Technical Report Documentation Page

1. Report No. FHWA/TX-07/0-5079-1	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle Use of Traveler Information to Improve Texas Transportation Network Operations in the Context of Toll Roads	5. Report Date October 2006 6. Performing Organization Code
7. Author(s) C. Michael Walton, Khali Persad, Zhong Wang	8. Performing Organization Report No. 0-5079-1
9. Performing Organization Name and Address Center for Transportation Research The University of Texas at Austin 3208 Red River, Suite 200 Austin, TX 78705-2650	10. Work Unit No. (TRAIS) 11. Contract or Grant No. 0-5079
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, TX 78763-5080	13. Type of Report and Period Covered Project Summary Report September 2004–August 2006 14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

16. Abstract

To repay bond debt for new toll roads, investors will depend on toll revenue, an uncertain source. Studies have found that traffic on toll roads is initially low, and grows slowly over time as motorists become aware of the time savings and other benefits of a toll road. Given this situation, this study was initiated by TxDOT to investigate the potential of using Advanced Traveler Information Systems (ATIS) to enhance the operations of both tolled and non-tolled roads.

Enhanced diversion of traffic to toll roads would have two benefits: increase toll road usage, and reduce congestion on non-tolled roads. Evaluation of the dual benefits is the primary objective and the essence of this study. The research team first synthesized the state-of-the-art in ATIS implementations. Then a commuter survey was conducted in Austin, Texas to examine commuter's travel patterns, preferences and requirements on traveler information, and attitude toward toll roads and ATIS implementations. Next, based on the survey results, a simulation case study was conducted on the transportation network of Austin, Texas using DYNASMART-P model. Finally, ATIS benefit and cost analysis, implementation issues, technologies, funding opportunities, and potential business models were investigated. It was found that the impact of traveler information on commuter's route switching and toll road choice is positive. The simulation results indicate that providing traveler information could significantly increase toll road (SH 130) usage and toll revenue. As a result of a portion of traffic diverting to toll road, the traffic operations on the non-tolled alternative route were improved. Deploying ATIS can be a very promising method to increase toll revenue and relieve traffic congestions on the non-tolled alternative route.

17. Key Words Advanced traveler information systems; ATIS; Travel behavior; Toll roads; Route choice; Revenues; Simulation; Value of time, DYNASMART.	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161; www.ntis.gov.

19. Security Classif. (of report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages 151	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Use of Traveler Information to Improve Texas Transportation Network Operations in the Context of Toll Roads

C. Michael Walton
Khali Persad
Zhong Wang

CTR Technical Report:	0-5079-1
Report Date:	October 2006
Project:	0-5079
Project Title:	Use of Traveler Information to Enhance Toll Road Operations
Sponsoring Agency:	Texas Department of Transportation
Performing Agency:	Center for Transportation Research at The University of Texas at Austin

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

Center for Transportation Research
The University of Texas at Austin
3208 Red River
Austin, TX 78705

www.utexas.edu/research/ctr

Printed in the United States of America

Disclaimers

Author's Disclaimer: The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation.

Patent Disclaimer: There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine manufacture, design or composition of matter, or any new useful improvement thereof, or any variety of plant, which is or may be patentable under the patent laws of the United States of America or any foreign country.

Engineering Disclaimer

NOT INTENDED FOR CONSTRUCTION, BIDDING, OR PERMIT PURPOSES.

Project Engineer: C. Michael Walton
Professional Engineer License State and Number: Texas No. 46293
P. E. Designation: Research Supervisor

Acknowledgments

This research is funded by TxDOT under research project number 0-5079. The authors would like to acknowledge TxDOT for their support of this research effort. Additionally, the authors are grateful to Robert Daigh, the program coordinator, and Frank Bushong, the project director. Also, the authors want to thank the Austin Chamber of Commerce for their generous help with the survey and the Capitol Area Metropolitan Planning Organization for their generous help with Austin transportation network and travel demand data.

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1 Background and Significance of Work

The primary strategy of the Texas Department of Transportation (TxDOT) for adding capacity to the Texas transportation network is to support the development of toll roads. Instead of waiting for gas tax revenues to accumulate, the department can use toll financing to build projects more quickly, and thus relieve congestion sooner. For example, SH 130 Toll Road, a relief route for IH-35 in Central Texas, will be completed in 2007 compared to around 2020 under traditional financing.

However, to repay bond debt for new toll roads, investors will depend on toll revenue, an uncertain source. Traffic on toll roads is initially low, and grows slowly over time as motorists become aware of the time savings and other benefits of a toll road. Persad et al. (2004) have shown that toll roads generally do not earn enough revenue in the first 15-25 years to cover all expenses.

There is anecdotal evidence that toll road prospects can be enhanced if motorists receive timely information about congestion in the region. For example, traffic growth on the tolled Melbourne City Link in Australia has been partially attributed to aggressive provision of information about delays on competing routes.

Enhanced diversion of traffic to toll roads would have two benefits: increase toll collections, and reduce congestion on non-tolled routes. The first benefit would lessen the need for state subsidy of toll projects, but it is the second benefit that may be of greater importance to TxDOT. Better utilization of the added capacity provided by toll roads would allow the public to realize the true purposes of supporting them: namely, greater mobility, improved safety, and reduced pollution for the entire system.

Evaluation of the dual potential of traveler information in the toll road context is the essence of this research idea as originally proposed by The University of Texas at Austin's Center for Transportation Research (CTR) team. The research addresses two TxDOT goals: relieving congestion on the existing system through innovative techniques, and supporting the addition of new capacity to meet growing transportation demand. Working from a clear understanding of TxDOT needs and the necessity of implementable products, the CTR team has conducted research to address the following four issues:

- What information would help users choose a toll road
- Potential increase in toll road share of traffic
- Operational effects on the non-tolled network
- Technical and financial considerations for deployment

In addition, the CTR team evaluated the potential of newer technologies to deploy travel information to likely toll road users. An implementation framework and potential business models were developed for ATIS deployments.

1.2 Research Questions

The following is a brief review of the state of practice in the four thrust areas identified by CTR in the research proposal, with discussion of the questions to be addressed by this project.

1. What information would help users choose a toll road?

Advanced Traffic Information Systems (ATIS) are "systems that acquire, analyze, communicate, and present information to assist surface transportation travelers in moving from trip origin to trip destination" (ITS America definition). Wolinetz et al. (2001) identified six concerns of commuters:

- Uncertainty of trip time.
- How to get information.
- How reliable is the information.
- How up-to-date is the information.
- Relevance to driver's situation—location, destination, trip purpose, etc.
- Affordability of the information.

Driver decisions based on information

There is ample evidence that travel information can change travel behavior. Yim et al. (1997) reported that 75% of commuters surveyed in San Francisco Bay Area listen to traffic information on the radio, and 50% of them change their travel behavior accordingly. Unexpected delays increase the propensity to change route. Khattak et al. (1999) found that with travel information, 17% of respondents in the Bay Area change routes while another 20% change at least two decisions among departure time, route, and mode.

A survey in the Seattle region (Mehndiratta et al. 2000) found that among the en-route travel information users, 34% change part of their routes while 22% change their routes completely. In Texas, a TTI study of 15 commuters in Houston who had access to travel time and incident information found that 8 changed trip patterns, and 5 changed routes (Balke et al. 1995). A better sample size of Texas commuters is needed to draw meaningful conclusions.

Information content and format

Travel information can be categorized as pre-trip or en-route. En-route information is preferred. Abdel-Aty et al. (1996) found that 37% of those surveyed in the Los Angeles area use pre-trip travel information and 51% listen to en-route information. Wolinetz et al. (2001) found that 78% of commuters want regular updates on the existence of traffic problems and expected delay. Kim et al. (1999) conducted a survey of commuters in Sydney, Australia, and found that information on accidents, traffic delays, and work zones are highest in importance (Table 1.1).

Table 1.1: Traffic information desired by commuters in Sydney, Australia
[Summarized from Kim (1999)]

Importance of types of information	**% Agree/Strongly agree**	**% Neutral**
Accidents	85	11
Traffic	77	14
Work zones	68	15
Alternative routes	49	34
Weather	49	29
Desired improvements	**% Agree/Strongly agree**	**% Neutral**
Estimated time to clear incident	77	9
Alternative routes	69	11
Estimated delay	51	14

Preferences on information format vary according to familiarity with the road network. Yang et al. (1998) studied subjects in a driving simulator, and found that for a familiar network, drivers' order of preference was audio only, combined audio/visual, then visual only. For unfamiliar territory, their preference was combined audio/visual, visual only, then audio only.

Current ATIS efforts

Many versions of ATIS are in development or trial, most telephone- or internet-based. TravInfo disseminates real-time traffic information and multimodal options to San Francisco Bay Area travelers via phone and internet. SmartTrek is being deployed in Seattle. ADVANCE, FAST-TRAC, and SmarTraveler (Boston) are also in use. Private initiatives include Pathfinder, which displays maps of area highway conditions, and TravTek, which provides "yellow pages" of area services. ITS America has established a National ITS Program Plan.

Several TxDOT districts have ATIS efforts underway. Houston's TranStar center is a partnership of TxDOT, Harris County Metro, the City of Houston, and Harris County. San Antonio's TransGuide center combines the efforts of TxDOT, City of San Antonio (police, fire and EMS), and VIA metropolitan transit. Newer centers include Fort Worth's TransVision center, and Austin's CTECC. Most of the centers monitor freeway operations, but Houston is planning to add arterial data.

2. Potential increase in toll road share of traffic

The premise of this research proposal is that commuters would be willing to pay a toll in exchange for travel information. When a driver is faced with a choice between a tolled route and a non-tolled route, the toll road is normally less attractive because of the obvious extra cost. However, in many situations, the toll road can actually save users time and money. In the literature search, no studies were found on willingness to pay a toll when provided with information, so the following is a review of the potential markets for information in the toll road context.

Who seeks roadway information?

Individuals who experience poor trip time reliability and longer trip times are more likely to seek information. Wolinetz et al. (2001) found that they are likely to be working, frequently experience congestion, have long commutes, and own a cell phone. Women are more likely than men to seek information. Radio information en route is more likely to influence trip changes than pre-planning information from TV or phone. Mehndiratta et al. (2000) categorize traffic information users as control freaks, web heads and trip planners. Deployment techniques and use rates are likely to be different for each group.

Value of information

Some commuters place a high value on traffic information. In 1995, Ng et al. (1995) found that U.S. drivers were willing to pay $227-$336 for an in-vehicle ATIS. Wolinetz et al. (2001) found that 73% of those who seek traffic information are willing to pay for it, at an average rate of $3.84 per month or $0.74 per use. New Yorkers are willing to pay more: 78% would pay a median $11/month. Women, those with higher income, and older people indicate greater willingness to pay.

Potential toll market

Supernak et al. (2002) in a study comparing non-toll lane users of IH-15 in San Diego, California, to toll lane users, found that the latter were:

- More highly educated
- From high-income households
- More likely to be 35-54 year old and less likely to be 65 or older
- More likely to be middle-aged women
- Belonged to households with two vehicles
- More likely to be homeowners

Similar studies are needed for Texas to identify the potential information/toll market in an area.

Information and the toll route choice

The important factors that affect drivers' en-route diversion behavior are travel time on current and alternative routes, awareness of congestion levels, and trip purpose (Hall 1999). Among these attributes, travel time is considered most important. In some studies, researchers proposed a notion of "anticipated travel time" because of the subjectivity of the travel time on which driver’s choice is based (Fujii and Kitamura 2000). These studies suggest that travel information will influence drivers’ judgment on anticipated travel time and finally influence drivers’ route choice. However, the location at which the “switch decision” is made when provided with information has not been studied.

Current popular route choice models can be categorized into two types: deterministic models and stochastic models. The deterministic model is the well-known Shortest-Path Model, which assumes that all drivers choose the least-cost route. The stochastic models include logit and probit models. Both assume that there is a probability of choice of every feasible route determined by route and driver attributes. Compared to the non-tolled road, the toll road basically has an exogenous cost - the toll plus effort to divert. Therefore, route choice models can be directly applied to the tolled/non-tolled route choice problem.

3. Operational effects on the non-tolled network

Research is relatively sparse regarding the impact information has on system operation. According to the ITS Performance and Benefits Study conducted by Lockheed Martin Federal Systems (1996), ATIS shows significant benefits in increasing transportation system efficiency and improving mobility.

Potential impacts

Wunderlich et al. (2000) examined the impact of integrating arterial data into freeway ATIS while considering interactions at regional and corridor levels. Estimated benefits include 0.2% increase in vehicle throughput, 0.4% increase in vehicle miles traveled, 7% reduction in vehicle-hours of delay, 2.7% decrease in number of stops, and 2.1% reduction in travel time variation. Modeling results for San Antonio, Texas (USDOT 2001) indicate a 5.4 % reduction of travel time for internet travel information users.

Techniques for assessing impacts

Due to the dynamic characteristics of traffic conditions and traveler behavior, dynamic (time-dependent) network equilibrium models are best suited to evaluate the impacts and benefits of ITS. One such program is DYNASMART, developed by CTR under contract with FHWA. The newest version is DYNASMART-P Version 0.930.8, which integrates traffic flow models, behavioral rules, and *information supply strategies* into a simulation-assignment framework.

DYNASMART-P is capable of modeling the evolution of traffic flows in a traffic network that result from the travel decisions of individual travelers. It overcomes many known limitations of traditional static traffic assignment models used in current practice. Features include (Mahmassani et al. 2004):

- Detailed representation of traffic networks with different link types such as freeways, highways, and arterial networks. Micro-simulation of individual trip-making decisions, particularly route choice
- Representation of multiple vehicle types in terms of operational performance (e.g. trucks, buses, passenger cars)
- Representation of traffic processes at signalized and non-signalized junctions, under a variety of operational controls
- Detailed output statistics at both the aggregate and the disaggregate levels

For example, DYNASMART-P produces the various traffic characteristics over time of each link in the network such as volume, speeds, densities, queues, etc. Statistics such as average travel times, average stopped times, and the overall number of vehicles in the network are also given at varying levels of aggregation. DYNASMART-P has a Graphical User Interface (GUI) that allows users to easily change inputs. It also allows users to view input and output files, the different statistics produced, and simulation results.

4. Technical and financial considerations

While the potential of ATIS to divert traffic has been demonstrated, its application in the toll road context has not been researched. Specifically, technical and financial issues need to be addressed.

Message design

In designing traveler information messages, human information processing ability must be taken into account (Yang 2001). Driver decision-making depends on the sensory mode in which the information is acquired, amount, and frequency of repetition, in relation to external conditions. Working memory can handle no more than 7+/-2 chunks, so information has to be presented in "bites." This is why traffic signs have to be repeated to allow drivers to absorb the message before they are ready to act on it.

Driver distraction is a concern. Visual and audio attention can be shared, since attention to the road and traffic is mostly visual, drivers can comfortably handle audio input, e.g., music or conversation. However, audio/audio sharing (listening to the radio and to a passenger) or visual/visual sharing (reading a map while driving) is not as efficient, resulting in overload or distraction. Message design is a key component of efficient information provision.

Deployment technology

Current deployment technologies include internet, telephone, and roadside-based systems. While a number of positive outcomes have been observed from the installation of roadside variable message signs (VMS), there are potential shortcomings as well. Once constructed, the technology is not nimble to advances. The infrastructure is static and expensive, and impact is limited to a small region around the sign. The amount of information that can be provided is very limited. In fact, many drivers never get the whole message unless they are already in congestion. Location and spacing guidelines for VMS are desirable.

Internet and telephone-based ATIS have shortcomings. Internet-based systems are primarily for pre-trip planning, but users may not have access to information that is relevant to their trip, or the information may be stale by the time the trip is made. Telephone-based systems have similar weaknesses, plus requiring the user to know whom to call. Phone use also requires some "visioning" while talking, which is the reason why phone use impairs driver performance. Many states have moved to ban cell phone use while driving.

In addition to evaluating the requirements for deploying current technologies, the research team proposes to review newer technologies under development in the national Intelligent Vehicle Infrastructure (IVI) initiative. Push technology may be more successful than demand-based systems because people prefer to be passive users rather than having to act to receive information. For example, a vehicle positioning system (VPS) on-board unit uses an autonomous positioning system such as a GPS to locate itself within a charge area or network, and information customized for location is fed to the unit (Figure 1.2).

Figure 1.2: OnStar Navigation System

One possibility being considered is feeding traveler information customized for vehicle location to in-vehicle audio and video systems. For example, if the user sets it for audio, it would briefly "over-talk" current music or commercial radio, refreshed as frequently as desired. If set to combined audio-video, it would temporarily "over-ride" current displays. In many European countries car radios are programmed to be overridden by emergency messages.

Possible advantages of this idea are that it would be intermittent with preferred in-vehicle entertainment, and would not involve significant new infrastructure. This idea could have other applications currently being handled by roadside VMS, such as Amber Alert and weather emergencies. This and other innovative ideas for "pushing" travel information will be explored in this project. Safety will be an important consideration.

Cost and benefits of deployment

The cost and returns of deploying traveler information must be evaluated. If deployed to in-vehicle systems, set up costs will be minimal. If deployed via roadside VMS, the location and frequency of such signs must be determined. Broadcasting the information appears to be well within the capabilities of existing traffic management centers, but this issue will be considered. It is anticipated that the cost should be no more than that of sending messages to VMS. If the costs are relatively low, they can be masked in a toll tag fee.

The returns will be primarily the increase in toll revenues. This estimate will be based on the increased traffic on the toll road, and resulting increase in toll revenue. In fact, if this concept turns out to have a high benefit /cost ratio, it may be worthwhile to give away toll tags as an inducement. The benefits of reduced congestion on the non-tolled system will also be evaluated. While congestion relief benefits may not translate directly into revenues, they can be estimated to justify funding for deployment.

Funding and implementation

FHWA has funded field operational tests to determine contribution of an ATIS deployment/technology to ITS America National Program Plan. ATIS deployment trials, called metropolitan model deployment initiatives, have been conducted in Seattle, Phoenix, San Antonio, and New York since 1996. These projects comprise a range of data collection and sharing technologies, incremental improvements to existing incident management capabilities, and enhancements to existing ATIS offered in a region (Wunderlich 2000).

All sources of funding must be considered if providing traveler information to likely toll road users is found to have high payback. Even toll road developers may be willing to fund it if the potential improvement in toll revenues is greater than the cost.

Conclusion

Modeling of route choice behavior under information will permit operational-level assessments of toll road and non-tolled system operations in Texas. Together with tasks related to identifying user requirements by surveys and a robust case study, results from these endeavors will permit a powerful set of recommendations. These will provide a careful and comprehensive set of tools and recommendations for TxDOT on the use of traveler information to enhance toll road operations in Texas.

1.3 Research Approach

The essence of this research project is to evaluate the potential of traveler information to divert traffic to toll roads and thus relieve congestion in the non-tolled network. The anticipated products have addressed two issues: system impacts, and deployment feasibility. Table 1.2 illustrates the research team's understanding of TxDOT's needs and desired products for this project, along with the research conducted.

Table 1.2: Research Tasks as the Bridge between TxDOT Needs and Outcomes

TxDOT Needs	Research Conducted	Delivered Products
Information that would help users choose a toll road	- Synthesize state-of-the art - Analyze potential users, types of information desired, possible sources, delivery technology	- Early recommendations on message design and deployment
Potential increase in toll road share of traffic	- Survey travelers to determine effect of information on route choice	-Likely changes in toll road usage and resulting revenue
Operational effects on the non-tolled network	- Conduct case study and demonstration for selected network	-Improvements in throughput, speeds, travel time, incidents, air quality for selected region
Technical and financial considerations	- Analyze technology, cost, potential sources of funding, implementation issues	-Deployment technology, costs, funding, and implementation plan.

In proposing this idea for TxDOT research, CTR had envisioned a two-pronged approach that would produce original research: capture Texas preferences regarding ITS in the toll road context, and quantify the impacts on networks. Tools for measuring the effect of ITS on toll road operations were carefully selected, and the research was conducted through comprehensive data collection, analysis, and engineering considerations.

In the first stage of this research, early recommendations were provided to the TxDOT panel on user requirements in terms of message design and deployment. The recommendations were developed through a rapid review and synthesis of the state-of-the-art in travel information provision. The literature review conducted for the *Background and Significance* discussion earlier found that there have been no studies in Texas of willingness to pay for travel information. To examine how the use of traveler information would alter commuter travel behavior, a survey of commuters was conducted to determine the effect of information on travelers' route choice, including toll roads. The survey area is limited to the greater Austin, Texas, metropolitan area and the target population is commuters who travel in and out of this area. The survey results were then used in a dynamic traffic assignment simulation to estimate traffic flows and potential toll revenue. The timing of this study is very appropriate considering that 67 miles of toll roads are slated to begin operation in the Austin area in late 2007. The simulation case study of the Austin network was conducted based on the commuter survey to assist in assessing diversion potential of traveler information, and impacts on the non-tolled network. In this study, the robust case study of the Austin area also assisted in developing guidelines and recommendations for deployment of traveler information systems. Finally in this research, the implementation issues and financial considerations were investigated for traveler information system deployments.

1.4 Summary of Research Activities

To accomplish the project objectives in a comprehensive manner, the research team completed the following seven tasks in a two-year schedule.

Task 1. Leverage industry expertise

The objective of this task was to integrate TxDOT efforts with state-of-the-art advances in the ITS arena and the toll-road industry. Experts from government agencies, the industry, and universities were contacted as necessary. Valuable data, insight and perspective on national and international ITS and tolling developments were obtained for the benefit of TxDOT.

Task 2. Synthesize state-of-the-art in travel information deployment

The objective of this task was to integrate CTR's considerable in-house knowledge in the areas of travel information, traffic modeling, and toll road operation with input from the expert panel to generate an early set of recommendations for the TxDOT panel. The research team reviewed plenty of literature and developed an annotated bibliography, covering technology for providing traveler information (both roadside and in-vehicle) and coming trends in telematics, e.g., navigations systems, satellite radio, dynamic messaging, etc. Current developments in message design and delivery, as well as the effects of traffic re-distribution on the non-tolled network, were considered. The results were synthesized into early recommendations on message design and deployment technology.

Task 3. Survey travelers to determine effect of information on route choice

The objective of this task was to identify the potential market for information users and likely toll road diversion factors. This task was done in conjunction with Task 4 with a survey-based methodology. To conduct the commuter survey, a focus group was used to develop a "straw man" survey questionnaire, followed by a traveler survey in the Austin area, which is considered a technology lead adopter area. Survey questions include: demographic information (e.g., working mothers, truckers, etc.), frequency of commute, kinds of information they desire (e.g., congestion ahead, expected delay, alternate routes), technology savvy, preferred deployment technology, likelihood of paying a toll based on information, amount of toll, etc.

Based on the analysis of survey results, likely changes in toll road usage and resulting revenue increases were estimated.

