, fax, e-mail, telephone	Both	Real-time highway/arterial traffic
PH-14	Traffic Data Web Pages	URL	Pre-trip	Real-time highway/arterial traffic
			Pre-trip	Real-time transit
PH-15	Transit Status Information	Variable Message Signs, Kiosks	En route	Real-time transit
SA-6	Traveler Information Kiosks	Kiosks	Pre-trip	Real-time transit
			Pre-trip	Real-time highway/arterial traffic
			Pre-trip	Trip Planning
			Pre-trip	Static transit
			Pre-trip	Other travel related information
SA-7	In-Vehicle Navigation Device	IVN	Pre-trip	Route Guidance
			En route	Route Guidance
			En route	Real-time highway/arterial traffic
			Both	Other travel related information
SA-8	Traffic Information Web Page	URL	Pre-trip	Real-time highway/arterial traffic
SE-17	Microsoft "Traffic View"	URL	Pre-trip	Trip Planning
			Pre-trip	Real-time highway/arterial traffic
SE-18	ETAK/MN/Seiko Personalized Traveler Information	Personalized messaging via various media	En route	Real-time highway/arterial traffic
			En route	Route Guidance
			Pre-trip	Real-time transit
SE-19	Fastline "Embarc" Handheld Personal Computer Software	PCD/Internet	Pre-trip	Route Guidance
			En route	Route Guidance
			Both	Real-time highway/arterial traffic
			Pre-trip	Static transit
			Both	Other travel related information

MMDI Project Number	Project Title	Device/Medium	Usage	Information Attributes
SE-20	Cable TV Traffic Channel	Cable Television	Pre-trip	Real-time highway/arterial traffic
SE-21	Washington Information Network Kiosks	Kiosks	Pre-trip	Static transit
			Pre-trip	Other travel related information
SE-22	Seattle Center Advanced Parking Information System	VMS and other media	Pre-trip	Real-time parking availability
			En route	Real-time parking availability
SE-23	King County Web Page	URL	Pre-trip	Real-time highway/arterial traffic
			Pre-trip	Static transit
			Pre-trip	Rideshare information
			Pre-trip	Real-time transit
SE-24	King County Transit Center Displays	VMS	Pre-trip	Real-time transit
SE-25	Washington State Ferry Service Web Site	URL	Pre-trip	Real-time transit
			Pre-trip	Static transit
SE-26	Enhanced WSDOT FLOW Map Web Site	URL	Pre-trip	Real-time highway/arterial traffic
SE-27	Traffic Hotline Phone	Telephone	Pre-trip	Real-time highway/arterial traffic
SE-28	Metro Transit RiderLink Web Site	URL	Pre-trip	Rideshare information