Task 4. Analyze potential users, types of information desired, possible sources, delivery technology

The objective of this task is to convert the information developed in Tasks 1-3 into a synthesis of user requirements using the analytic approach. The types of information that motorists want/seek, including timing, location/ frequency in relation to trip length and routing decisions, were analyzed. Message design and format were scoped. Information sources, processing requirements, and delivery technology were assessed. This task was conducted in conjunction with Task 3.

Task 5. Conduct case study and demonstration for selected network

The objective of this task was to analyze the impacts of the proposed system on a real network. A case study was conduced in the Austin area (IH 35 corridor/SH 130/SH 45). The timing of this case study is very appropriate, since SH 130 is likely to open in late 2007. The researchers reviewed modeling techniques and tools, including their flexibility for analyzing the effects of information. Then the CTR team coded the SH 130 and SH 45 segments into the Austin network and simulated the traffic volumes, travel speeds, impacts on safety, air quality, etc., with and without information. The results were translated into an estimation of benefits to both tolled and non-tolled system.

Task 6. Analyze technology, cost, potential sources of funding, implementation issues

The objective of this task was to analyze the feasibility of the proposed system, and to develop a plan for implementation. Tasks 3 and 5 had provided an analysis of the benefits of the system. This task examined the cost and implementation needs and included a review of alternatives, and the cost of installing infrastructure and delivering information. In the final portion of this research task, the CTR team identified potential sources of funding and implementation issues, and developed an implementation plan.

1.5 Organization of Report

The remainder of this report is organized as follows: Chapter 2 presents a synthesis of state-of-the-art in traveler information implementations. Early recommendations are made based on the literature review. Chapter 3 presents the results and findings of a commuter survey conducted in Austin, Texas. Commuter’s travel patterns, preferences and requirements on traveler information, and their attitudes toward toll road and traveler information system are examined and presented. Chapter 4 presents a simulation case study using DYNASMART-P model to examine the impact of traveler information on traffic operations of toll roads and non-tolled network. Chapter 5 describes the research efforts and findings in ATIS benefit and cost analysis, implementation issues, technologies, funding opportunities, and potential business models. Finally, Chapter 6 summarizes the important findings, conclusions, and recommendations from this study.

2. Literature Review

2.1 Introduction

Traveler information systems have the potential to mitigate congestion in the road network. Polydoropoulou et al. (1996) found that information acquisition influences en-route diversion. Route switching can benefit a system of tolled and non-tolled roads by increasing the use of toll roads and relieving congestion on non-tolled routes. Khattak et al. (1999) found that the largest stated propensity to divert is obtained when the users get real-time information about traffic conditions on alternate routes. That study did not address how propensity to divert would change if the alternate route was a toll road. In a simulation exercise, Sanhouri et al. (1994) found that information always helps to reduce total travel costs although toll costs (revenues) may increase. In effect, traveler information can also increase toll revenues.

2.2 State-of-the-Art in ATIS Implementations

2.2.1 Benefits of Traveler Information

There is a significant amount of research verifying that traveler information could affect traffic conditions on roads and bring benefits to drivers. Following a nationwide ITS evaluation and field test, Lockheed Martin Federal Systems (1996) reviewed the results and confirmed that ATIS could generate significant benefits by increasing transportation system efficiency and improving mobility. Other potential benefits include reduced fuel and environmental costs, improved safety, and a viable ITS market. Table 2.1 shows a summary of the level of those benefits possible from specific ATIS market packages (Lockheed Martin, 1996).

Table 2.1: Benefits of Market Packages for Achieving ITS System Goals (Lockheed Martin, 1996)

Market Packages		Increase Transportation System Efficiency	Improve Mobility	Reduce Fuel and Environmental Cost	Improve Safety	Create an Environment for ITS Market
ATIS	Broadcast Traveler Info	*	**	*		***
	Interactive Traveler Info	**	***	*		***
	Autonomous Route Guidance	**	***			***
	Dynamic Route Guidance	**	***	*	*	***
	ISP-based Route Guidance	**	***	*	*	***
	Integrated Transportation Mgmt/Route Guidance	***	***	**	*	**

Key: * = low benefits, ** = moderate benefit, *** = high benefit

Table 2.2 is a summary of results and findings on ATIS benefits from various sources

Table 2.2: Documented ATIS Benefits

Study	Results/Findings
Sanhouri et al., 1994	Macroscopic simulation was used to assess an integrated driver information and congestion pricing system. It was found that information always helps to reduce the total travel costs although the toll costs may increase (toll revenue increase).
Balke et al. 1995	A TTI study of 15 commuters in Houston who had access to travel time and incident information found that 8 changed trip patterns, and 5 changed routes.
Carter, et al., 2000	Over a one-year period, a traveler using an in-vehicle navigation device could experience an 8.1% reduction in delay in the San Antonio area.
Wunderlich et al., 2000	Integrating arterial data into freeway ATIS may provide a 0.2% increase in vehicle throughput, 0.4% increase in VMT, 7% reduction in vehicle-hours of delay, 2.7% decrease in number of stops, and 2.1% reduction in travel time variation.
USDOT, 2001	Internet traveler information users saved 5.4% of travel time in San Antonio area.
Toppen et al., 2002	ATIS allows unfamiliar drivers to predict trip time with greater confidence and can significantly improve travel time reliability. ATIS users save about 5 minutes of total travel expenditure compared to non ATIS users, which is a 10% improvement.
Shah et al., 2003	ATIS users experienced a 56% reduction in early arrivals and a 52% reduction in late arrivals compared to nonusers. About 40% of OD pairs in the Washington, D.C. region could get an annual benefit more than 60 dollars (ATIS subscription fee) with 200 trips. The ATIS is beneficial from 7AM to 6:30PM.

The benefits derived by drivers depend on both the level of information and the level of congestion in the system. For example, in a simulation study conducted by Levinson (2003), it was found that informed drivers consistently have lower travel time than uninformed drivers and their highest gains in travel time come when incidents are most severe. It was also found that the amount of time savings is greatest when traffic flows average 95% of capacities. When the traffic flows exceed capacity, the time savings from ATIS drops precipitously. At under- capacity levels (50% and 67% for instance) the value of information is little. In the incident scenario, the simulation results indicate that information is net beneficial: the more informed drivers, the lower is total travel time. The time saving percentage peaks when incidents reduce capacity by 33% to 50%. An interesting result is that uninformed drivers will be best served if others are informed.

With ATIS, unfamiliar drivers can predict their trip time with greater confidence so that they could waste less time by avoiding arriving at their destination too early during the AM peak and PM peak hours. As seen in several studies, pre-trip ATIS can clearly help commuters to improve departure time choice (Shah et al. 2003). Some evidence shows that in an unfamiliar network, drivers tend to change departure time more frequently than to change routes (Toppen et al. 2002). However, ATIS cannot perfectly forecast travel time and eliminate uncertainty.

There is also anecdotal evidence that toll road prospects can be enhanced if motorists receive timely information about congestion in the region. The Melbourne City Link in Australia has had greater traffic growth than projected with travel information provided. Motorists on SR 91 in California receive congestion information via variable message signs and have the opportunity to use the tolled SR 91 Express Lanes. However, relatively high levels of congestion throughout the network may make alternate routes unattractive (Shah et al. 2003).

It is clear that ATIS can provide significant benefits to motorists. However, there are also potential drawbacks. According to Polydoropoulou et al. (1996): "Traveler information is a double-edged sword in congestion management. When the system and information are properly designed, it will result in a better usage of system capacity. However, if the traveler information messages are not well understood or properly responded to, they may lead to either a spatial transfer of congestion or even a worsen congestion level."

Based on the review of previous studies, the observed benefits of ATIS can be summarized as follows:

- Reduced travel time
- Reduced delay
- Increased travel time reliability
- Improved commuters' confidence in arriving trip destinations on time
- Reduced number of stops
- Increased vehicle throughput in the transportation network
- Reduced fuel and environmental cost

2.2.2 Traveler Information and Route Choice

Inherently people are not inclined to change their travel patterns, including departure time, mode, and route. However, in unexpected delay situations, pre-trip quantitative delay information may help travelers overcome the resistance to change travel decisions. Unexpected delays will increase the propensity to change route and drivers who are under time pressure will try to avoid congestion by switching to alternative routes. When a driver is informed that the traffic condition of his normal route is worse than usual, he is more likely to switch to an alternate route. The significant factors that could affect travelers' route-switching decision include (Polydoropoulou et al. 1996):

- Travel time on both the usual and the alternate route
- Congestion levels on alternate routes
- Knowledge of the travel time on the alternate route
- The existence of radio-broadcasted travel information

This behavior provides an opportunity to use ATIS to inform travelers of delay and congestion, and encourage them to switch to alternate routes, including toll roads.

It has been found that the travel information users are more likely to use alternate routes, and that commuters are more likely to switch routes if the travel time on their primary routes has substantial variations from day to day (Abdel-Aty et al. 2001). Khattak et al. (1999) found that with travel information, 17% of respondents in the Bay Area change routes while another 20% change at least two decisions among departure time, route, and mode. They also found that people who work are more likely to adjust trip decisions based on information. Radio information en route is more likely to influence trip changes than pre-planning information from TV or phone.

Mehndiratta et al. (2000) conducted a survey in the Seattle region and found that among the en-route travel information users, 34% change part of their routes while 22% change their routes completely. It was also found that travel information users are more likely to travel during peak periods despite having more flexibility in their working hours. A study of Boston's SmarTraveler system shows that 15% of users changed their usual route, and 14% altered their departure times in response to congestion information (Shaheen, 2003). A study conducted on the 600-km freeway network around Paris showed that message signs could cause a significant number of drivers to change their routes. For example, the longer the queue length posted on the message sign, the greater number of drivers diverted.

Sometimes the response to traveler information is mixed. Koo et al. (1998) analyzed commuters' response to traffic information on an incident through a telephone survey. The results of that study indicate that 51% percent of participants obtained information prior to departure and 71% of them did not change their travel plan. Seven percent of participants changed their routes based on incident information and 6% changed their routes by observation of the incident. Almost 40% of participants said the information saved them time while 12% of participants felt the information actually cost them time.

It can be seen that ATIS shows significant impact in changing driver’s behavior, especially route choice. As reported in different studies and in different regions, 15%–34% of travelers changed their routes in response to travel information. Route choice models have been developed to gauge drivers' responses. Most assume that travelers always choose the route with the minimum travel time when that information is available. A more useful model could be one that predicts the likelihood of their changing routes if they are given information that they perceive to be reliable (Orrick, 2003).

2.2.3 Information Seekers

The potential consumer market of ATIS includes private passenger cars, recreational vehicles, emergency service vehicles, trucking industry, rental cars, commercial traffic reporting agencies, autonomous and advisory traveler information systems, and subscription or fee-based traveler information services.

For individual commuters, studies have found that certain groups of travelers are more likely to use traveler information than others. Higher propensity for seeking travel information was found among those who are taking longer trips, facing unexpected congestion, female, employed, and own a cell phone (Yim et al. 2001). Another study found that the commuters who are seeking traveler information are more likely to be working, frequently experience congestion, have long commutes, and own a cell phone. Women are more likely than men to seek information (Wolinetz et al. 2001).

Mehndiratta et al. (2000) studied the characteristics of Seattle commuters who seek traveler information. In that study they used cluster analysis to identify segments of respondents with similar characteristics. The clusters were assigned catchy titles such as “road warriors,” “web heads,” “mellow techies,” “wired, with children,” etc. It was found that likely traveler information seekers are significantly younger than the general population, wealthier than average, slightly more likely to be male, and likely to have more children. The study also found that travel information users are more likely to travel during peak periods despite having more flexibility in their working hours.

In Texas, there have been two recent surveys of commuter behavior and attitudes to toll roads. Podgorski et al. (2004) studied the Texas public's perception of toll roads. Bhat (2004) found that the average Austin commuter is willing to pay $12.00 for an hour of commute time savings and that commuters value travel time savings and improved reliability about equally. A very high percentage (87%) of Austin commuters have internet access in their homes. The high percentage of Austin commuter residences with internet access has potential implications for commuter surveys: Abdel-Aty et al. (2001) found that internet responses to surveys were more complete and of higher quality than responses received by mail. The odds of response by internet were much higher for young users, professionals, and regular toll road users. The internet also proved to be cost-effective for surveys because it reduced printing, mailing, and coding expenses.

In general, it can be seen that the potential users of ATIS are characterized with high income, high education, frequent driving, long-distance trip, facing unexpected delay, young, female, employed, and having a cell phone.

2.2.4 Desirable Information

Wolinetz et al. (2001) found that commuters usually have the following concerns regarding travel information:

- Uncertainty of trip time
- How to get information
- How reliable is the information
- How up-to-date is the information
- Relevance to driver's situation—location, destination, trip purpose, etc.
- Affordability of the information

Travel information can be categorized into two types: pre-trip information and en-route information. Pre-trip information informs travelers of travel options and typical traffic conditions. It can also include static information such as maps, roadside services, and planned disruptions. Such information assists users in deciding whether to make a trip and/or in selecting a mode, route, or departure time. En-route information provides travelers real-time information pertaining to traffic conditions, incidents, construction, weather conditions, hazardous road conditions, alternate routes, travel times to destinations, and other useful information while en-route. This information allows travelers to switch to alternate routes or take a break during the trips.

The types of information sought by pre-trip and en-route users are different. Abdel-Aty et al. (1994) examined both groups in a study of Los Angeles commuters. They found that 37% of survey participants use pre-trip travel information and 51% listen to en-route information, and concluded that:

1. Uncertainty in travel time on commuters' usual commute routes will significantly encourage them to use pre-trip traffic information.
2. Longer-distance commuters are more likely to switch routes on the basis of pre-trip travel information.

3. Freeway users tend to switch routes more frequently on the basis of en-route information.

Khattak et al. (1998) examined stated versus revealed preferences with regard to pre-trip information. Their major findings include:

1. In unexpected delay situations, pre-trip quantitative delay information may help travelers overcome the resistance to change travel decisions.
2. A lack of experience on alternative modes and routes is the critical factor in travelers' willingness to divert. Therefore, accurate real time information on alternative routes and modes will encourage people to switch modes or routes.
3. In the unexpected delay situations, the most effective system provides prescriptive route information. Fifteen to 18% of travelers were willing to switch when predictive and prescriptive route information were provided. Only 10% of travelers chose to switch when qualitative and quantitative information were provided. However, 50% of travelers stated that they are willing to switch when they were advised to do so.

Polydoropoulou et al. (1996) examined stated versus revealed preferences with regard to en-route information. Their findings include:

1. The revealed preference survey results indicate that, after acquiring the en-route travel information, 17% of the drivers actually switched to an alternative route.
2. The stated preference survey results indicate that most respondents were willing to use the information if there is an in-vehicle traveler information device giving accurate delay information on their trips.

Table 2.3 gives an example of the information content desired by travelers in Sydney, Australia (Kim et al. 1999).

Table 2.3: Information Desired by Commuters in Sydney, Australia

Importance of Types of Information	**% Agree/Strongly agree**	**% Neutral**
Accidents	85	11
Traffic	77	14
Work zones	68	15
Alternative routes	49	34
Weather	49	29
Desired improvements	**% Agree/Strongly agree**	**% Neutral**
Estimated time to clear incident	77	9
Alternative routes	69	11
Estimated delay	51	14

The major findings from the literature about the type of information sought by travelers are summarized in Table 2.4.

Table 2.4: Information Sought by Travelers

Study	Results/Findings
Hobeika et al., 1996	70% of the respondents consider pre-trip information on weather, traffic conditions, and constructions either very or somewhat important. More than 80% of respondents consider en-route information on construction, alternative routes, weather, and traffic conditions either very or somewhat important.
Wolinetz et al., 2001	78% of commuters want regular updates on the existence of traffic problems and expected delay.
Pattern et al., 2002	Pennsylvania turnpike drivers are most interested in knowing traffic conditions (17.1% of drivers), weather condition (15.2%), and map of route (13.2%) while pre-trip. 95% of turnpike uses think it is important to get travel information en-route. The drivers are most interested in location of congestion and duration of delay (96.4%), alternative routes that could be used in case of road closure (94.8%), food, fuel, and lodging service (84.7%) while en-route.

It can be seen that commuters are interested in both pre-trip and en-route information. However, the types of information sought by commuters usually depend on the trip purpose and commuters' characteristics. Each group has different attitudes toward using travel information. Hence, the deployment techniques and use rates of each type of information are likely to be different for each group.

2.2.5 Message Design

Commuter response to travel information has implications for the design and delivery of messages. Evidence shows that the percentage of travelers who are willing to switch to an alternative route varies when different types of information are provided (Polydoropoulou et al. 1996): 27% when qualitative information for the usual route is provided; 52% when quantitative information is provided; 55% when predictive information for the usual route is provided; 58% when delay information on both the usual route and the best alternate route is provided; 61% when prescriptive information to take an alternate route is provided.

Commuters will not respond to information unless they are confident of its accuracy and timeliness. Abdel-Aty et al. (1994) found that Los Angeles commuters are more likely to switch routes if they perceive the pre-trip or en-route information is accurate. Ng et al. (1995) surveyed private vehicle drivers, commercial vehicle drivers, and commercial vehicle operators throughout the U.S. to determine user preferences. They found that cost, accuracy, and timeliness of the information are important to drivers and dispatchers. They also tentatively concluded that motorists prefer in-vehicle to out-of-vehicle information, and visual information is preferred to auditory information for in-vehicle users.

Yang et al. (1998) found that more traveler information is not always better. The ideal type of information should reduce driver's uncertainty regarding traffic conditions instead of overwhelming him or her with unneeded data. They also found that people have a low preference for visual displays in situations in which such a method is unnecessary. An auditory method is adequate and effective when drivers are familiar with the network. The duration of message, updating frequency, style, and format should be considered in the message design process.

Scriba (2002) found that the effective capacity and safety in work zones can be increased by providing delay information on dynamic message signs, providing alternative route guidance, and providing pre-trip travel information. To maintain public credibility it is very important to ensure that information provided is accurate, current and useful. Also, the amount of information should be kept at an appropriate level so that recipients will not receive more information than is useful.

By nature, people tend to comply with ATIS suggestions. Therefore, the type of information should be carefully selected. According to Mitretek Systems Inc. (1998), the desirable characteristics of traveler information can be summarized as:

- Accuracy/ reliability
- Timeliness
- Cost (capital and operating)
- Degree of decision guidance and personalization
- Convenience (ease and speed of access)
- Safety (of operation)

2.2.6 Information Provision

Audio and visual methods are two basic information delivery measures that are effective. The traveler's preference on the two methods depends on his/her familiarity of the territory (Yang et al. 2001). It was found that an auditory method is adequate and effective when drivers are familiar with the network. For familiar territory, order of preference on format was audio only, combined audio/visual, then visual only. For unfamiliar territory, preference was combined audio/visual, visual only, then audio only. It is also found that people have a low preference for visual displays in situations in which such a method is unnecessary.

The prevailing pre-trip information delivery technologies include internet, telephone, cell phone, TV, radio, kiosks, fax subscription service, and other means. The evidence from some surveys shows that the preferred media used by information seekers to gather pre-trip travel information are TV/radio and internet. En-route information can be provided by Variable Message Signs (VMS), commercial radio, Highway Advisory Radio (HAR), personal communication devices (pagers, cell phones) or in-vehicle navigational systems. Evidence shows that that VMS and HAR are two media gaining use in broadcasting en-route travel information (Pattern et al. 2002). Drivers are most likely to divert when elaborate quantitative information or prescriptive information is provided by radio or VMS (Madanat et al. 1995).

The current prevailing audio delivery technology is radio. Yim et al. (1997) report that in the San Francisco Bay Area, about 75% of survey participants listen to the radio traffic information and 50% of traffic information users change their travel behavior accordingly. Unexpected delays increase the propensity to change route. Khattak et al. (1998) found that "drivers who received delay information via radio rather than other means such as self-observation" are more likely to switch to alternate routes. Radio and, to a lesser extent, television broadcast traffic reports (and some ATIS delivered over cable networks) are also popular, though they tend to be generalized and only available at limited times of day. Commercial broadcasts, which are the most widely listened to, usually occur only during rush hour and cover only the busiest routes.

Most of radio stations obtain the traffic information from either private companies or transportation agencies like Department of Transportation (DOT). Yim et al. (1996) analyzed on radio traffic reporting in San Francisco, including data dissemination, rate of reporting, and content of radio information. The survey of the radio stations shows that:

1. Most radio stations obtain the traffic information from two private companies, either the Metro Networks or Shadow Broadcast Service. Only one surveyed radio station gathers its own traffic information by aircraft.
2. Morning traffic reports are broadcast most frequently, with an average frequency of 12 reports between 6AM to 9AM, with an interval of about 15 minutes.
3. Most radio stations do not edit the traffic reports from the two private companies.
4. The duration of each report is about 30 to 45 seconds.
5. All stations agreed that content has precedence over style, although all stations emphasized the importance of an articulated report.
6. The content of traffic information consists of six major categories – status of flow, bridge metering, incident/accident location, rail transit operation, advice on alternative route, and local traffic conditions.
7. Because radio traffic reports are delivered under strict time constraints, traffic reporters often formulate sentences that are incomprehensible to those who are not familiar with the area.

Publicly operated HAR, which broadcasts information on a dedicated radio frequency, tends to provide more detailed, localized information, but keeping the information current is so labor-intensive that HAR is often limited to seasonal services like winter snow-chain advisories or services for discrete geographic regions that present particular information challenges, such as flood-prone areas.

In Europe, dedicated radio frequencies are widely used to deliver information to drivers. The French toll agency Autoroutes reports that, in France, the single frequency broadcast (FM 107.7) is the primary information supply method for motorway customers. In 2003, it was estimated that 85% of the total length of concession motorway network (922km) were covered by the motorway radio. The motorway radio provides the following contents every hour: two to four traffic updates (more updates in emergency), at least one general news bulletin, safety and traffic advice, articles/reports/ interviews, and good music. The radio audience varies between 40% and 65% of the drivers according to traffic difficulties. 70% of the listeners are satisfied with the radio programming and 85% are satisfied with the traffic information (Autoroutes 2002).

Dynamic message signs (DMS) are widespread in the U.S. and are extremely popular among motorists, as long as the signs are placed in the proper spot and convey messages that are helpful and easy to understand (Orrick, 2003). DMS have been made even more effective with wireless technologies that allow them to be updated remotely in response to changing conditions. Luedtke et al. (1996) said that HAR has a credibility problem because of its inability to disseminate real time information. To solve the credibility problem, the authors suggested that HAR operation should be coordinated with DMS operations. The inter-agency coordination, message development, standard message formats and abbreviations, general DMS/HAR operations and uniform field installation guidelines are important factors that may help address the issue.

Some other technologies have not proved successful. Williams et al. (1996) reported on a traveler information kiosk project implemented in Atlanta, Georgia to serve the 1996 Summer Olympics Games. The information that could be accessed from the kiosks included real time traffic conditions, route planning, bus/rail service, weather, airline departure and arrival information, travel and tourism, and special events (Olympic-related information). It was found that, for marketing the kiosks to potential partners, the approach that would be both the most practical and the most likely to succeed would concentrate only on kiosk sponsors. A marketing and public relations firm was invited to the kiosk project team and took over marketing the kiosks to potential partners. One lesson learned from this project is that the value of the project to the partner must be established, substantiated, and emphasized, and potential partners' willingness to pay should be considered when pricing partnership levels.

Telephone advisory services continue to be important sources of traveler information, especially for transit users. With the Federal Communications Commission's assignment of 511 as a nationwide traveler and traffic information number in July 2000, telephone-based ATIS is expected to expand further, as is overall awareness of ATIS. The 511 Traffic Information Service is a telephone-based system that provides real-time information on road surface and weather conditions, accidents, road closures, work zones, public transportation scheduling and tourism (Orrick 2003).

One study found that new technologies, specifically cell phone and internet, are the main growth market in acquisition of travel information (Yim et al. 2001). Also, the Dedicated Short Range Communication (DSRC) technology has already been introduced into the implementation of ATIS (Mustafa et al. 1995), which enables the electronic toll collection facility to transmit traffic and other information to passing drivers with microwave communication technology. That survey found that a traveler information system adds value to the electronic toll collection function, is reliable and flexible, and has received positive public acceptance.

According to the FHWA (2000), Web and wireless ATIS providers now operate in markets that account for 92% of the population in the U.S. Most of the websites are hosted by public agencies (usually regional transit authorities or departments of transportation). The agencies collect most of their data from loop detectors, closed circuit TV cameras, and incident reports from highway patrols. Hoping that broader dissemination of traveler information would ease congestion; agencies also share their data with private service providers. Although these providers tend to have roots in traditional radio traffic reporting, the traveler information that they are offering is "advanced." However, even as the number of public ATIS websites increases, many private internet ATIS providers have ceased operations (FHWA 2000).

ATIS is increasingly associated with "telematics," two-way communication devices that can connect a traveler to virtually any number of information sources. Telematics for personal automobiles has attracted the greatest initial attention in the private sector. In the U.S., GM's OnStar system and Clarion's Joyride are the best-known pioneers. As of the end of 2001 model year, GM reported that 1 million of the vehicles it had sold were equipped with on-board telematics devices. By the 2003 model year (cars that went on sale in 2002), nearly all new cars from the major U.S. automakers have telematics either built in at the factory or offered as an option. Most automakers waive the first year's fee for new car buyers, so it remains to be seen whether car owners will renew in sufficient numbers to generate adequate revenue. Telematics is much more widespread in Europe and Japan, primarily as DVD or CD-ROM map-reading devices with little or no interactivity through internet. In Japan, more than 2 million vehicles are equipped with interactive devices that can receive real-time information. In addition, communication providers are starting to offer traveler information as part of Web-phone and personal digital assistant subscription services (Orrick 2003).

The new wireless and Web technologies are used both to gather traffic information (e.g., cell phone probes, incident reports by cell phone users, GPS/GIS tracking for incident management) and disseminate it (e.g., internet postings of up-to-date transit schedules, advice issued through on-board navigation systems, advisory services delivered through cell phones, pagers, and other devices capable of receiving e-mail or logging onto the Web). With wireless ATIS, the historic distinction between pre-trip and en-route information is starting to blur. Travelers are increasingly able to receive information, often in real or nearly real time, both before and during their trips. For drivers, that could be in the form of on-board, Web-based navigation screens or Web phones; for transit users, it could mean dynamic message boards in transit stations or at bus stops (Orrick 2003).

Advanced technologies enable providers to customize their services to a much greater degree, which addresses a key failing of most traveler information, its lack of timeliness and specificity. But growing internet use among ATIS providers and customers has created a new challenge: how to match competitors' enhancements and how to meet expectations among customers for constant improvements in the quality of information and the ease with which they can get access to it. To attract and retain customers, ATIS providers must keep pace with improvements in the medium as a whole and continue to enhance their traveler information services (Orrick 2003).

2.2.7 Revenue Potential

The market for providing traveler information is still somewhat unsettled. Hobeika et al. (1996) evaluated the traveler information needs of I-95 corridor users to determine the market potential for traveler information. Three stakeholders were identified: information user group, information providers, and the information producers. Several survey mechanisms were used to assess the user and provider information needs and the potential market. The users’ willingness to pay for pre-trip information through interactive touch screens (60 percent) and computers (56 percent) indicates the respondents’ desire to adopt newer technology to receive information.

Wolinetz et al. (2001) found that 73% of those who seek traffic information are willing to pay for it, at an average rate of \$3.84 per month or \$0.74 per use. However, users were found to prefer a per-call fee to a monthly flat rate. A study on ARTIMIS Telephone Travel Information Service (Aultman-Hall et al. 2000) found that 65% of survey participants were willing to pay for the telephone travel information service. The average maximum amount people would pay per call is 25 cents, with an average of 4.3 calls per week. 80% of the users believe that they would personally benefit from a nationwide N11 dialing number. Mitretek Systems Inc. (1998)

conducted a study and found that a 78% majority of respondents said they would be willing to pay to access an improved ATIS. Consumers' willingness to pay is summarized in Table 2.5.

Table 2.5: Commuters' Willingness to Pay for Travel Information

Percent	Willing to Pay
56%	\$5/month
40%	\$10/month
30%	\$15/month
44%	\$1/call to obtain travel information
64%	50cents/call to obtain travel information

The market for traveler information will keep expanding as traffic congestion increases and new broadcast and resale platforms are exploited. The evolving traffic information market combines the "pull" force of market and the "push" force of technology and public policy in the presence of increasing environmental/economic cost of worsening road traffic. These two forces will eventually determine the market for the traffic information business (Lappin et al. 1994).

Initially, private-sector ventures tended to focus on marketing traffic information to individual drivers, who would receive it through a variety of wireless and internet-based methods. Revenues would come from a combination of subscription fees and advertising (on websites). However, the market for for-profit traffic information failed to mature as rapidly as had been hoped, partly because of insufficient data and because of consumers' resistance to paying for information, some of which they received free via broadcast radio, telephone or roadside signs. Also, the lack of a common standard for information transmission and collection made it difficult for providers to achieve sufficient market penetration to overcome consumers' natural resistance to unfamiliar devices (FHWA 2000). Brian Burke, director of Austin's traffic management center CTECC, reported in December 2004 that a private traffic reporting company had surveyed the Austin market and determined that the market was not ready for a traffic information business.

The literature indicates that people do not place a large value on traveler information, so much so that they will not pay for it as a stand-alone product in enough numbers to warrant the service. There is some evidence to suggest they might be willing to pay for it as part of a larger subscription package (FHWA 2000). Toll road subscription accounts may be a way to achieve multiple objectives.

2.2.8 Implementation

Grasso et al. (1996) proposed a model for evolution of a traveler information system from the end-user's standpoint. Phase I (0–2 years) of ATIS implementation should be focused on rapidly deployable baseline information dissemination to the broadest possible public, at little or no charge. Rapid communication about incidents and traffic should be available. Phase II (2–5years) of the corridor ATIS should be focused on the interactive multimedia traveler information services provided via TV, telephone, internet, PDA, etc. More sophisticated private-sector information dissemination media proliferates during this time. After seeing the value of travel information, the public is more likely to purchase and use the information which will be delivered over private media at the expense of either consumer or wholesaler.

The authors of that study suggest that the private information dissemination service can make extensive use of the travel information database and a reasonable fee on the database usage could potentially reduce the public subsidy on ATIS. Phase III (5–10 years) has a heavy emphasis on the deployments of in-vehicle real-time information services. The authors also state that the primary goal of regional traveler information center is to compile, integrate, format, and manage data to be distributed to end users and ISPs. Four functions are required to achieve the goal: data gathering, data fusion and processing, data delivery, and end-user device processing.

Nelson (1996) assessed the strengths and weaknesses of both the public sector and private sector in data gathering, data fusion, and data dissemination. That study concluded that there are opportunities for public/private partnerships, mainly in data gathering and data fusion.

Owen (1996) analyzed the state of the U.S. ATIS market and forecasted the future potential of ATIS market through 2001. In-vehicle ATIS was the main concern of that study. The author indicated that "private entities could invest in the necessary infrastructure required for real time traffic information provision by operating the systems through commercial advertising or subscription availability." However, the initial provision of infrastructure is more likely to be provided by public sector. The potential user markets include private passenger cars, recreational vehicles, emergency service vehicles and rental cars.

Table 2.6 is an evaluation of the main ATIS services in use in the U.S. as of the mid-1990s. It is taken from "What Have We Learned About Advanced Traveler Information Systems and Customer Satisfaction?", Chapter 4 of *What Have We Learned About ITS?* (US DOT, FHWA, December 2000).

Table 2.6: ATIS services in the U.S. in 1996 (from FHWA, 2000)

ATIS Service	Deployment Level	Limiting Factors	Comments
Real-time traffic information on the internet	Widespread deployment	While deployment is widespread, customer satisfaction with the services seems related to local traffic conditions and website information quality	**Mixed**—the characteristics of the websites vary, depending on the availability and quality of the user interface and underlying traffic data
Real-time transit status information on the internet	Limited deployment	Transit authorities have limited funds for ATIS investments and little data that establish a ridership - ATIS relationship	**Holds promise**—where the service is available, reports suggest that there is high customer satisfaction
Static transit info via internet	Widespread deployment		**Successful**
Real-time traffic information on cable television	Limited deployment	Limited by information quality and production costs, although one service provider has developed a way to automate production	**Successful**—as evaluated in a highly congested metropolitan area where consumers value the easy, low-tech access to traffic information
Real-time transit status information at terminals and major bus stops	Limited deployment	Cost	**Successful**—where evaluated in greater Seattle
Dynamic message signs	Widespread deployment	Positive driver response is a function of sign placement, content, and accuracy	**Successful**—drivers really appreciate accurate en-route information
In-vehicle navigation systems (no traffic info)	Limited deployment*	Purchase cost	**Holds promise**—as prices fall, more drivers will purchase the systems
In-vehicle dynamic route guidance (navigation with real-time traffic information)	No commercial deployment*	Irregular coverage and data quality, combined with conflicting industry geocode standards, have kept this product from the market	**Holds promise**—manufacturers are poised to provide this service once issues are resolved
Fee-based information services on palm computers	Unknown deployment	Service providers make this available through their websites, actual subscriptions levels are unknown	**Jury is still out**—requires larger numbers of subscribers becoming acclimated to mobile information services

* San Antonio MMDI installed prototype systems in public agency vehicles

Emmerink et al. (1996) examined the opportunities and challenges associated with a combined implementation of toll road pricing and ATIS. Possibilities for integration are important because the required technology required to implement the two systems are similar and because it likely would be desirable to governments wishing to tackle congestion problems to implement several measures simultaneously. The interaction of road pricing and motorist information may have benefits that exceed the benefits of individual implementation.

The authors of that study believe that a combined road-pricing scheme and ATIS may enhance public acceptance of road-pricing schemes. Difficulties include issues of technology standardization, differing market penetration levels of the two technologies (all toll users will be subject to road-pricing, while use of ATIS capabilities is optional to drivers), and a potential conflict of interest between the two technologies (ATIS has a positive image while road pricing has a negative image). Additional benefits include vehicle identification for law enforcement purposes.

2.3 Preliminary Recommendations

This literature review has found that ATIS has the potential to reduce travel time, increase travel time reliability, increase vehicle throughput in the transportation network, and reduce fuel and environmental cost. These benefits are achieved because ATIS can change driver's behavior, especially route choice. Uncertainty in travel time on commuters' usual commute routes will significantly encourage them to use pre-trip traffic information. Longer-distance commuters are more likely to switch routes on the basis of pre-trip travel information. Freeway users tend to switch routes more frequently on the basis of en-route information. The amount of time savings is greatest when traffic flows average 95% of capacities.

Potential users of ATIS are characterized with high income, high education, frequent driving, long-distance trip, facing unexpected delay, young, female, employed, and having a cell phone. Customers of toll road tend to have similar demographics. Therefore, use of ATIS to enhance toll road operations is a natural convergence. The findings of this literature review verify the potential for toll roads to attract more traffic with travel information. The enhanced diversion of traffic to toll roads would increase toll collections as well as distribute traffic on the network more efficiently.

As reported in different studies and in different regions, 15%–34% of travelers changed their routes in response to travel information. However, ATIS is a double-edged sword in congestion management. If the messages are not well understood or properly responded, ATIS may lead to either a spatial transfer of congestion or even worsen congestion level. On the other hand, when properly designed, ATIS will result in a better usage of system capacity. The MUTCD provides guidance for ATIS implementation.

Based on a thorough literature review, the following preliminary recommendations have been formulated:

1. Desirable characteristics of ATIS include: (a) provide route and decision guidance (b) be timely, accurate, available, and cost effective, and (c) be easy to access and safe to use.
2. Although en-route information is favored, having both pre-trip and en-route information capabilities can broaden system appeal.
3. Pre-trip information contents should include traffic conditions, route information, construction zones, and weather condition.

4. En-route information contents should include location of congestion and duration of delay, expected travel times to destinations on current and alternate routes, and directions for alternate routes.
5. The ideal message design should reduce driver's uncertainty regarding traffic conditions instead of overwhelming him or her with unneeded data. Visual displays are only desirable for unfamiliar drivers. An auditory method is adequate and effective when drivers are familiar with the network.
6. Advanced traveler information is increasingly associated with "telematics," two-way communication devices that can connect a traveler to virtually any number of information sources. Personal communication devices and in-vehicle systems are recommended for further investigation.
7. There are opportunities for public/private partnerships, mainly in data gathering and data fusion. However, the initial infrastructure is more likely to be provided by public sector.
8. The required technologies for vehicle registration/identification, toll collection, and ATIS are similar, and possibilities for integration should be pursued.

3. Commuter's Stated Preference on Traveler Information and Toll Road Usage

3.1 Introduction to an Commuter Survey in Austin, TX

3.1.1 Survey Objectives

Evaluation of the dual potential of traveler information in the toll road context is the essence of this research project as originally proposed by the CTR. The overall objective of the commuter survey, which is one of the core tasks in the study, is to identify the potential market for information users and likely toll road diversion factors. Specifically, this commuter survey has the following four objectives:

1. Identify Austin area commuters' demographic characteristics and travel patterns. The questions to be addressed under this first objective included the following: What are the demographic characteristics of Austin area commuters (e.g., income, age, employment, number of commuters in a household, and number of vehicles in a household)? How many days per week do Austin commuters commute during peak traffic hours? What are the main trip purposes of Austin commuters? What type of transportation do Austin commuters use most often when traveling during morning and evening rush hours? Which highways do Austin commuters use most often when commuting during rush hours? What are the average travel times and travel distances of the commuters?
2. Examine Austin commuters' preferences for traveler information. The questions to be addressed under this first objective include the following: How often do Austin commuters typically seek traveler information during morning and evening rush hours? How do commuters currently receive traveler information on the Austin roadway system? What devices do commuters prefer to use to receive traveler information on the local roadway system? When do commuters seek out traveler information? What types of information are sought by commuters to determine traffic conditions? How does the traveler information impact commuters' travel decisions (e.g., change departure time, change travel mode, cancel trip)?
3. Examine Austin commuters' attitude toward toll roads and their route switching behavior. The questions to be addressed under this first objective include the following: How likely are commuters to switch to another route given a specific type of traveler information? What is the minimum time savings that would encourage commuters to switch routes and how much would they be willing to pay? Will commuters choose a toll road if traveler information indicates time savings?

3.1.2 Survey Approach and Administration

The survey was distributed as an online questionnaire accessible through an online survey provider at http://www.zoomerang.com/survey.zgi?p=WEB224BSKBS56C. The advantages of using a web-based survey approach include:

- Low cost. Compared to mailing out survey forms and door-to-door interview or other means of interview, the web-based survey is inexpensive to researchers.
- Convenience of answering for respondents. If the questionnaire is well structured, it is straightforward and easy to follow. People can access the survey wherever and whenever they have internet access.
- Targeted audience. Internet users are also likely to be travel information seekers. Abdel-Aty et al. (2001) found that the odds of response by internet were much higher for young users, professionals, and regular toll road users.
- Convenience for data processing. The online survey results are in digital format and are updated instantaneously. For researchers, it is convenient to obtain and process the most up-to-date results.

The questionnaire can be found in the Appendix A. In general, it consists of four parts. The first section contains eight introductory questions about commuters' commuting patterns such as number of weekly commuting days, trip purpose, transportation mode, trip time, and trip distance, and so on. The second section targets commuters' usage and requirement of traveler information. The third section focuses on commuters' response to traveler information and their anticipated time savings from route switching. The last section captures commuters' demographic data. The Austin Chamber of Commerce (ACC) assisted in distributing the survey by including an article in its electronic newsletter, which is widely distributed among employers in the Austin area. Subsequently, a number of other agencies in the Austin area, including the Center for Transportation Research, provided a link to the survey on their Web pages.

3.2 Survey Results and Analysis

3.2.1 Geographic Distribution of Survey Participants

After the survey was open to the public, the information about the survey was disseminated though the help of ACC. By the end of October 2005, a total number of 706 responses were received. These 706 survey participants (of which 692 provided their zip codes) live in the urban and suburban areas of Austin, including seven counties. Shown in Figure 3.1, these counties are Travis County, Williamson County, Hays County, Burnet County, Blanco County, Bastrop County, and Caldwell County.

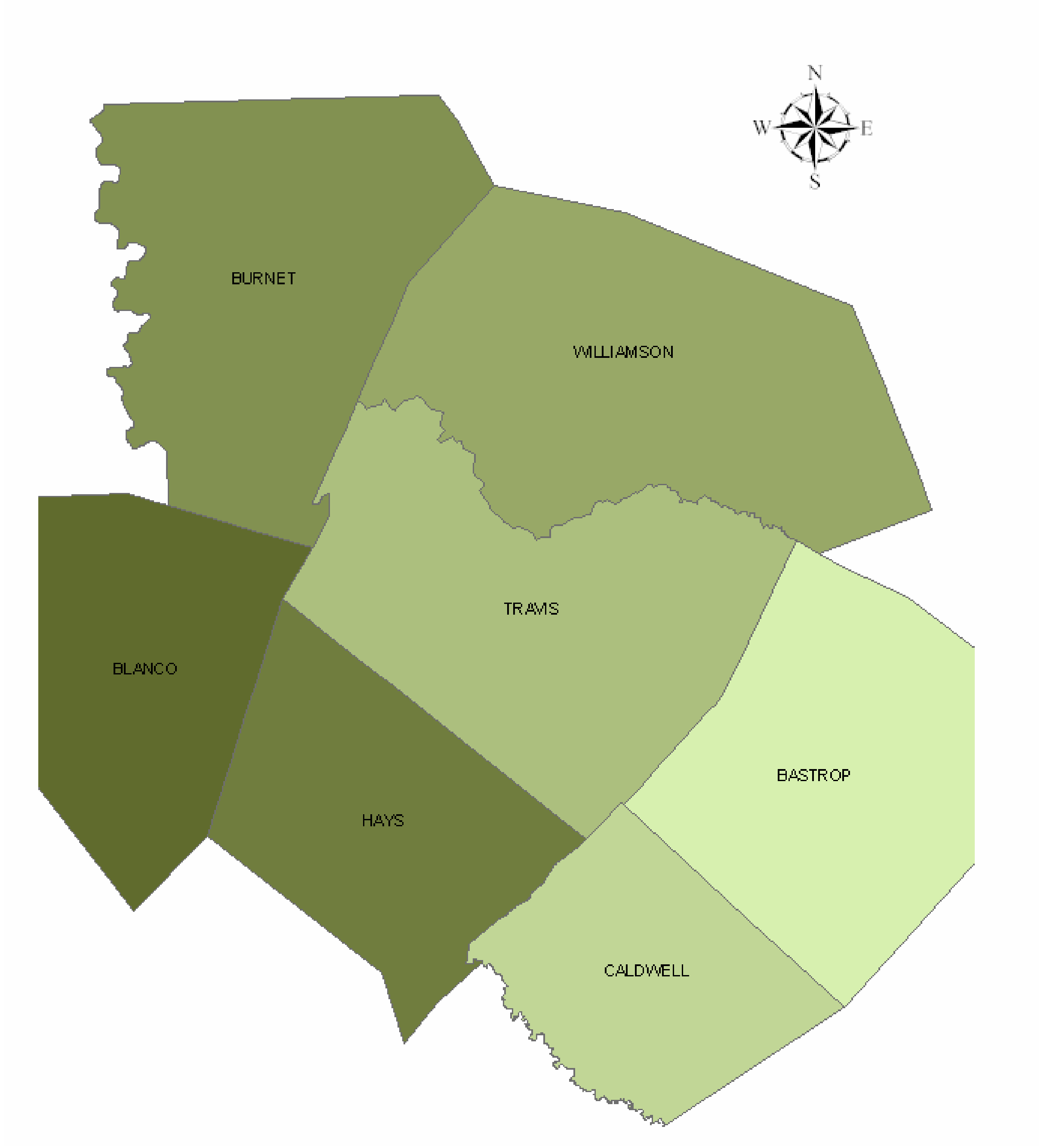


Figure 3.1: Residential Area of Survey Participants

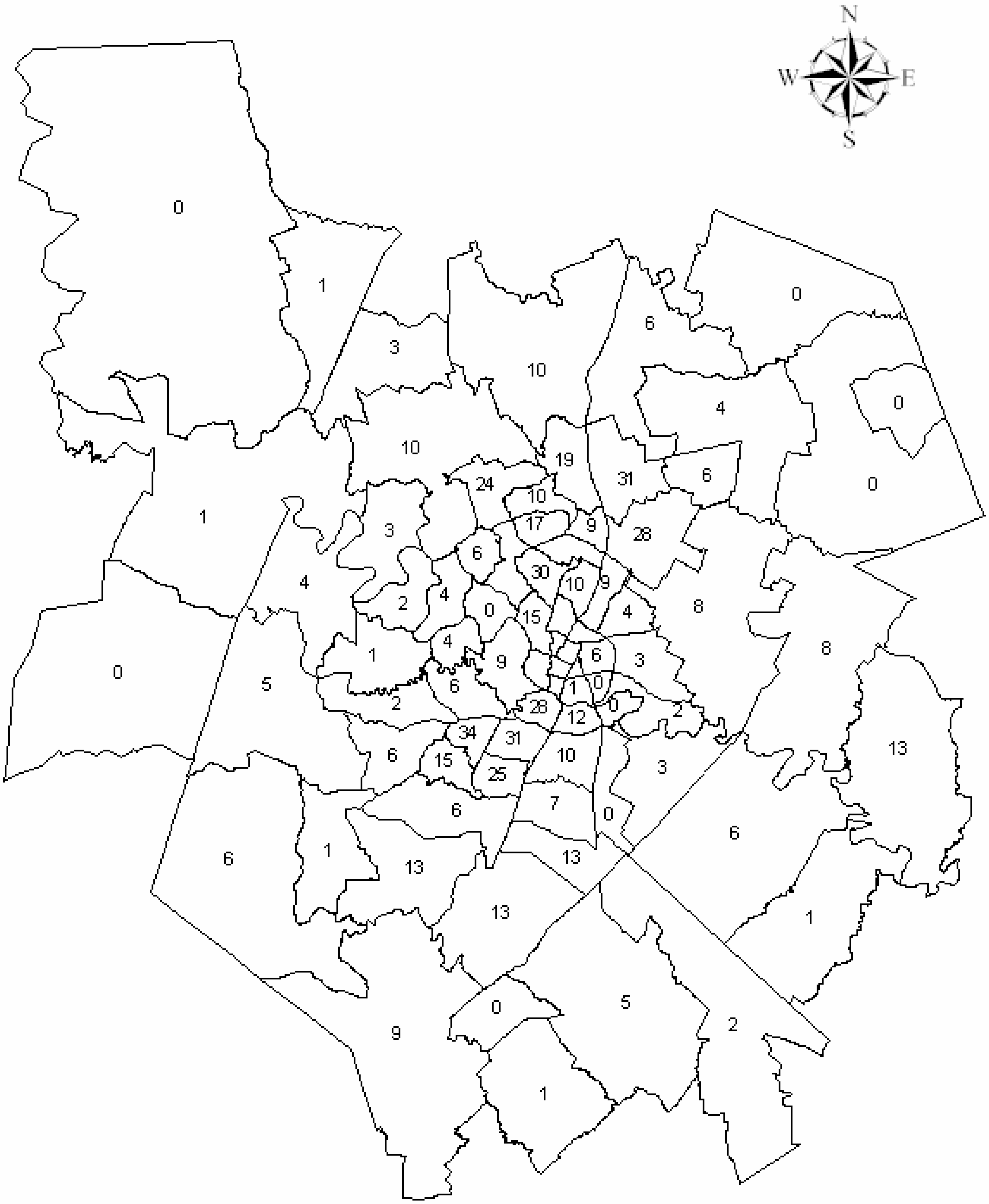


Figure 3.2: Geographic Distribution of Survey Participants

Figure 3.2 shows the number of survey participants from each zip code area in the seven counties. It can be seen that the survey participants were distributed over most of the greater Austin metropolitan area. Only a small portion of the eighty-five zip code areas have no survey participants. The number of survey participants in a sub-area is generally proportional to the population density. The sample obtained through the survey well represents the population distribution in the greater Austin area.

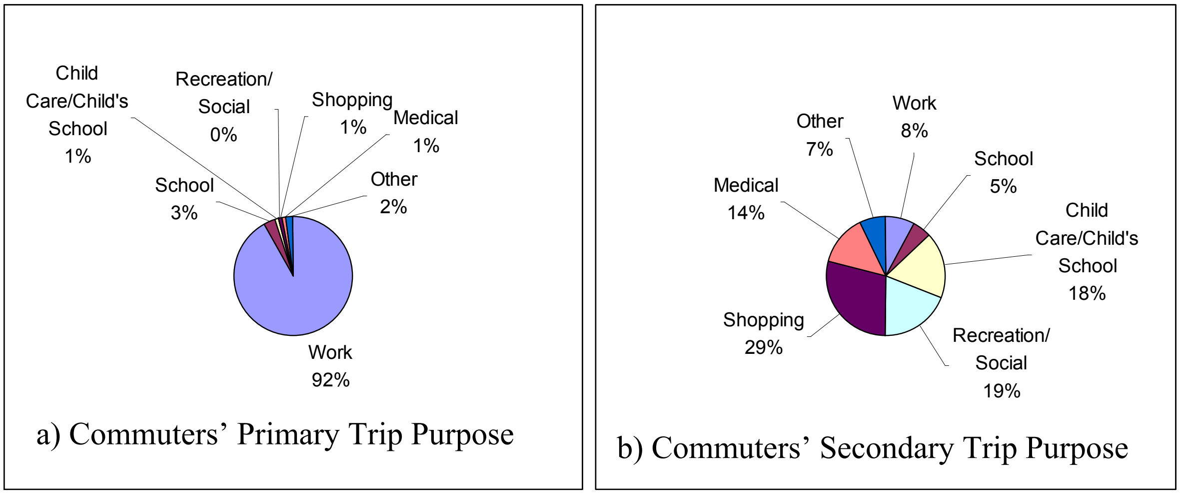
3.2.2 Austin Travelers' Commuting Patterns

About 76% of survey respondents commute 5 days a week at an average trip distance of 19 miles with an approximate arrival time of 8:00 a.m. Although the average outbound and homebound trip distances are almost the same, the average outbound and home-bound travel time are significantly different. As shown in Table 3.1, the average homebound travel time for the respondents is approximately 15% higher than the time for outbound trips. One explanation is that people are using the evening homebound trip rather than the morning inbound trip to catch up on errands or other non-work related activities.

Table 3.1: Travelers' Commuting Patterns in Austin, Texas

Weekly Commute Days	# of Responses	Percentage	Outbound Trip		Homebound Trip	
			Average Travel Time (min.)	Average Travel Dist. (mi.)	Average Travel Time (min.)	Average Travel Distance (mi.)
4	59	8.3	35	24.4	50	24.5
5	377	79.7	35.3	18.8	39.8	18.9

As shown in Figure 3.3, work is cited as the primary trip purpose by 92% of respondents, with 29% of respondents identifying shopping as their secondary trip purpose, followed by recreation/social at 19% and child care or child's school at 18%. The most common mode of transportation is the automobile at 91.8%. Public transit comes in at an expected low of 5.5%. Few commuters, less than 3%, commute by walking or riding motorcycles and bicycles.



a) Commuters' Primary Trip Purpose

b) Commuters' Secondary Trip Purpose

Figure 3.3: Austin Commuters' Main Trip Purposes

As shown in Figure 3.4, 90% of respondents indicate that they are familiar enough with local Austin's roadways to find an alternate route if necessary. Austin's population concentrations and resulting road usage is reflected in the study data with 73% of respondents commuting on at least one of these roads—IH-35, Loop 1, and US 183 shown in Figure 3.5. Specifically, 44%, 29%, and 15% of respondents commute on IH-35, Loop 1, and US 183, respectively.

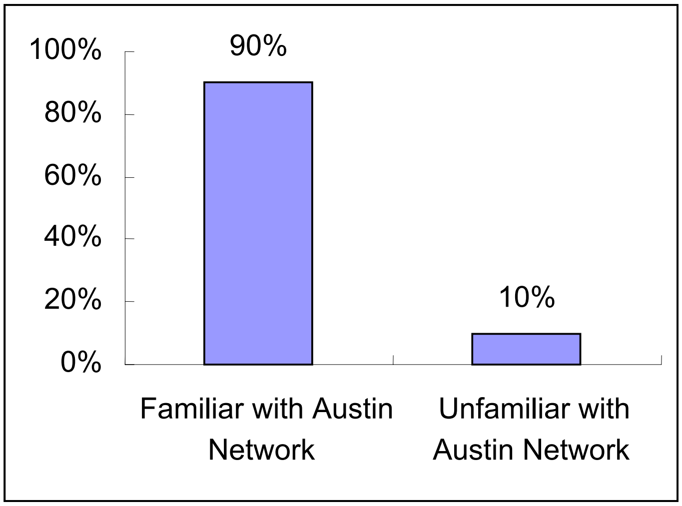
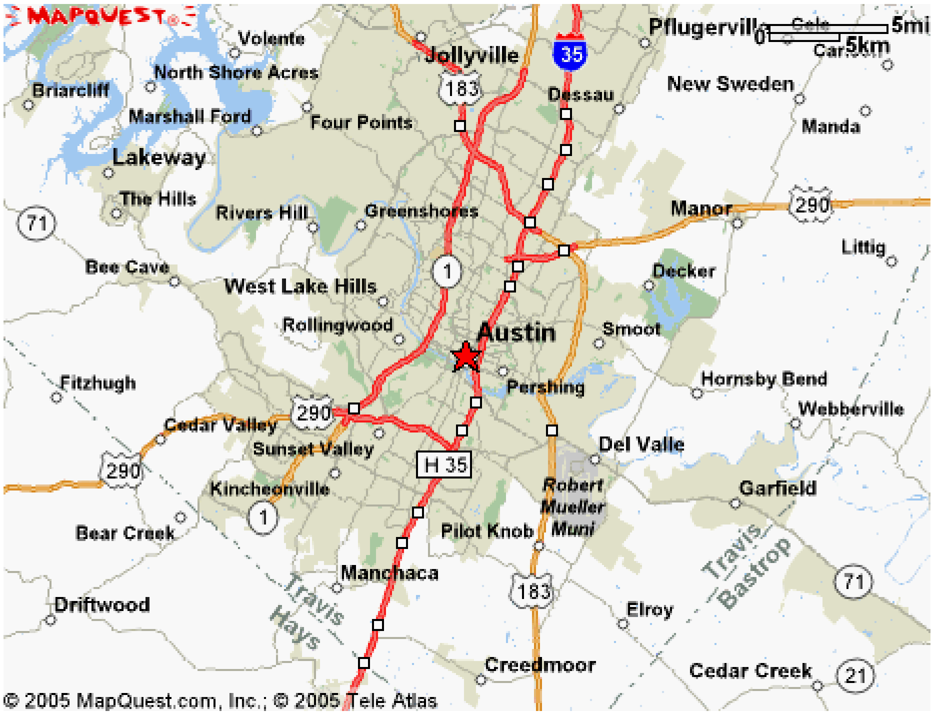


Figure 3.4: Commuters' Familiarity with Austin Network



© 2005 MapQuest.com, Inc.; © 2005 Tele Atlas

Figure 3.5: Major Routes in the Austin Area

3.2.3 Traveler Information Usage

Most respondents indicate that they do seek traveler information during their commute trips. The findings in Table 3.2 show slightly more commuters seeking traveler information during morning versus evening rush hours. When seeking traveler information, 45% of respondents reported that they often seek information during morning rush hours, compared to 43% who often seek information during evening rush hours. This can be explained by the fact that commuters usually have more pressure on travel time during the morning rush hours.

Table 3.2: Commuters' Frequency to Seek Traveler Information in Austin, Texas

Time	**Frequency to Seek Traveler Information (%)**			
	Never	**Sometimes**	**Fairly Often**	**Very Often**
Morning Rush Hours	19	36	20	25
Evening Rush Hours	21	36	20.6	22.4

In terms of traveler information types, 49% of respondents indicate that they seek pre-trip information and 78% indicate they seek en-route information, which is very close to findings presented by Hobeika et al. (1996) on commuters' needs in the I 95 northeast corridor.

When seeking traveler information to determine traffic conditions, commuters show particular interests in accident locations, road congestions, weather conditions, and lane closures. Table 3.3 presents a summary of Austin commuters' interests in seeking traveler information.

Table 3.3: Traveler Information Sought by Commuters in Austin, Texas

Content of Traveler Information	**Likelihood of Seeking Information**	**Time of Day Information Is Important**		
	Likely/Very Likely (%)	AM Rush Hours (%)	PM Rush Hours (%)	Both AM and PM (%)
Accident Location	80	12	6	75
Congested Roads	70	14	7	68
Weather Conditions	59	11	6	67
Road Work	48	18	7	64
Lane Closure	57	15	7	68
Road Hazard Warning	44	14	6	62
Estimated Trip Time	32	18	7	46
Alternate Route	NA	13	8	58

The findings on commuters' likelihood of seeking information are consistent with a study conducted in Sydney, Australia, by Kim and Vandebona (1999). In addition to commuters' likelihood of seeking a certain type of information, time when information is sought was also investigated. As shown in Table 3.3, the percentages of commuters seeking each type of information during morning rush hours are significantly higher than those during evening rush hours. This is consistent with the findings shown in Table 3.2.

Previous studies indicate a preference for en-route information (Abdel-Aty et al. 1996) and a need for regular updates on the existence of traffic problems and expected delays (Wolinetz et al. 2001). The findings in Austin support this argument—more commuters are seeking en-route information. Eighty-nine percent of the survey respondents cite the radio, assuming in-vehicle radio, as their current most frequently used means for retrieving traveler information. Table 3.4 shows commuters' current usage and preference in the manners of retrieving traveler information. Following radio, TV is the second largest traveler information source for commuters. When asked about their preference, commuters show greater interest in receiving traveler information by radio and roadside dynamic message signs (DMS) than by other means. It can be seen that the DMS and internet, especially the DMS, are "under-marketed." The potential to deliver traveler information to commuters via DMS is great. The cell phone is often cited in the "other" category for receiving traffic updates. This may imply that the demand is increasing for en-route delivery mechanisms other than the radio. In addition, use of cell phones may also indicate a level of comfort with new technology as a medium for traveler information delivery and retrieval.

Table 3.4: Austin Commuters' Preference in Receiving Traveler Information

Question	Radio	TV	Local Newspaper	DMS	Internet
How do you *currently* receive traveler information on the local roadway system?	89%	36%	4%	12%	15%
Which of the following would you *prefer* to use to receive traveler information on the local roadway system?	78%	19%	2%	37%	18%

3.2.4 Traveler Information and Commuters' Route Switching

The important factors that affect travelers' en-route diversion behavior are travel time on current and alternative routes, awareness of congestion levels, and trip purpose (Hall 1999). Among these attributes, travel time is considered most important. In some studies, researchers proposed a notion of "anticipated travel time" because of the subjectivity of the travel time on which driver's choice is based (Fujii and Kitamura 2000). Those studies suggest that traveler information will influence drivers' judgment on anticipated travel time and finally influence drivers' route choice. In this survey, several questions were designed to investigate the potential impact of traveler information on commuter route switching.

When queried about the impact traveler information has on travel behavior, 67% of the respondents stated that they would select an alternate route, followed by 18% who said they would leave earlier than planned and 3% reporting no impact on travel decisions. Table 3.5 presents Austin commuters' likelihood of switching routes after being given particular traveler information. For example, it can be seen that about 88% of respondents are likely or very likely to seek an alternate route if they are informed of an accident on their regular routes. Fifty-five percent of respondents are likely or very likely to change route if they know that the travel time on an alternate route is shorter than their current route. Sixty-six percent of respondents indicate that they are likely or very likely to change route if an alternate route is recommended.

Table 3.5: Potential Impact of Traveler Information on Austin Commuters' Route Change

Traveler Information Content	Likelihood of Switching Route (%)				
	Very Unlikely	Unlikely	Neutral	Likely	Very Likely
Road Work	4	7	12	47	30
Lane Closure	4	8	15	40	34
Road Hazard Warnings	5	9	23	41	21
Accident Locations	4	3	6	37	51
Estimated Travel Time	6	9	28	33	22
Recommended Alternate Route	5	7	24	40	26
Weather Conditions	8	11	26	32	23

Saving time is clearly an impetus for route switching. However, few efforts have been found in the existing literature to address how much time savings would eventually change commuters' decisions about choosing a new route. Table 3.6 presents respondents' minimum anticipated time savings from route switching. It can be seen that the majority of respondents hope to save 5 to 15 minutes from changing their routes. The anticipated time saving accounts for 36% of commuters' regular one-way commute time on average.

Table 3.6: Austin Commuters' Minimum Anticipated Time Savings from Route Switching

Minimum Time Saving to Switch (min.)	# of Respondents	Percentage
5	169	24
10	295	42
15	172	25
20	37	5
25	4	1
30	24	3

3.2.5 Commuters' Attitude toward Toll Roads

People are inherently reluctant to change their travel patterns, including departure time, mode, and route. When a commuter is faced with a choice between a tolled route and a non-tolled route, the toll road is normally less attractive because of the obvious extra cost. However, in many situations, traveler information may help travelers overcome the reluctance to change travel decisions. Previous studies and this survey have found that unexpected delays will increase the propensity to change route and that drivers who are under time pressure will try to avoid congestion by switching to alternate routes. When a driver is informed that the traffic condition of the regular route is worse than usual, he will be more likely to switch to an alternate route. The significant factors that could affect travelers' route-switching decisions have been identified by Polydoropoulou et al. (1996):

- Travel time on both the usual and the alternate route.
- Congestion levels on alternate routes.
- Knowledge of the travel time on the alternate route.
- Existence of radio-broadcasted travel information.

The impact of these factors is confirmed by this commuter survey (see Table 4.5). The findings verify the potential of using advanced traveler information systems (ATIS) to inform travelers of delay and congestion so as to encourage them to switch to alternate routes, including toll roads.

In the literature search, no studies have been found on traveler's willingness to choose a toll road when provided with travel information. In order to address this problem, an additional question was asked in the survey to see how much a commuter would be willing to pay to save the time mentioned in Table 3.6. The findings show 49% of respondents are not willing to pay and 11% of respondents are unsure. About 40% of respondents indicate they are willing to pay a fee, ranging from $0.05 up to $275.50, with most respondents preferring to pay less than $1, for the time savings described. For those respondents who are willing to pay, the average amount is $2.07, with an average anticipated time saving of 12.5 minutes. It is equivalent to about $10 for 1 hour, a finding consistent with another commuter survey in Austin (Bhat 2004).

When asked if a commuter would like to choose a toll road when traveler information indicated that he could save time on the toll road, 46% of respondents said they would choose it, whereas 54% said the toll road was not an option. When looking at the reasons for "not choosing" toll roads, "tax already paid" is often cited. Table 3.7 illustrates that as income level increases, the percentage of respondents willing to choose toll roads also increases.

Table 3.7: Austin Commuters' Willingness to Choose Toll Roads by Income Levels

Household Income Level	**Willingness to Choose Toll Roads if Information is Provided**		**Total**
	No	**Yes**	
$25,000 to $34,000	61% (30 respondents)	39% (19 respondents)	100.0%
$35,000 to $49,000	52% (43 respondents)	48% (39 respondents)	100.0%
$50,000 to $74,000	57% (90 respondents)	43% (67 respondents)	100.0%
$75,000 to $99,000	49% (70 respondents)	51% (74 respondents)	100.0%
$100,000 to $149,000	53.5% (77 respondents)	46.5% (67 respondents)	100.0%
$150,000 to $199,999	48.6% (17 respondents)	51.4% (18 respondents)	100.0%

Table 3.8 shows that, when provided with traveler information, male commuters are more likely to choose toll roads than female commuters.

Table 3.8: Austin Commuters' Willingness to Choose Toll Roads by Gender

Gender	**Willingness to Choose Toll Roads if Information is Provided**		**Total**
	No	**Yes**	
Male	59% (159 respondents)	41% (110 respondents)	100.0%
Female	50.8% (212 respondents)	49.2% (207 respondents)	100.0%

3.3 Summary of Findings

The primary objective of the study is to examine how the use of traveler information would affect commuter travel behavior in the context of toll roads. In particular, the study looks at:

- The type of information influencing commuters' decisions.
- Commuters' requirements for traveler information.
- Market for traveler information.
- Value of information.
- Traveler information and toll road choice.
- Potential toll market and revenue increase if ATIS is provided.

Key findings of this commuter survey are summarized as follows:

1) Most respondents, around 90%, indicate they are familiar enough with the Austin road network to find an alternate route if necessary. On the other hand, 46% of respondents said they would choose a toll road when traveler information indicates that maybe they could save time on the toll road. Hence there is a tremendous opportunity to use ATIS to improve the operations of both tolled and non-tolled roads.
2) Seventy-three percent of respondents commute on at least one of IH-35, Loop 1, and US 183. This finding would be very useful for regional traffic management, toll road marketing, and ATIS deployments.
3) Commuters have more pressure on travel time during the morning rush hour. As a result, commuters seek traveler information more often during the morning rush hour than evening rush hour. Nevertheless, the majority of commuters seek traveler information during both morning rush hour and evening rush hour.
4) The traveler information sought by the majority of commuters includes accident locations, congested roads, road work, weather conditions, and lane closures. This finding, along with finding 3, is particularly useful for ATIS marketing.
5) Although radio and TV are currently most often used by Austin commuters to receive traveler information, VMS is the most "under-marketed" means of information delivery. The survey results show that DMS, internet, and in-vehicle technologies have great potential in delivering traveler information to commuters.
6) The majority of survey participants, 67%, cite "choose an alternate route" as the response to traveler information. This percentage is far higher than those citing "choose an alternate transportation mode," "change departure time," "cancel trip," and "no impact." The impact of traveler information on commuters' route switching is quite impressive.
7) Most respondents, 91%, indicate that they expect to save 5 to 15 minutes by changing their routes. The anticipated time saving accounts for 36% of commuters' regular one-way commute time. This is one of the unique findings in this study.

8) About 40% of respondents indicate they would pay for saving travel time. For those respondents who are willing to pay, the average amount is \$2.07, with an average anticipated time saving of 12.5 minutes. It is equivalent to about \$10 for 1 hour. This figure represents the value commuters in the Austin area place on personal travel time.

9) Forty-six percent of respondents said they would choose a toll road if traveler information indicated that they could save time. It was confirmed that income level and gender have effects on commuters' willingness to choose toll roads.

4. Impact of Traveler Information on Transportation Network Operations

4.1 Description of the Case Study in Austin, TX

4.1.1 Traffic Simulation Approach

Route choice models: In order to examine commuters' route choice behaviors, a number of theories and tools have been developed. Current route choice models can be categorized into two types: deterministic and stochastic. The deterministic model is the well-known Shortest-Path Model, which assumes that all drivers choose the least-costly route. The stochastic models include logit and probit models, both assuming that there is a probability of choice of every feasible route determined by route and driver attributes. Compared to the non-tolled road, the toll road basically has an exogenous cost—the toll plus the effort to divert. Therefore, it is feasible to apply route choice models to the tolled/non-tolled route choice problem.

Traffic simulation: Traffic simulation techniques have been used since the early days of the development of traffic theory. The ever-increasing power of personal computers and search for solutions to growing urban transport problems have led to the emergence of a number of microscopic simulation models as practical traffic analysis tools. Simulation is useful because of increasing levels of system complexity and uncertainty involved in the operation of urban traffic networks. There is great potential for useful application of simulation models to the analysis of complex traffic problems in urban areas, alongside the analytical techniques already in use.

In general, simulation is defined as dynamic representation of some part of the real world achieved by building a computer model and moving it through time (Drew 1968). Computer models are widely used in transportation system analysis, but only those with the dynamic approach are the focus of this research. The use of computer simulation started when D.L. Gerlough published his dissertation: "Simulation of Freeway Traffic on a General-Purpose Discrete Variable Computer" at the University of California, Los Angeles, in 1955 (Kallberg 1971). Since that time, simulation has become a widely used tool in transportation engineering with a variety of applications from scientific research to planning, training, and demonstration. The driving forces behind this development are advances in traffic theory, in computer hardware and programming tools, development of the general information infrastructure, and society's demand for detailed analysis of the impacts of traffic measures and plans.

Simulation tools: The applications of traffic simulation programs can be classified in several ways. Some basic classifications are the division between microscopic, mesoscopic, and macroscopic, and between the continuous and discrete time approaches. According to the problem area, the intersection, road section, and network, simulations can be separated. Special areas are traffic safety and the effects of advanced traffic information and control systems. A new area is demand estimation through microscopic simulation.

One of the oldest cases of the use of simulation in theoretical research is the car-following analysis based on the General Motors (GM) models. In those models, a differential equation governed the movement of each vehicle in the platoon under analysis (Gerlough and Huber 1975). Car-following, like intersection analysis, is one of the basic questions of traffic flow theory and simulation and is still under active analysis almost 40 years after the first trials (McDonald et al. 1998).

Most urban transportation problems are network related. In networks, different kinds of intersections (signalized, unsignalized) and links (arterial roads, motorways, city streets) have to be combined. This makes the simulation quite complicated, and the number of comprehensive simulation tools for network analysis is quite low in comparison to that of programs for isolated intersections and road sections. The most widely known package in this area is probably the American NETSIM from the 1970s (Byrne et al. 1982). Later examples of tools in this area are INTEGRATION, AIMSUN2 (Algers et al. 1997), and DYNASMART (Mahmassani et al. 2003).

4.1.2 Objectives of Simulation Study

The primary objective of this simulation experiment is to analyze the impacts of traveler information deployment on a real network. DYNASMART-P program was selected to conduct the simulation experiment since it best suits the scope of this research. The traffic operations on toll roads, non-tolled alternative routes, and the overall performance of the entire transportation network were examined. Considering TxDOT's interest and available data resource, the research team selected the Austin area (IH-35 corridor, SH 130, SH 45) to conduct the simulation case study. The timing of this case study is very appropriate, because SH 130 is likely to open in late 2007. The CTR team coded the Austin network into the DYNASMART-P simulation program. The SH 130 and SH 45 toll road segments were added into the Austin network. With all the preparation work completed, traffic operations on both toll roads and non-tolled network were simulated with and without traveler information in the DYNASMART-P program. Traffic volumes, travel speeds, total vehicle miles traveled (VMT), total delays, and network level performance were simulated. The impacts of traveler information on toll road usage and non-tolled network were then examined based on the simulation results.

Keeping the primary objective in mind, the research team focused on the traffic operations of the IH-35, SH 130, and SH 45 corridors. Among the three corridors, the SH 130 and SH 45 are toll roads planned to open in 2007. To achieve the objectives listed in the project proposal, the research team set the following three specific goals for the DYNASMART-P simulation case study:

1. Examine the entire network performance with and without traveler information.
2. Examine traffic operations on IH-35 with and without traveler information.
3. Examine the impact of traveler information on traffic operations of tolled SH 130 and SH 45 roads.

4.1.3 DYNASMART-P Model

Owing to the dynamic characteristics of traveler behavior, dynamic models are best suited to evaluate the impacts of ITS. One such program is DYNASMART, developed by CTR and Maryland Transportation Initiative under contract with the Federal Highway Administration (FHWA). The newest version is DYNASMART-P 1.0, which integrates traffic flow models, behavioral rules, and ATIS into a simulation-assignment process. DYNASMART-P 1.0 is capable of modeling the evolution of traffic flows in a traffic network that result from the travel decisions made by individual travelers. It overcomes many limitations of the static traffic assignment models in current use. Features include (Mahmassani et al. 2004):

- Detailed representation of traffic networks with different link types, such as freeways, highways, and arterial networks. Micro-simulation of individual trip-making decisions, particularly route choice.
- Representation of multiple vehicle types in terms of operational performance.
- Representation of traffic processes at signalized and non-signalized junctions under a variety of operational controls.
- Detailed output statistics at both the aggregate and the disaggregate levels.

For example, DYNASMART-P produces traffic characteristics over time of each link in the network, such as volume, speeds, densities, queues, etc. Statistics such as average travel times, average stopped times, and the overall number of vehicles in the network, are also given at different levels of aggregation. DYNASMART-P has a Graphical User Interface (GUI) that allows users to easily change inputs, view output files, the statistics produced, and simulation results.

4.1.4 Network Data Description

Data sources: The Austin metropolitan area was chosen because new toll roads are being built, and there is an opportunity to test the research hypothesis with recent data. The input data for the DYNASMART-P model were obtained from the Capital Area Metropolitan Planning Organization (CAMPO) in Austin, Texas. The transportation network includes the freeways, highways, arterials, and local streets in the CAMPO planning area, which covers Travis, Williamson, and Hays Counties.

The CAMPO Year 2007 network contains 1,117 Traffic Analysis Zones (TAZ), 5,964 nodes, and 12,421 links. Figure 4.1 gives an overview of the entire network. The highlighted links, which represent the IH-35 corridor and SH 130-SH 45 toll road corridor, were examined in detail.

Data processing: To make the DYNASMART-P program handle the network more efficiently, the 1,117 TAZs were aggregated into 111 super zones, each containing one or more TAZs. The links in those 111 super zones are shown in Figure 4.2, in which each color (see color copy) represents one super zone.

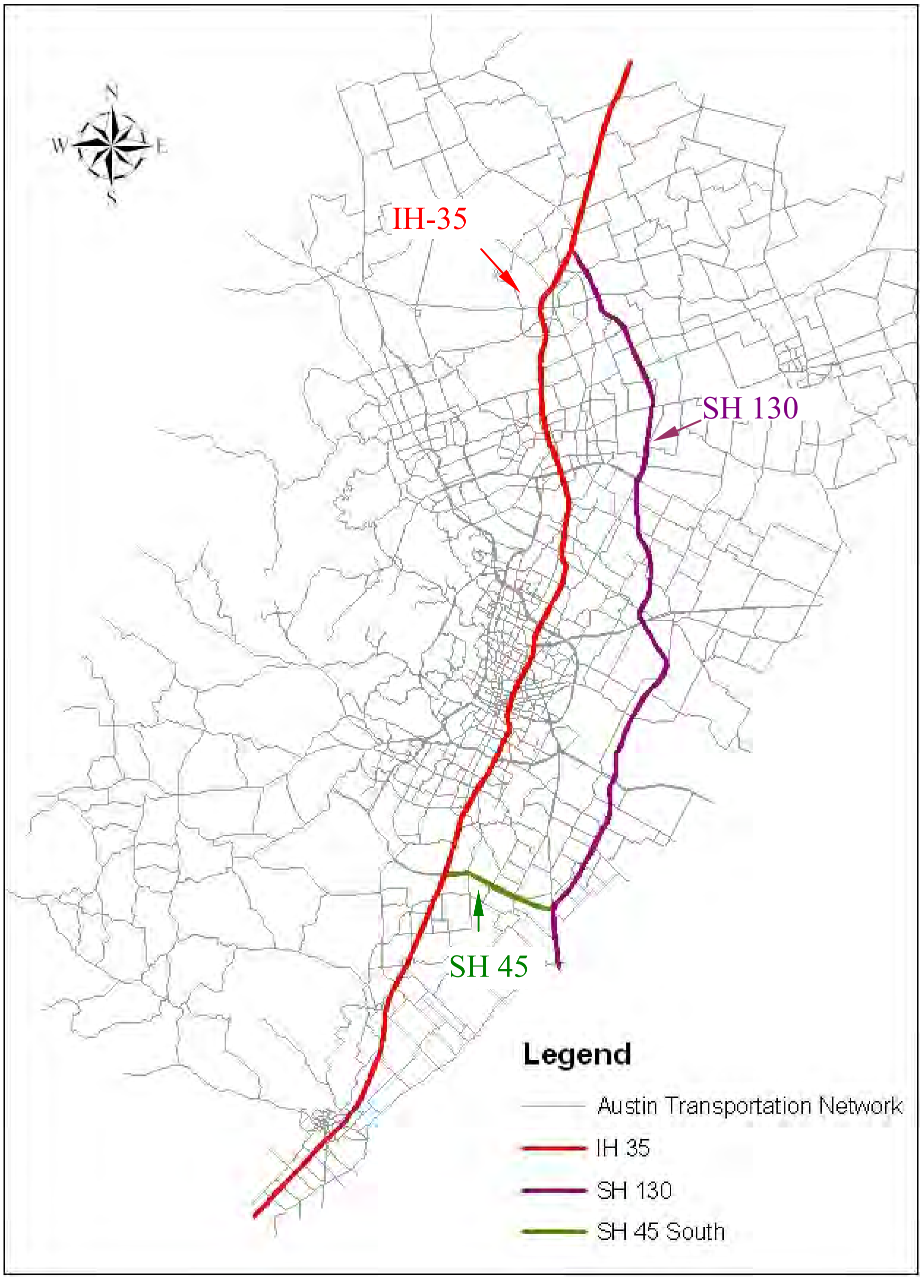


Figure 4.1: An Overview of the Austin 2007 Transportation Network

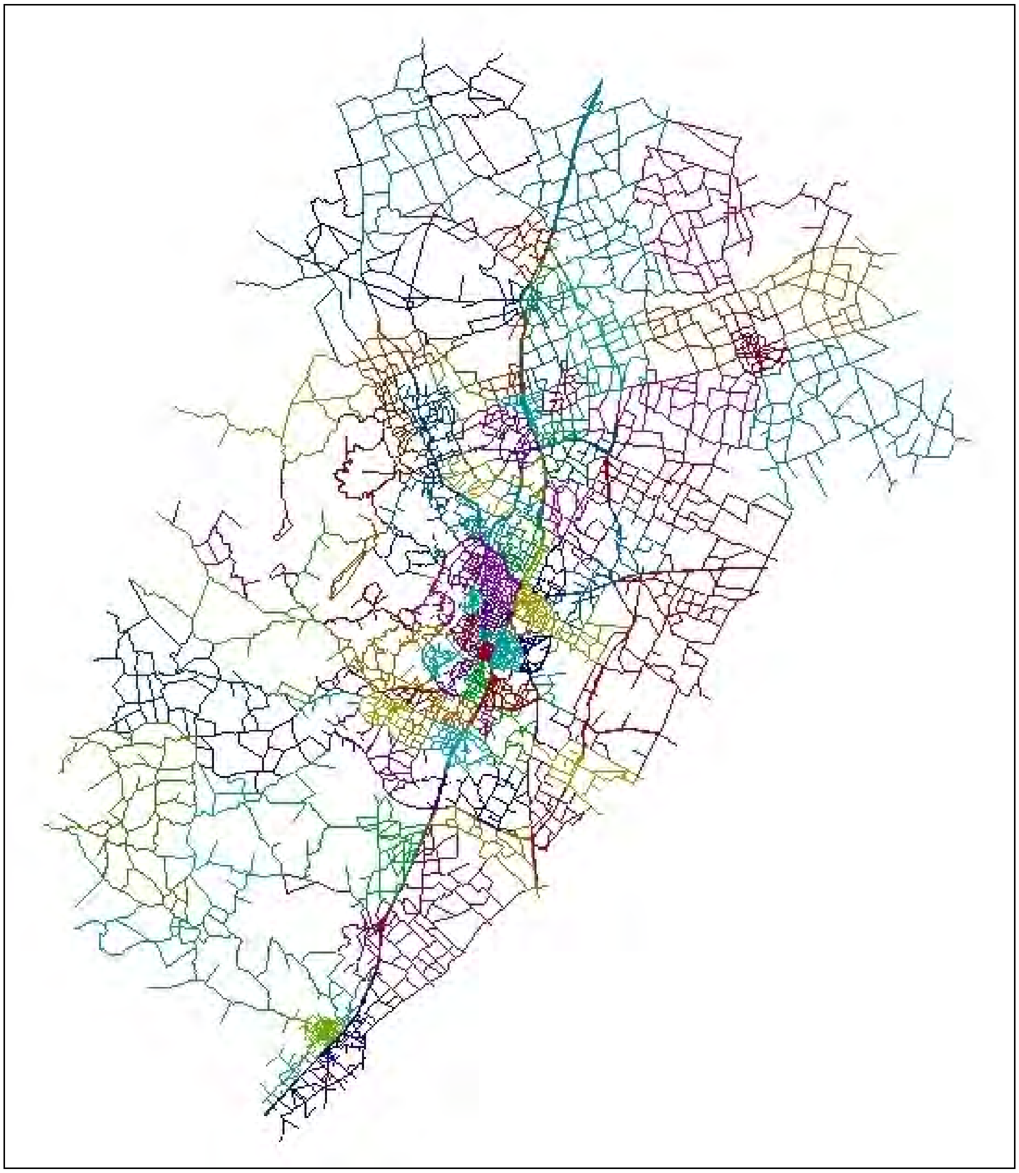


Figure 4.2: Aggregation of the Austin Transportation Network (111 Super Zones)

The travel demand used in this study is the year 2007 demand, a CAMPO prediction. The original Origin-Destination (O-D) matrix contains 1,117 origins and 1,117 destinations. Because the 1,117 TAZs were aggregated into 111 super zones, the travel demand was aggregated into 111 origins/destinations as well. When the input data are imported into the DYNASMART-P program, the simulation of the network traffic operations is ready to run. Figure 4.3 gives a screenshot of the Austin transportation network representation in DYNASMART-P when all the necessary data are loaded.

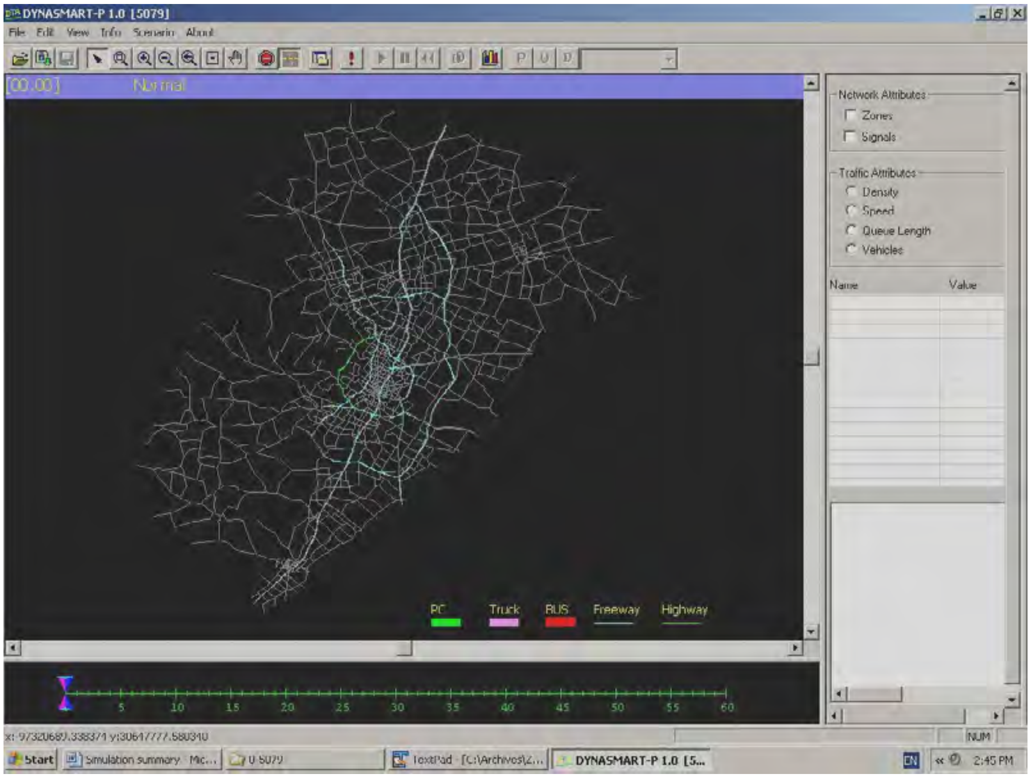


Figure 4.3: Screenshot of the Austin Transportation Network in DYNASMART-P

4.1.5 Experiment Design

DYNASMART-P enables users to analyze the impact of some traveler information strategies, such as variable message (DMS) signs and en-route information systems. Two scenarios were deliberately designed to achieve the research goals:

1. Scenario 1: SH 130 tolled, no traveler information provided.
2. Scenario 2: SH 130 tolled, traveler information provided through DMS at selected locations along IH-35.

In the scenarios with traveler information provision, en-route information is assumed to be provided prior to nineteen potential diversion locations along the IH-35 corridor. DYNASMART-P allows the user to define the location at which drivers receive traveler information, e.g., by DMS, and can model the effects of different DMS locations. The diversion locations chosen for this simulation include the junctions of major freeways in the Austin area, for instance, the junction of IH-35 and SH 130 in the north, the junction of IH-35 and SH 45 north, the junction of IH-35 and US 183, etc. The ATIS locations and their representations in DYNASMART-P are shown in Figure 4.4.

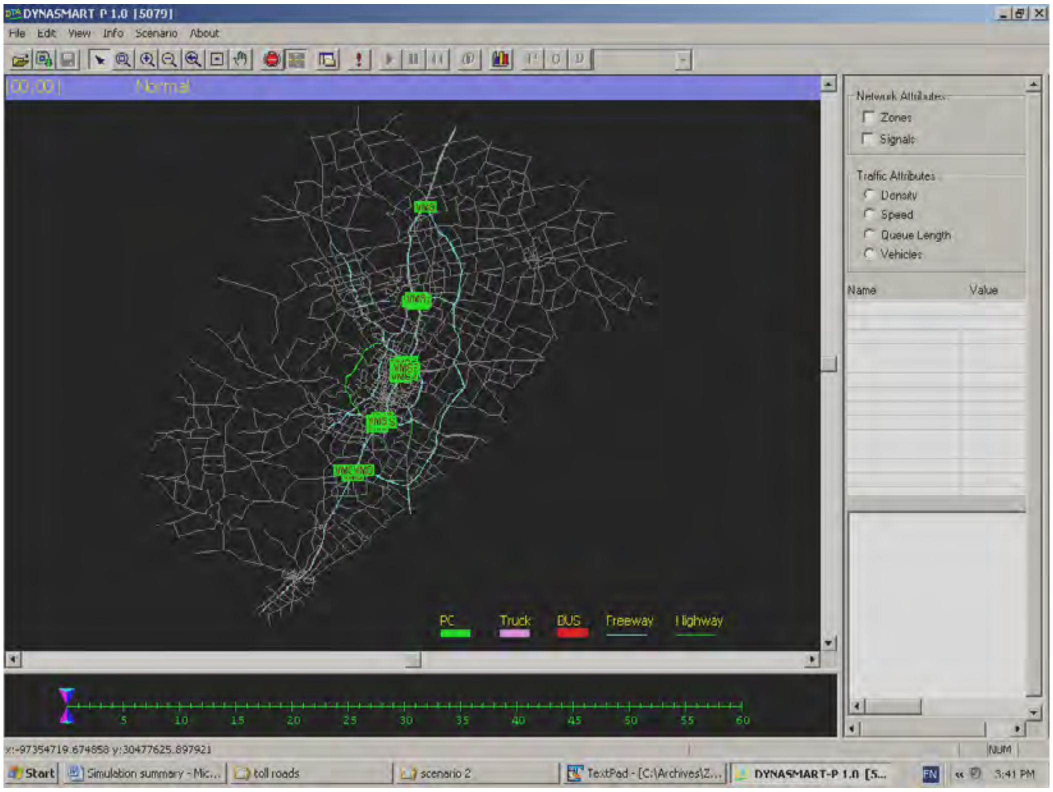


Figure 4.4: ATIS Deployments Projected in DYNASMART-P

4.1.6 Simulation Settings

Assumptions: Before running the simulation with the DYNASMART-P program, some parameters and system settings must be determined or reasonably estimated. The parameters that need to be identified include the following:

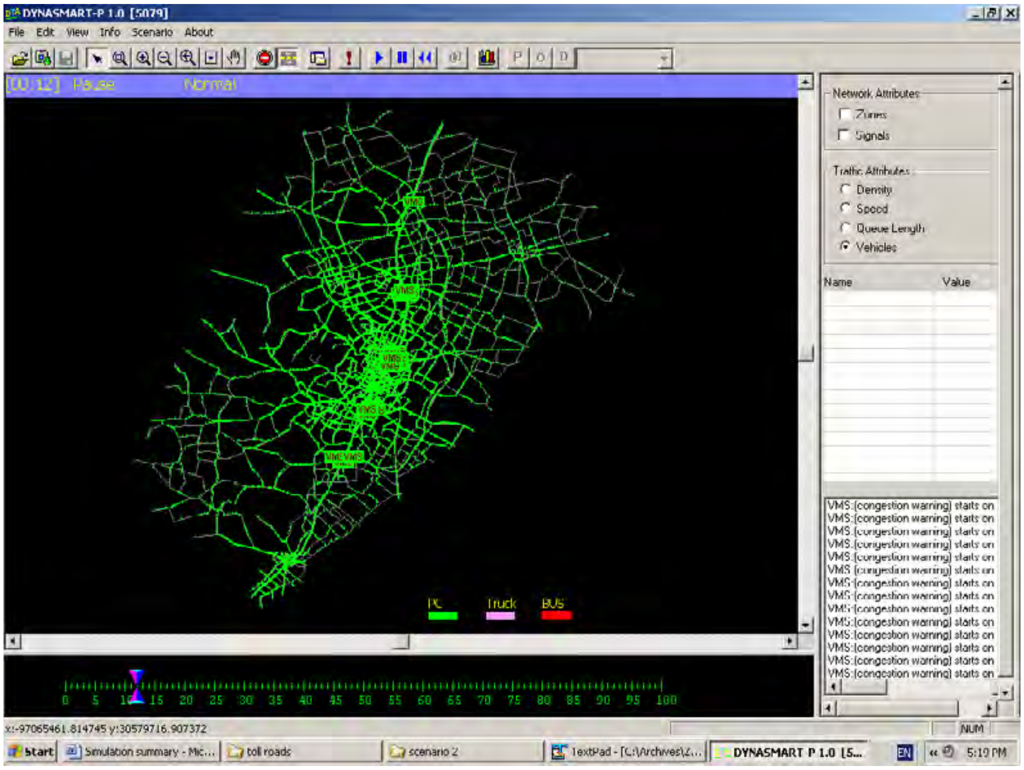
- *Simulation type*. DYNASMART-P allows users to run a one-shot simulation assignment, an iterative consistent assignment (equilibrium), or a day-to-day simulation. In this study, the research team selects the one-shot simulation assignment to examine the traffic operations during peak morning hours.
- *Planning horizon.* This parameter enables users to set the simulation period. In this study, it was set at 100 minutes.
- *Demand type.* In this study, it is an O-D matrix.
- *Traffic management strategies.* DYNASMART-P allows users to use four traffic management strategies: Ramp metering, ATIS, path coordination, and corridor coordination. The ATIS strategy was picked in this experiment.

- *Vehicle types*. Three types of vehicles are available in DYNASMART-P. They are passenger cars, trucks, and High Occupancy Vehicles (HOVs). Because the CAMPO travel demand prediction only provides the passenger car demand, the research team set all the simulated vehicles in the network as passenger cars (100 %).
- *User class percentage of combined demand*. This parameter is one of the unique features of the DYNASMART-P program. It allows users to define the percentage of travelers that are responsive and not responsive to ATIS. Using the results from a survey of Austin commuters conducted earlier in this project, 40% of travelers are assumed to be unresponsive to traveler information, 50% of the travelers divert at the next opportunity, and 10% choose the shortest path, based on their knowledge of the network.
- *Pricing strategy*. Users are allowed to define the pricing attributes, including the amount of the toll, tolled links, and the value of time. Based on the earlier traveler survey, the Austin commuter's time value is about $10 per hour. SH 130 and SH 45 South are assumed tolled at a price of 10 cents per mile.
- *Threshold for switching decisions.* This parameter specifies the minimum time savings that would make a driver change a route. In this experiment, the value of this parameter is assumed to be 5 minutes.
- *ATIS settings*. Users must specify the period in which ATIS is functional and the ATIS information type. In this experiment, ATIS is assumed to be in operation all the time, i.e., 100 minutes, the same as the simulation period. DYNASMART-P allows users to choose one type of information out of four: speed advisory, mandatory detour, congestion warning, and optional detour. The congestion warning was selected in this experiment.

DYNASMART-P also allows users to examine the impact of ITS options, such as incident management systems, ramp metering, work zone management, etc. However, these are out of the scope of this research. So all the parameters on these ITS options are either voided or set to the default value.

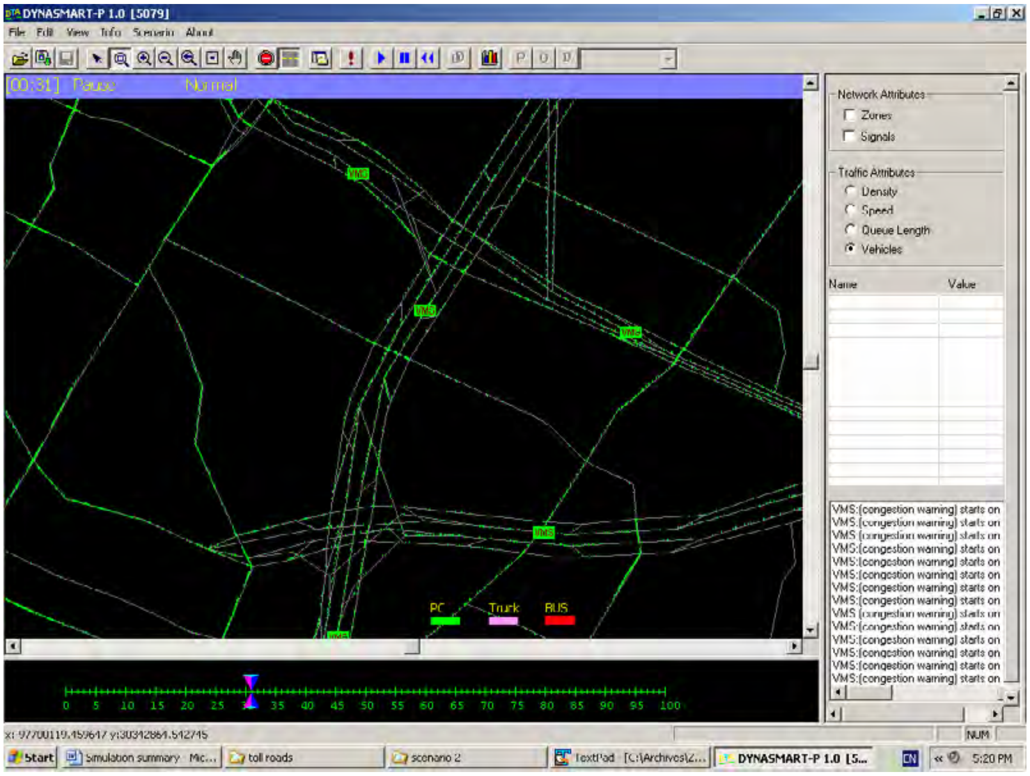
Outputs: DYNASMART-P has a GUI that shows the animation of vehicle movements. Figure 4.5 and Figure 4.6 show two snapshots of vehicle movement during the simulation. DYNASMART-P simulation outputs provide users the following two types of data:

- *Network performance.* The outputs provide network average speed, total travel time, average travel time per trip, total stop time, average stop per trip, queue length, etc. With these data, the research team can analyze the performance of the entire network in different scenarios.
- *Link performance.* The outputs provide the speed, density, and volume information for each link. With these data, the research team can analyze the performance of a specific link.



VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on

Figure 4.5: DYNASMART-P Simulation on the Entire Austin Network



VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on
VMS:[congestion warning] starts on

Figure 4.6: Vehicle Animation in DYNASMART-P (IH-35, US 183, and US 290 Triangle Area)

4.2 Overall Network Performance Improvement

The following sections present the network and link performance for both scenarios. The simulation period is 100 minutes, representing peak morning hours.

Scenario 1: SH 130 tolled, no traveler information provided: This scenario is considered the baseline scenario. In this scenario, SH 130 and SH 45 South are toll roads. No other toll roads are assumed in the Austin network. In addition, no traveler information is provided. The outputs of DYNASMART-P are provided in Appendix B, and summarized in Table 4.1.

In the no-ATIS scenario, the average trip distance was 8.4 miles and the total trip distance during the 100-minute period was about 4.5 million vehicle miles. The average travel time for all the trips made during the 100-minute peak morning period was 29 minutes, in which 12.8 minutes were stopped time. The overall travel time was about 260,000 vehicle hours and the total stopped time was about 115,000 hours.

Scenario 2: SH 130 tolled, traveler information provided: In this scenario, SH 130 is tolled and traveler information is provided along IH-35. The output given by DYNASMART-P is provided in Appendix B and summarized in Table 4.1.

According to the simulation outputs, the average trip distance was 8.9 miles, which is 0.5 miles longer than the baseline scenario. The total trip distance during the 100-minute period was about 4.8 million vehicle miles. The average travel time for all the trips made during the 100-minute peak morning period was 28.45 minutes, in which 11.45 minutes were stopped time. The system average travel time was about 0.5 minutes less than the baseline scenario, and the average stop time was about 1.4 minutes less than the baseline scenario. The overall travel time in this scenario was about 255,000 vehicle hours and the total stop time was about 102,000 hours.

A comparison of the network performance with and without traveler information provision shows that when traveler information is provided, the average trip distance increased slightly, mainly because of route switching. However, the average travel time, total travel time, average stopped time, and total stopped time in the entire network decreased. The total stopped time and average stopped time were significantly reduced by switching routes.

Table 4.1: Network Performance with and without Traveler Information

	No-Information	**Information Provided**	**Change**
Average Trip Distance (miles)	8.4	8.9	+6%
Total VMT	4,492,723	4,777,624	+6.3%
Total Travel Time (hrs)	259,229	254,549	-1.8%
Average Travel Time (min.)	29	28.45	-1.8%
Total Stopped Time (hrs)	114,641	102,425	-10.6%
Average Stopped Time (min.)	12.8	11.45	-10.6%

Figure 4.7 illustrates the network performance with regard to average speeds. The comparisons of average link speed, average freeway speed, and average arterial speed show that

the network performance improves when traveler information is provided. Detailed link speeds are provided in Appendices 1 and 2.

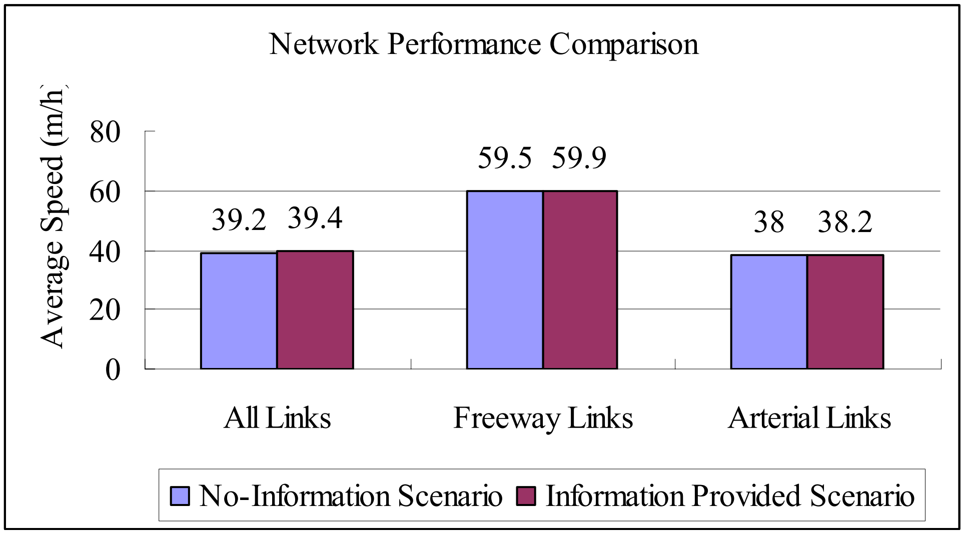


Figure 4.7: The Impact of Traveler Information on Network Speeds

4.3 Potential Impact of ATIS on Non-tolled Freeways

One of the goals of this study was to see if traveler information would encourage travelers to choose the SH 130 toll road if informed of traffic congestion on IH-35. Such traffic diversion to SH 130 could potentially relieve congestion on the IH-35 corridor. To better understand the resulting impact of traveler information on IH-35 operations, the performances of selected IH-35 links were examined. The simulation results are presented in Appendix C, and the summaries presented here.

Figure 4.8 through Figure 4.11 illustrate how traffic speeds and traffic throughputs change at various IH-35 segments. These figures provide a *big-picture* of how traveler information will affect traffic operations on the non-tolled alternative route. It shows that by providing traveler information, the average speeds on different IH-35 segments generally increase. In addition, since a portion of the traffic diverts to the SH 130 toll road, the traffic volume on IH-35 is slightly reduced. As a result of less traffic and higher speeds, the throughputs on heavily congested segments such as IH-35 at Austin's downtown area also increase. Even though the changes are modest, they are positive. The results prove that ATIS has the potential to provide economic benefits for travelers.

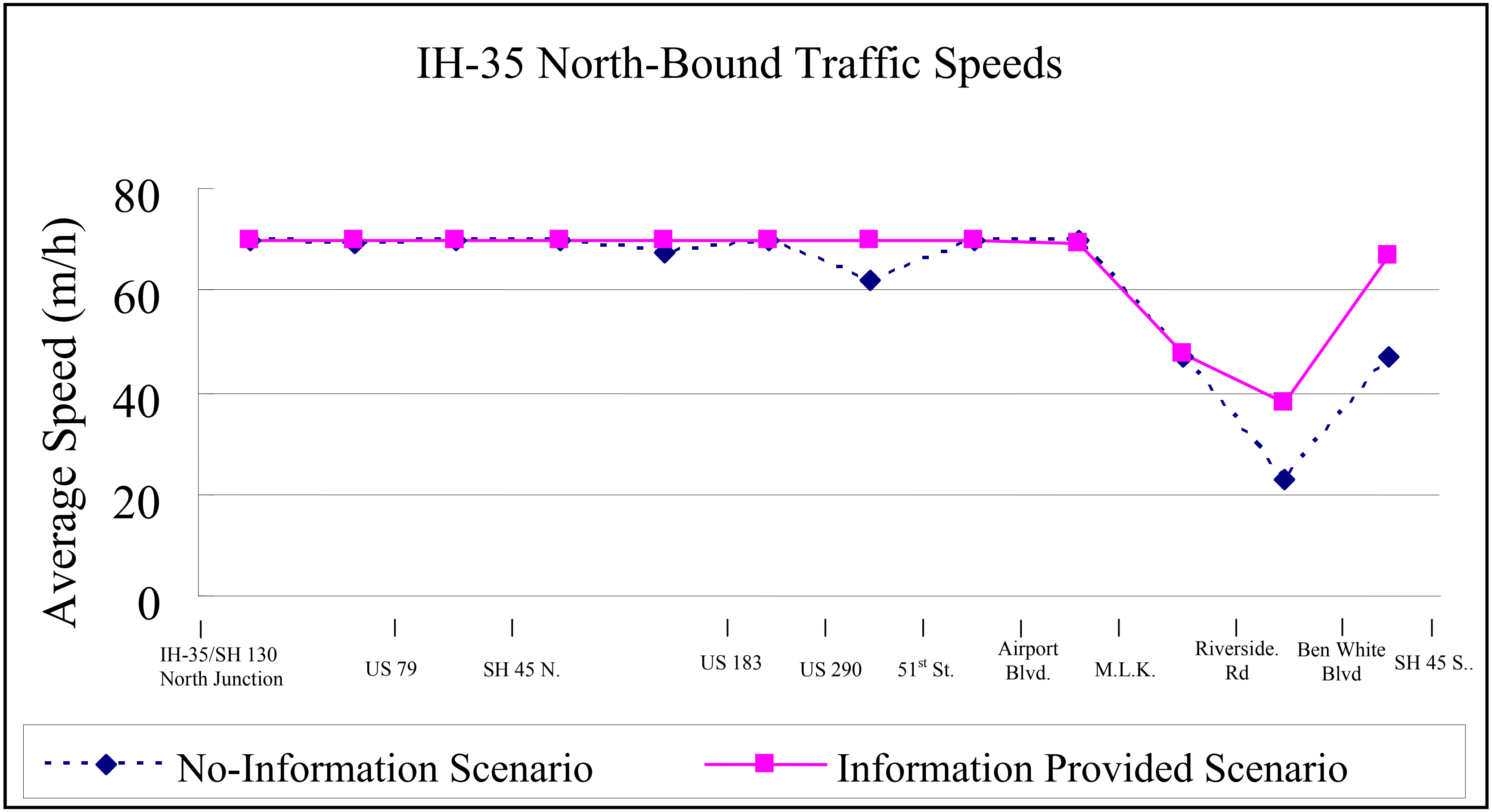


Figure 4.8: IH-35 North-Bound Traffic Speeds

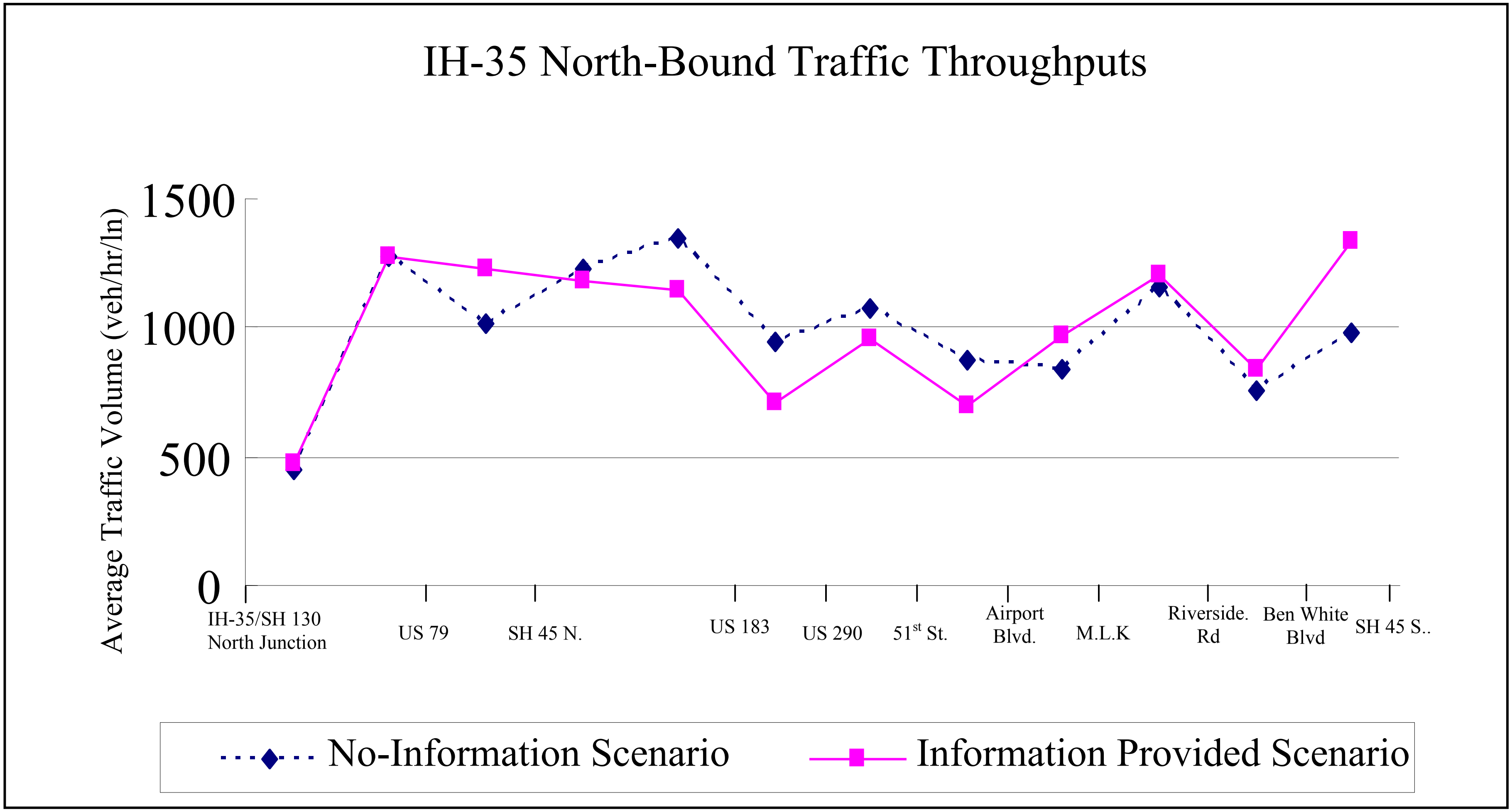


Figure 4.9: IH-35 North-Bound Traffic Throughputs

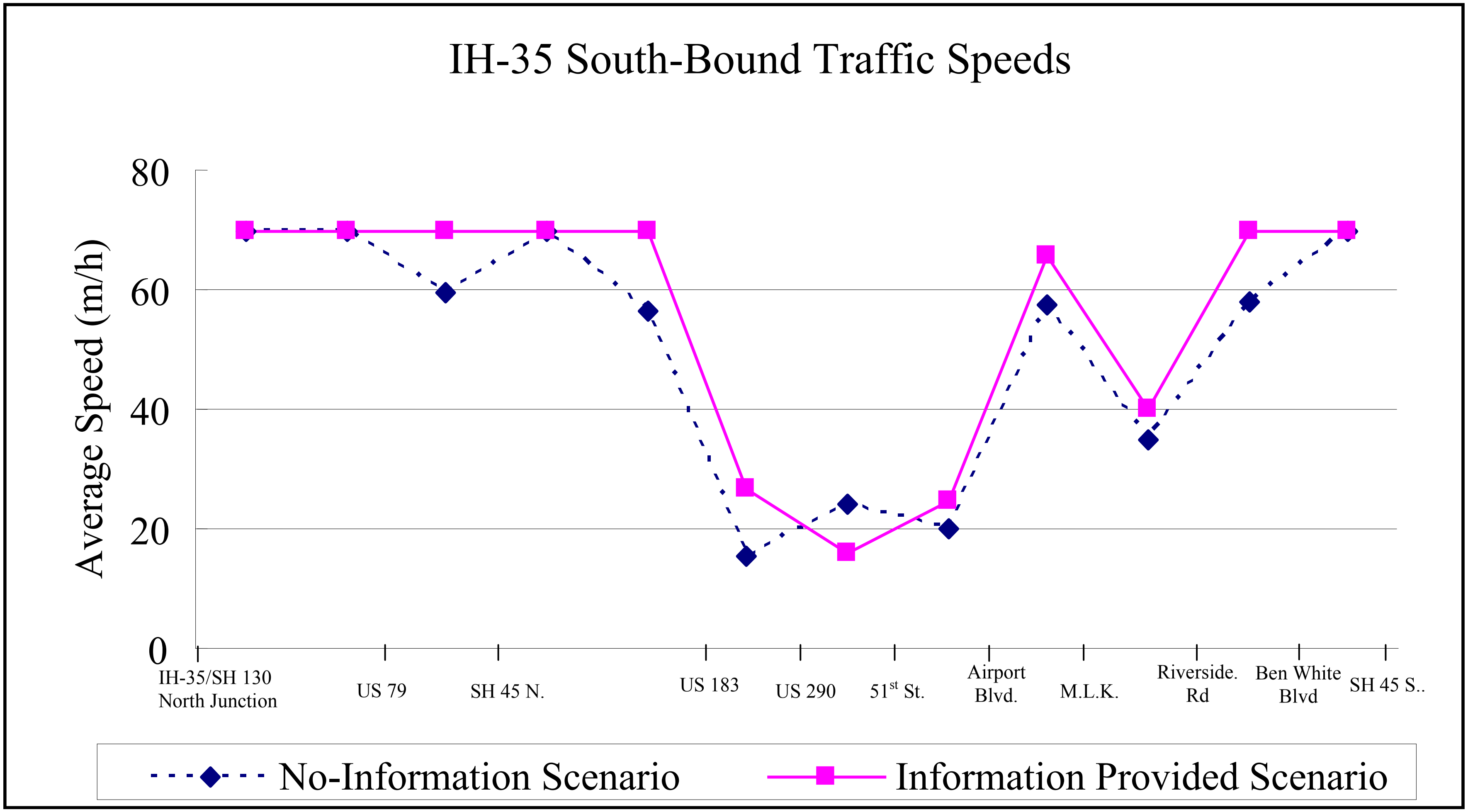


Figure 4.10: IH-35 South-Bound Traffic Speeds

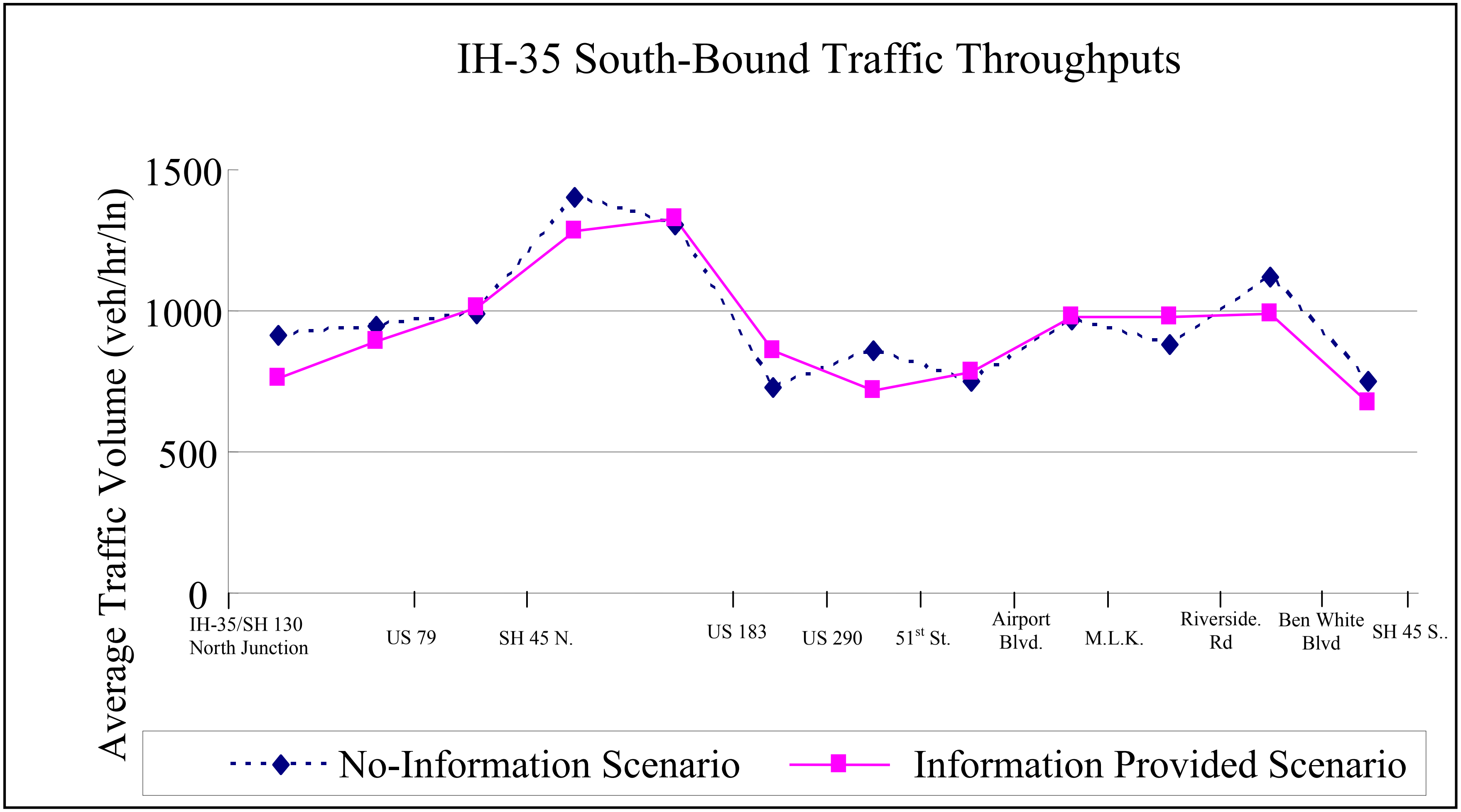


Figure 4.11: IH-35 South-Bound Traffic Throughputs

4.4 Potential Impact of ATIS on Toll Road Operations

4.4.1 Potential Toll Road Usage Increase

Traffic diversion to toll roads: Evaluation of toll road traffic volume changes with the provision of traveler information is one of the core goals of this study. The DYNASMART-P simulation results provide the link performance data. Based on these data, an analysis on the performance of toll road links on SH 130 was conducted. A number of SH 130 toll road links are analyzed and results presented in Appendix C. Simulation results from the DYNASMART-P include volume, speed, and density for every link in the network. Therefore, the volume on each tolled link can be obtained and the corresponding vehicle miles traveled (VMT) can be calculated. Figure 4.12 illustrates traffic volumes on southbound SH 130 with and without traveler information provided and Figure 4.13 illustrates traffic volumes on northbound SH 130.

Significant increases: With the provision of traveler information, the traffic volumes on toll road links increase by as much as 110% in some segments, and by about 50% on average. A reasonable explanation is that a portion of travelers divert to SH 130 toll roads to save travel time when they are informed of traffic congestion on the non-tolled alternative IH 35 route. Even with this increased traffic volume on the toll road, free-flow speed is maintained. No congestion occurs on toll roads at the current travel demand level. More information on the toll road traffic simulations and revenue increase are included in Appendix C of this document.

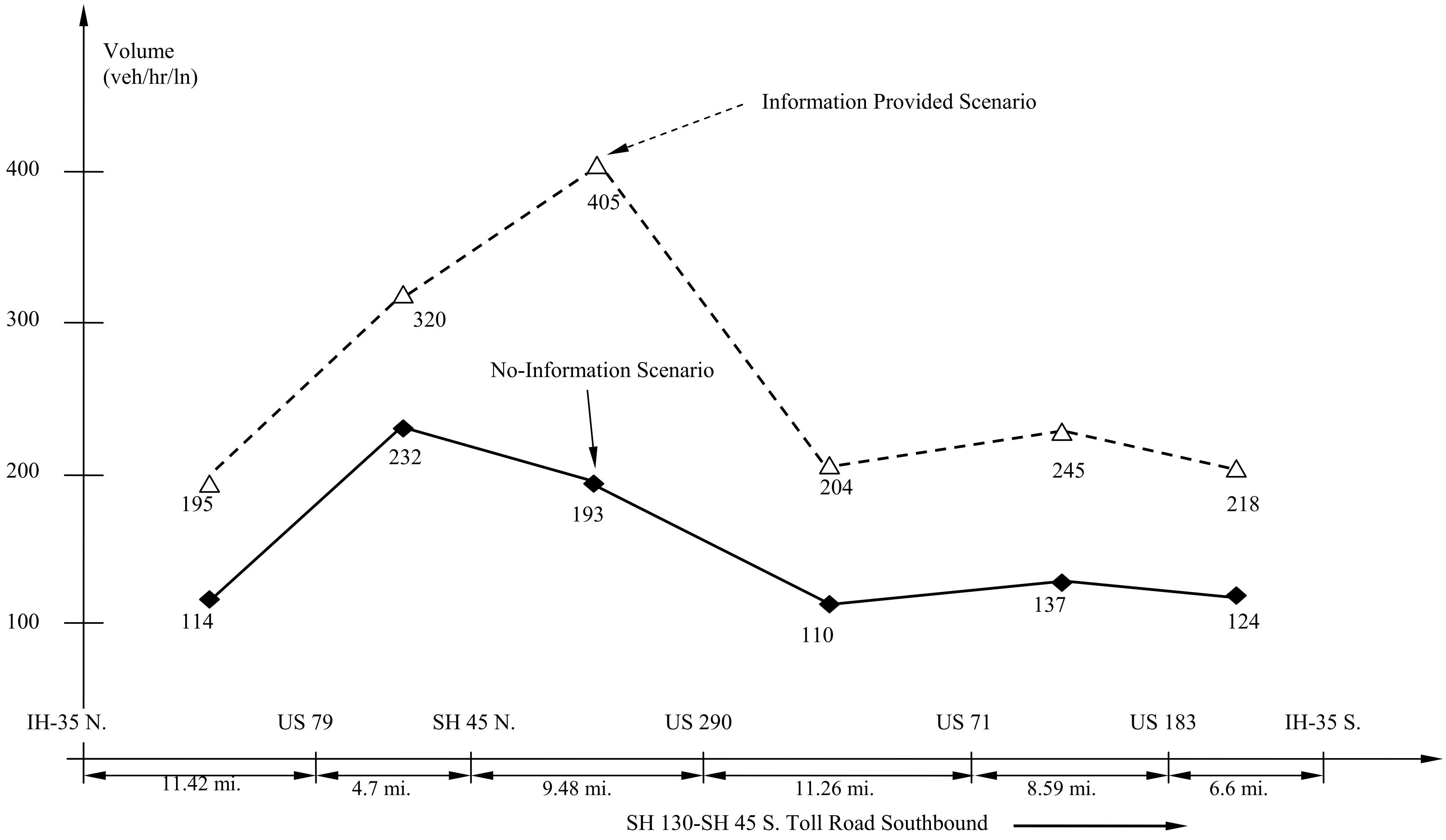


Figure 4.12: Traffic Volumes on SH 130 Toll Road Southbound Links

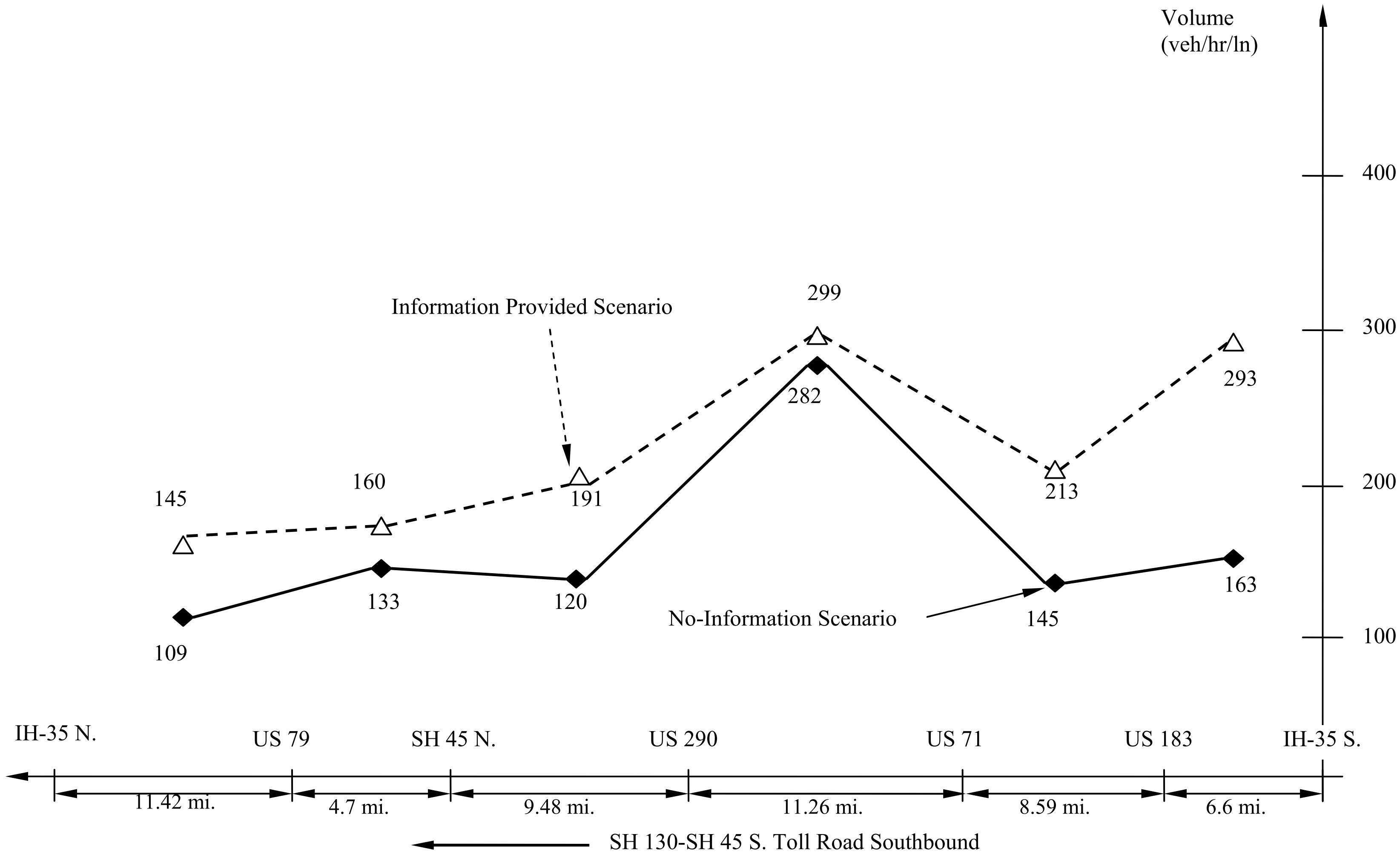


Figure 4.13: Traffic Volumes on SH 130 Toll Road Northbound Links

4.4.2 Potential Toll Revenue Increase

The simulation results indicate that with provision of traveler information the traffic volume on toll roads increases significantly. Consequently, the toll revenue will increase as well. In order to better explain the potential impact of traveler information on toll roads, the potential toll revenue increase will be estimated in this section. Given a set of unit prices ($c_1, c_2, \ldots, c_m$), which are unit toll costs for *m* types of vehicles ($/mile), and the vehicle miles traveled (VMT) on toll roads for each type of vehicle ($VMT_1, VMT_2, \ldots VMT_m$), the total toll revenue can be roughly estimated as follows:

$$R = \sum_{i=1}^{m} (c_i \times VMT_i) \tag{4.1}$$

and

$$VMT_i = \sum_{j=1}^{n} l_j \times N_{ij} \tag{4.2}$$

where

l_j—the length of toll link *j*
N_{ij}—the volume of type *i* vehicle on link *j*

Based on equations 4.1 and 4.2, the toll revenue can be estimated. Here the SH 130 toll road is used as an example to illustrate the estimation of potential toll revenue increase. Simulation results from DYNASMART-P provide analysts with volume, speed, and density for every link in the network. Therefore, the volume on each tolled link can be obtained and the corresponding VMT can be calculated. Figure 4.12 illustrates traffic volumes on southbound SH 130 with and without traveler information provided and Figure 4.13 illustrates traffic volumes on northbound SH 130.

Assume an average 0.1$/mile toll rate, the toll revenue during morning peak hour from the SH 130 toll road is estimated as follows:

Scenario 1: without DMS deployment
Southbound:

$$\begin{aligned} R_S &= \sum_{i=1}^{m} (c_i \times VMT_i) \\ &= 0.1 \times \left[(114 \times 11.42 + 232 \times 4.7 + 193 \times 9.48 + 110 \times 11.26 + 137 \times 8.59) \times 2 \right] \\ &= 1327.47 \quad \$ / hr \end{aligned}$$

Northbound:

$$\begin{aligned} R_N &= \sum_{i=1}^{m} (c_i \times VMT_i) \\ &= 0.1 \times \left[(109 \times 11.42 + 133 \times 4.7 + 120 \times 9.48 + 282 \times 11.26 + 145 \times 8.59) \times 2 \right] \\ &= 1310.01 \quad \$ / hr \end{aligned}$$

Total = 1327.47 + 1310.01 = 2637.48 $/hr

Scenario 2: with DMS deployment

Southbound:

$$R_{S-DMS} = \sum_{i=1}^{m}(c_i \times VMT_i)$$

$$= 0.1 \times \left[(195 \times 11.42 + 320 \times 4.7 + 405 \times 9.48 + 204 \times 11.26 + 245 \times 8.59) \times 2\right]$$

$$= 2394.38 \quad \$/hr$$

Northbound:

$$R_N = \sum_{i=1}^{m}(c_i \times VMT_i)$$

$$= 0.1 \times \left[(145 \times 11.42 + 160 \times 4.7 + 191 \times 9.48 + 299 \times 11.26 + 213 \times 8.59) \times 2\right]$$

$$= \quad 1883 \quad \$/hr$$

Total = 2394.38 + 1883 = 4277.38 $/hr

The resulting estimates indicate that the toll road revenue increases significantly with the provision of traveler information. In the no-DMS scenario the toll revenue from SH 130 is about 2637.5 $/hr and in the DMS scenario the toll revenue increases to about 4277 $/hr, a 62% increase. Because the toll rate was assumed to be 0.1$/mile on average in this study, the real revenue might be different. However, it is very likely that the proper traveler information provision will increase toll usage as well as toll revenue.

The revenue estimations are further compared with the official results published in the Central Texas toll road project revenue forecasting report. The official revenue forecasts are shown in Table 4.2.

Table 4.2: SH 130 Element Toll Revenue Forecast

Year	Annual Toll Revenue (x1000) by Segment				
	1	2	3	4	Total
	IH 35-US 79	US 79-US 290	US 290-US 71	US 71-US 183	IH 35-US 183
2008	$ 5,053	$ 6,839	$ 4,123	$ 2,470	$ 18,485

Assuming a 120-minute duration of peak hours in the morning and evening and a peak-to-daily ratio of 34.5% in traffic volume, the revenue estimations based on DYNASMART model outputs are calculated and illustrated in Table 4.3. Because the CAMPO 2007 travel demand forecasts were used in DYNASMART modeling, the annual toll revenue estimations are for the fiscal year 2007.

Table 4.3: SH 130 Element Toll Revenue Forecast Comparison

Year	Scenario	Annual Toll Revenue (x1000) by Segment				
		1	2	3	4	Total
		IH 35-US 79	US 79-US 290	US 290-US 71	US 71-US 183	IH 35-US 183
2008	Official	$ 5,053	$ 6,839	$ 4,123	$ 2,470	$ 18,485
2007	No DMS	$ 1,990	$3,475	$ 3,275	$ 1,797	$1,0537
	DMS	$ 2,881	$ 5,867	$ 4,203	$ 2,919	$15,870

In Table 4.3 one can see that the official revenue forecasts are significantly (about 80%) higher than the base-case (no DMS) estimation results based on DYNASMART outputs. Several reasons caused the difference. First, the official revenue forecast is based on the year 2008 travel demand and the DYNASMART revenue forecast is based on the year 2007 demand. Both demand data are provided by CAMPO. However, the 2008 demand is higher than that in 2007 with a certain demand growth rate. Thus the official forecast on traffic volume and resulting revenue should also be higher. Second, the DYNASMART revenue estimation uses a weighted average toll rate of 0.1$/mile, which is 22% lower than the toll rate in the official report ($0.122/mile). Third, when calculating the revenues, the official forecasts use longer link-segment length (about 10% longer) because some collectors are included. Finally, the official forecasts are generated based on traditional static traffic assignment and the DYNASMART forecasts are generated with dynamic traffic assignment. As a result, the forecasted link volumes and the revenues are different. In this study, the toll road traffic volume predictions from the DYNASMAT model are lower than the official predictions.

Although the revenue estimations are different from the official forecasts, the results indicate that providing traveler information can significantly increase the toll revenue. With DMS deployments the estimated toll revenues become close to the official forecasts. Thus ATIS deployment can be used as an effective method to increase toll revenue and reduce the financial risk of toll road projects.

4.5 Summary of Findings

Benefits of traffic redistribution: Greater diversion of traffic to toll roads has two benefits: increased toll collections, and reduced congestion on non-tolled routes. The first benefit reduces the need for state subsidy of toll projects, but it is the second benefit that may be of greater importance to TxDOT. Better utilization of the added capacity provided by toll roads helps the public realize the true purposes of supporting toll roads: namely, greater mobility, improved safety, and reduced pollution for the entire system. To assess the impacts of ATIS in the toll road context, a case study was conducted of the Austin transportation network. DYNASMART-P program was chosen for the simulation experiments because it represents the state of the art of dynamic traffic simulation models. In addition, it has the unique function that allows users to examine the impact of traveler information on the transportation system, which best suits the research goals in this study.

Simulation results: The simulation results indicate that the ATIS deployments would encourage more travelers to choose toll roads if information regarding congestion on alternate routes were provided. The overall system performance would be improved with the deployments of ATIS. In the case of the SH 130 toll road and the nontoll alternative IH-35 route, providing traveler information to travelers on the IH-35 corridor would:

- Improve the overall network performance in travel times, delays, and number of stops.
- Significantly increase the number of SH 130/SH 45 toll road users. All six toll road links examined in this study show higher traffic volume in the ATIS scenario.
- Reduce the traffic on IH-35. The examination of link 10242 indicates that a portion of IH-35 traffic diverted to SH 130 toll roads at the IH-35 and SH 130 junction.
- Improve the performance of IH-35 main lanes. Four out of six IH-35 links examined show improvement. However, traveler information would not necessarily improve the performance of every link, although the entire network performance would be improved. The performance of some links could be worse if more informed drivers used that link.
- DYNASMART-P model well suits the scope of assessing the impact of traveler information in the context of toll roads. It may be the best tool so far to do this type of analysis.

5. Implementation Issues and Strategies for ATIS Deployment in Texas

5.1 Introduction

The potential of traveler information systems to divert traffic to toll roads has been demonstrated in two previous chapters of this report. This chapter focuses on the implementation issues. Specifically, the technical and financial issues are presented so that traveler information systems could be better used to enhance both freeway and alternative toll road traffic operations in Texas.

Current ATIS technologies include internet, telephone, in-vehicle, and roadside-based systems, each with unique strengths and weaknesses. For example, while a number of positive outcomes have been observed from the installation of roadside dynamic message signs, there are potential shortcomings. Once constructed, the technology is not nimble to advances and may be very costly to operate and maintain. The infrastructure is static and expensive, and impact is limited to a small area around the sign. In addition, the amount of information that can be provided is very limited. In fact, many drivers never get the whole message unless they are already in congestion. Internet and telephone based ATIS have shortcomings, too. Internet-based systems are primarily for pre-trip planning, but users may not have access to information that is relevant to their trip, or the information may be stale by the time the trip is made. Telephone-based systems have similar weaknesses, plus requiring the user to know whom to call. Phone use also requires some "visioning" while talking, which is the reason why phone use impairs driver performance and traffic safety. Many states have moved to ban cell phone use while driving.

In addition to evaluating the cost effectiveness and requirements for deploying current technologies, the research team reviewed newer technologies under development in the national Intelligent Vehicle Infrastructure initiative. For example, push technology is known to be more successful than demand-based systems because people prefer to be passive users rather than having to act to receive information. To facilitate motorists, a Vehicle Positioning System On-Board Unit (OBU) with an autonomous positioning system such as a Global Positioning System (GPS) is able to "announce" itself within a network, and information customized for location can be fed to the unit.

In this chapter, the costs and benefits of deploying traveler information are evaluated. Costs include installation, operating, and maintenance. The benefits to toll roads are estimated on the basis of increased traffic and resulting increase in toll revenue. The benefits of reduced congestion on the non-tolled system are also evaluated. While congestion relief benefits may not translate directly into revenues, they can justify funding for deployment.

Funding opportunities will also be explored in this chapter. For example, the Federal Highway Administration (FHWA) has funded operational field tests to determine contribution of an ATIS deployment/technology to ITS America National Program Plan. ATIS deployment trials, called metropolitan model deployment initiatives, have been conducted in Seattle, Phoenix, San Antonio, and New York since 1996. These projects comprise a range of data collection and sharing technologies, incremental improvements to existing incident management capabilities, and enhancements to existing ATIS offered in a region (Wunderlich 2000). The new SAFETEA-LU legislation has provisions for ITS funding. Since providing traveler information to toll road users is found to have high payback, all sources of funding including funding from the private sector are examined. These results indicate that it would be beneficial to the TxDOT to pursue more resource for ATIS deployment.

5.2 Costs and Benefits of ATIS

The costs associated with an ATIS deployment usually include installation costs and operation & maintenance (O&M) costs. The benefits of an ATIS deployment can be categorized into two types: benefits to travelers and benefits to transportation agencies. Understanding the cost and benefit structures of various ATIS deployments would help TxDOT in decision-making on ATIS investments.

5.2.1 Costs of Various ATIS Technologies

The cost of an ATIS deployment includes installation cost and O&M cost. Installation cost is usually the total of published ATIS unit prices plus any additional labor or materials required to satisfactorily complete the installation. All ATIS systems can be considered depreciable properties. Therefore, the unit cost of an ATIS deployment can be measured by its capital cost, which is usually the total of the purchase price, the cost of any upgrades or improvements, and soft costs such as interest, legal and accounting fees, etc.

O&M costs include those major components required to operate and maintain a facility, i.e. labor, fuel, electricity, equipment and material. In order to apply any O&M costing methodology to a specific facility, it is necessary to make adjustments that consider the life of the facility, its physical condition, type of construction and the accessibility to the site/costs, costs of utilities/services and if required, programming costs.

The ITS Joint Program Office (ITS JPO) of the U.S. Department of Transportation (USDOT) has surveyed nationwide ITS projects and developed a cost database for various ITS equipment. This database provides the ITS professional community with quick and easy access to costs data to be used in developing cost estimates of ITS deployments. Table 5.1 shows an example of the roadside information equipment costs in terms of capital cost and O&M cost. In general, the installation and O&M costs vary depending on where the ATIS project is deployed and what equipment is used.

Table 5.2 presents a summary of equipment costs for an in-vehicle information system. Table 5.3 presents a summary of equipment costs for information kiosks and personal devices. Table 5.4 shows the equipment costs for information service providers.

Table 5.1: Equipment Costs for Roadside Information

Unit Cost Element	Life	Capital Cost	O&M Cost	Description
	Years	**$K, 2004 Dollars**	**$K, 2004 Dollars**	
Roadside Message Sign	20	39 - 59	2 - 3	Fixed message board for HOV and HOT lanes.
Wireline to Roadside Message Sign	20	6 - 8		Wireline to VMS (0.5 mile upstation).
Variable Message Sign	10	47 - 117	2.4 - 6	Low capital cost is for smaller VMS installed along arterial. High capital cost is for full matrix, LED, 3-line, walk-in VMS installed on freeway. Cost does not include installation.
Variable Message Sign Tower	20	25 - 120		Low capital cost is for a small structure for arterials. High capital cost is for a larger structure spanning 3-4 lanes. VMS tower structure requires minimal maintenance.
Variable Message Sign - Portable	14	21 - 25	1.1 - 1.8	Trailer mounted VMS (3-line, 8" character display); includes trailer, solar or diesel powered.
Highway Advisory Radio	20	15 - 30	0.6 - 1	Capital cost is for a 10-watt HAR. Includes processor, antenna, transmitters, battery back-up, cabinet, rack mounting, lighting, mounts, connectors, cable, and license fee. Super HAR costs an additional $9-10K (larger antenna). Primary use of the super HAR is to gain a stronger signal.
Highway Advisory Radio Sign	10	5 - 9	0	Cost is for a HAR sign with flashing beacons. Includes cost of the controller.
Roadside Probe Beacon	5	5 - 8	0.5 - 0.8	Two-way device (per location).
LED Count-down Signal	10	0.307 - 0.426		Costs range from low (two 12 x 12-inch dual housing unit) to high (16 x 18-inch single housed unit). Signal indicates time remaining for pedestrian to cross, and a walk or don't walk icon. Count-down signals use low 8-watt LED bulbs, which require replacement approximately every 5-7 years.
Pedestrian Crossing Illumination System	5	26.9 - 41	2.6 - 4	The capital cost range includes cost of equipment and installation. Equipment includes fixtures - 4 lamps per lane - for a three lane crosswalk, controller, pole, and push button activator. Installation is estimated at 150 - 200 % of the total equipment cost. Capital cost would be greater if the system included automated activation of the in-pavement lighting system. O&M is approximately 10% of the equipment cost.
Variable Speed Display Sign		3.5 - 4.7		Low range is for a variable speed limit display system. High range includes static speed sign, speed detector (radar), and display system.

(Source: US Department of Transportation, ITS Joint Program Office, 2006)

Table 5.2: Equipment Costs for In-Vehicle Information System

Unit Cost Element	Life	Capital Cost	O&M Cost	Description
	Years	$K, 2004 Dollars	$K, 2004 Dollars	
Communication Equipment	7	0.2 - 0.4	0.004 - 0.007	Wireless data transceiver.
In-Vehicle Display	7	0.04 - 0.1	0.001 - 0.002	In-vehicle display/warning interface. Software is COTS.
In-Vehicle Signing System	7	0.13 - 0.31	0.002 - 0.006	Interface to active tag reader, processor for active tag decode, and display device for messages.
GPS/DGPS	7	0.2 - 0.4	0.004 - 0.01	Global Positioning System/Differential Global Positioning Systems.
GIS Software	7	0.2 - 0.3		Geographical Information System (GIS) software for performing route planning.
Route Guidance Processor	7	0.08 - 0.12	0.002	Limited processor for route guidance functionality.
Electronic Toll Equipment	7	0.03 - 0.1		Active tag interface and debit/credit card interface.
Software, Processor for Probe Vehicle	7	0.05 - 0.14	0.001 - 0.003	Software and processor for communication to roadside infrastructure, signal generator, message generator. Software is COTS.
Toll Tag/Transponder	5	0.025		Most toll tags/transponders cost approx. $25. Some toll agencies require users to pay a refundable deposit in lieu of purchasing a tag. The user is charged the cost of the tag if the tag is lost.
In-Vehicle Navigation System	7	2.5		COTS product that includes in-vehicle display and supporting software.

(Source: US Department of Transportation, ITS Joint Program Office, 2006)

Table 5.3: Equipment Costs for Information Kiosks and Personal Devices

Unit Cost Element	Life	Capital Cost	O&M Cost	Description
	Years	$K, 2004 Dollars	$K, 2004 Dollars	
Informational Kiosk	7	11 - 24	1.1 - 4.4	Includes hardware, enclosure, installation, modem server, and map software.
Integration of Kiosk with Existing Systems	7	2.1 - 26.3		Software costs are for COTS (low) and developed/outdoor (high).
Kiosk Upgrade for Interactive Usage	5	5 - 8	0.5 - 0.8	Interactive information display interface (upgrade from existing interface).
Kiosk Software Upgrade for Interactive Usage	5	10 - 12		Software is COTS.
Basic PDA	7	0.1 - 0.3		Personal digital assistant. Personal digital assistant. O&M estimated at 2% of capital.
Advanced PDA for Route Guidance, Interactive Information	7	0.4 - 0.6		Personal digital assistant with advanced capabilities (route guidance, interactive).
Modem Interface, Antenna for PDA	7	0.14 - 0.2	0.003 - 0.004	Modem interface and separate antenna for wireless capability.
PDA with Wireless Modem	2	0.2 - 0.6	0.11 - 0.3	Personal digital assistant with wireless modem. O&M based on monthly subscriber rate plans of 50 KB (low) and 150 KB (high).

(Source: US Department of Transportation, ITS Joint Program Office, 2006)

Table 5.4: Equipment Costs for Information Service Provider

Unit Cost Element	Life	Capital Cost	O&M Cost	Description
	Years	$K, 2004 Dollars	$K, 2004 Dollars	
Information Service Provider Hardware	5	27 - 40	0.54 – 0.8	Includes 2 servers and 5 workstations. O&M is estimated at 2%; could be higher for responsive and preventative maintenance.
Systems Integration	20	85 - 104		Integration with other systems.
Information Service Provider Software	20	264 - 528	13.2 - 26.4	Includes database software (COTS) and traffic analysis software.
Map Database Software	2	14 - 29		Software is COTS.
Information Service Provider Labor			239 - 341	Description is based on 1995 data: 2 Staff @ 50K to 75K and 1 staff @ 75K to 100K. Salary cost are fully loaded prices and include base salary, overtime, overhead, benefits, etc.
FM Subcarrier Lease			111 - 221	Cost is per year.
Hardware Upgrade for Interactive Information	5	12 - 18	0.24 - 0.36	Includes 1 server and 2 workstations. O&M is estimated at 2%; could be higher for responsive and preventative maintenance.
Software Upgrade for Interactive Information	20	240 - 480	24-Dec	Trip planning software (includes some development costs).
Added Labor for Interactive Information			136 - 205	Description is based on 1995 data: 1 Staff @ 50K to 75K for 2 shifts. Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Software Upgrade for Route Guidance	20	240 - 480	24-Dec	Route selection software. Software is COTS.
Map Database Upgrade for Route Guidance	2	96 - 192		Map database software upgrade.

(Source: US Department of Transportation, ITS Joint Program Office, 2006)

5.2.2 Benefits of ATIS Technologies

Benefits to Travelers: Incident locations, travel time, alternative route information, weather information, and amber alert are made available to travelers via ATIS infrastructure, road signs, on-board units, radios, and personal devices. The commuter survey in the Austin area has shown that commuters strongly desire better traffic information and more reliable travel time information that can be provided by various types of ATIS equipment.

It has been widely recognized that providing traveler information to drivers has the potential to mitigate congestion in the road network by influencing travelers' pre-trip and en-route decisions. Providing real-time information, as documented in Chapter 4, can enhance traffic distribution and benefit a system of tolled and non-tolled roads by increasing the use of toll roads and relieving congestion on non-tolled routes. The resulting benefits of ATIS to travelers and transportation agencies include:

- Increase customer satisfaction.
- Reduce travel time.
- Reduce delay.
- Increase travel time reliability.
- Improve commuters' confidence in arriving trip destinations on time.
- Reduce number of stops.
- Increase vehicle throughput in the transportation network.
- Reduce fuel and environmental cost.

Benefits to Transportation Agencies: In this study the DYNASMART-P simulation experiments have shown that providing congestion information to traveler information could increase toll road usage and alleviate congestion on alternative freeways. The findings imply that transportation agencies can use ATIS as an effective method to enhance traffic operations on both toll roads and non-tolled roads. Increased throughput on toll roads and alternative freeways will enhance the effectiveness of transportation infrastructure. Better utilization of existing capacity may reduce the need for adding new capacities. Previous studies have reported 8-22% increases in throughput by making more efficient use of existing capacity. This study found that ATIS could benefit 2007 Austin network with a 2% travel time reduction and an 11% stop time reduction. Therefore, ATIS is a promising ITS deployment that can make such improvements for transportation agencies.

In addition, ATIS deployments enable traffic managers monitor and control traffic operations remotely. Traffic information, hazard warnings, roadway safety, and recommendations on alternative routes can be disseminated to travelers in ways never before possible. Better traffic management can bring substantial benefits to transportation agency operations.

5.2.3 A Cost-Benefit Analysis of ATIS Technologies

Cost-benefit analysis is often used to determine cost effectiveness of an ITS deployment at the stage of planning. Zavergiu (1996) presents an ITS cost-benefit analysis framework that can be used to predict benefits for three categories of beneficiaries: the first order beneficiary consists of travelers, the second order beneficiary consists of transportation agencies, and the third order beneficiary is comprised of external economy and environment. The classification of the beneficiaries provides a better understanding of the true benefits of ITS. Lee (2000) presents a cost-benefit study on a traveler information system deployed in Washington State in which all internal benefits to travelers and external benefits to the environment and congestion were converted into dollar values. The value of time, dollar value of pollution cost, and the marginal cost of congestions were used in this cost-benefit analysis. Using similar method, in this section, a case study of cost-benefit analysis for the Austin, TX region is presented, using available tools, and collected or simulated traffic data.

ITS Deployment Analysis System (IDAS): In order to assist decision makers in such cost-benefit analysis, some computer programs were developed at the federal level. The most often used programs include IDAS (Cambridge Systematics, 2001) and SCRITS (SAIC, 1999), which were discussed and compared by Peng et al. (2000) along with other ITS evaluation programs. The application of these computer programs has remarkably enhanced the ITS benefits evaluation process (Sadek and Baah, 2003).

IDAS is a sketch-planning tool designed to assist transportation planners and ITS specialists in completing a comparative cost-benefit analysis for potential ITS projects. It can be used to estimate impacts, benefits, and costs attributed to deploying ITS components. IDAS is a post-planning tool that requires travel demand models to be processed before being imported. IDAS is also capable of implementing mode split and traffic assignment steps associated with the traditional model. Working with the output of existing transportation planning models, IDAS is capable of predicting costs and benefits for more than 60 types of ITS options. Within IDAS, the users can:

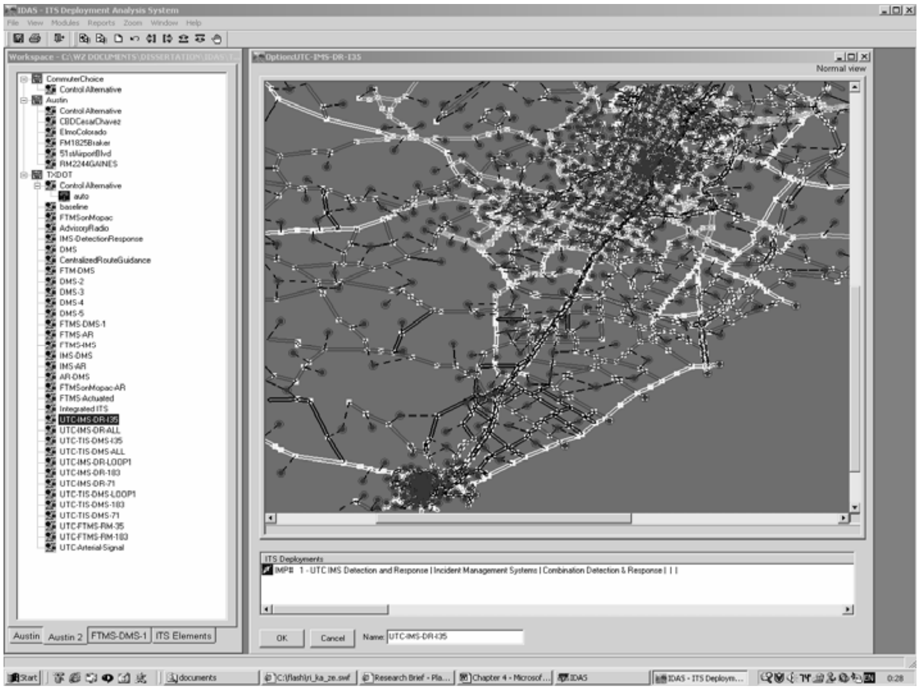
- Compare and screen ITS deployment alternatives.
- Estimate the impacts and traveler responses to ITS.
- Develop inventories of ITS equipment needed for proposed deployments and identify cost sharing opportunities.
- Estimate life-cycle costs including capital and O&M costs for the public and private sectors.
- Provide documentation for transition into design and implementation.

The performance measures used by IDAS include:

- Changes in user mobility
- Changes in travel time/speed.
- Changes in travel time reliability (non-recurring congestion duration)
- Changes in fuel costs.

- Changes in operating costs.
- Changes in accident costs.
- Changes in emissions and noise.

Figure 5.1 shows a snapshot of IDAS analysis interface.



IMP# 1 - UTC IMS Detection and Response | Incident Management Systems | Combination Detection & Response | | |

Name: UTC-IMS-DR-I35

Figure 5.1: Evaluate ITS Options with IDAS

Compared to other ITS evaluation programs such as SCRITS, IDAS is a complicated program to evaluate for ITS options. Basically, IDAS can estimate the costs as well as the benefits of an ITS option. The outputs of IDAS are the costs and benefits of the ITS options in dollars. A benefit-cost ratio is calculated for each ITS option. All of the ITS options benefits are measured in dollars. For example, IDAS use the average value of time to measure the benefits of time savings, travel time reliabilities, etc. In order to apply IDAS to a certain area, some parameters in the program need to be customized such as the average fuel price, the average value of time, etc. If the parameters are difficult to measure, then the default values in IDAS programs can be used. An example is the emission costs ($/ton). The IDAS program gives the basic values for the costs of hydrocarbons, carbon monoxides, nitrous oxides, etc. If users are not able to customize these values, the default values can be applied.

Numerical Analysis: A simulation study has already been completed using the DYNASMART-P model to assess the impact of traveler information on both tolled and non-tolled roads. As described already in Chapter 4, two scenarios have been designed to perform the simulation experiment:

Scenario 1: SH 130 tolled, no traveler information provided. This scenario is considered the baseline scenario. In this scenario, SH 130 and SH 45 South are toll roads. There are no other toll roads in the Austin network. In addition, no traveler information is provided. In this no-ATIS scenario, DYNASMART-P simulation results show that the average trip distance is 8.4 miles and the total trip distance during the 100-minute period is about 4,492,723 vehicle miles. The average travel time for all the trips made during the 100-minute morning peak period is 29 minutes, in which 12.8 minutes are stop time. The overall travel time is about 259,229 vehicle-hours and the total stop time is about 114,641 hours.

Scenario 2: **SH 130 tolled, traveler information provided via DMS**. In this scenario, SH 130 is tolled. Traveler information is provided along IH-35 via DMS deployments. A total of 19 DMSs are deployed along IH-35 at major diversion points, which include the junctions of IH-35 and major freeways in the Austin area, for example, the junction of IH-35 and SH 130 in the north, the junction of IH-35 and SH 45 North, and the junction of HI-35 and US 180.

According to the DYNASMART-P simulation outputs, the average trip distance is 8.9 miles, which is 0.5 miles longer than the baseline scenario. The total trip distance during the 100-minute period is about 4,777,624 vehicle miles. The average travel time for all the trips made during the 100-minute morning peak period is 28.45 minutes, in which 11.45 minutes are stop time. The system average travel time is about 0.5 minute less than the baseline scenario and the average stop time is about 1.4 minute less than the baseline scenario. The overall travel time in this scenario is about 254,549 vehicle-hours and the total stop time is about 102,425 hours.

IDAS program was used to perform cost-benefit analysis for the DMS deployments from the simulation study. The simulation outputs (i.e., the operational impact of DMS deployments described earlier) are used to determine the parameters and user inputs in IDAS. Table 5.5 presents the improvements of traveler information deployment.

Table 5.5: Network Performance with and without Traveler Information

	No-Information	Information Provided	Change
Average Trip Distance (miles)	8.4	8.9	+6%
Total VMT	4,500,000	4,800,000	+6.3%
Total Travel Time (hrs)	260,000	255,000	-2%
Average Travel Time (min.)	29	28.5	-2%
Total Stop Time (hrs)	115,000	102,000	-11%
Average Stop Time (min.)	12.8	11. 5	-11%

After running analysis in IDAS, the results are obtained on the proposed DMS deployments. Table 5.6 presents a summary of the costs of DMS deployments and video surveillance for incident detection and response.

Table 5.6: Cost Estimations for IH-35 DMS Deployment

Cost	**Amount ($)**
DMS at IH-35 N./SH130 (19 units)	
Public Capital	$489,975.18
Private Capital	$0.00
Public O&M	$234,600.00
Private O&M	$0.00
SUBTOTAL	**$724,575.18**
IH-35 Incident Detection & Response (Video)	
Public Capital	$116,888.58
Private Capital	$0.00
Public O&M	$929,175.00
Private O&M	$0.00
SUBTOTAL	**$1,046,063.58**
TOTAL:	
Public Capital	$606,863.75
Private Capital	$0.00
Public O&M	$1,163,775.00
Private O&M	$0.00
GRAND TOTAL:	**$1,770,638.76**

Table 5.7 presents a summary of the cost-benefit analysis results. All benefits and costs are converted into dollar values.

Table 5.7: Cost-Benefit Analysis Output from IDAS

Benefit/Cost Summary			
Benefits are reported in 2003 dollars			
Annual Benefits	**Weight**		**DMS on IH-35**
Change in User Mobility	1.00	$	2,498,203
Change in Costs Paid by Users			
Fuel Costs	1.00	$	3,921,847
Non-fuel Operating Costs	1.00	$	
Accident Costs (Internal Only)	1.00	$	979,001
Change in External Costs			
Accident Costs (External Only)	1.00	$	172,765
Emissions			
HC/ROG	1.00	$	60,220
Nox	1.00	$	240,007
CO	1.00	$	705,219
Noise	1.00	$	0
Total Annual Benefits		**$**	**8,577,335**
Annual Costs			
Average Annual Private Sector Cost		**$**	0
Average Annual Public Sector Cost		**$**	1,770,639
Total Annual Cost		**$**	**1,770,639**
Benefit/Cost Comparison			
Net Benefit (Annual Benefit - Annual Cost)		**$**	**6,806,696**
B/C Ratio (Annual Benefit/Annual Cost)			**4.84**

According to the benefit-cost analysis results, it can be seen that the proposed DMS deployments yield positive net benefits, with a benefit-cost ratio of 4.84. Providing traveler information, in this case, yields benefits to improving user mobility, reducing fuel costs, enhancing traffic safety, and reducing air pollution. The costs include equipment capital costs and O&M costs. A benefit/cost ratio greater than 1 indicates that the proposed ATIS deployment is cost-effective. It provides decision makers a good measure on the ATIS investment. The toll revenue, however, is not considered a benefit or a cost in IDAS because toll road users have to pay for that.

In addition to DMS, IDAS is capable of analyzing the costs and benefits of some other information provision strategies such as:

- Highway Advisory Radio.
- Telephone-Based Multimodal Traveler Information System.
- Kiosk Traveler Information.
- Handheld Personal Device.
- In-Vehicle Navigation System.

Analysts can customize the equipment costs and O&M costs according to local market. In general, IDAS provides analysts a practical tool to perform cost-benefit analysis for various ATIS deployments.

5.3 A Framework for Information Acquiring, Processing, and Delivering

This section presents the potential implementation strategy of ATIS to improve both the operations of nontoll routes and the revenue potential of toll roads. Technologies and a framework for implementing ATIS in the toll road context are presented.

5.3.1 Message Design and Format

The primary goal of ATIS is to provide useful traffic and travel-related information to travelers based on existing data and new supplemental data by using a variety of information dissemination technologies. This includes information for traveling in normal and poor weather, congested and emergency conditions, etc. Table 5.8 shows the types of traveler information sought and the percentage of the 706 respondents likely to seek that information, as found in the Austin commuter survey conducted for this research project. The table also shows the desirable frequency of updates to the content.

Table 5.8: Traveler Information Content and Update Frequency

Type of Information Sought	% Likely to Seek	Desirable Frequency of Updates
Accident locations	80%	Dynamic
Congestion locations	70%	Dynamic
Lane closures	57%	Dynamic
Estimated trip time	32%	Dynamic
Alternate routes	NA	Dynamic
Weather conditions	59%	Semi-dynamic
Road hazards	44%	Semi-dynamic
Road work	48%	Semi-static

Accidents, congestion, lane closures, trip time, and alternate routes are the most dynamic content, i.e., frequent updates are necessary. Weather and road hazards change less frequently, while road work is likely to be scheduled far in advance and, therefore, is virtually static information with regard to trip and route planning. Lane closures can result from static (road work), semi-dynamic (weather or hazards), or dynamic conditions (accidents/incidents), and therefore should be treated as dynamic information. These parameters serve as guidance on priorities for information to be collected and disseminated.

In the commuter survey for this project, it was found that the information content likely to affect route switching is as shown in Table 5.9.

Table 5.9: Information Content Likely to Affect Route Switching

Traveler Information Content	**Likelihood of Switching Route (%)**		
	Likely/ Very Likely	**Neutral**	**Unlikely /Very Unlikely**
Accident Locations	88	6	7
Road Work	77	12	11
Lane Closure	74	15	12
Recommended Alternate Route	66	24	12
Road Hazard Warnings	62	23	14
Estimated Travel Time	55	28	15
Weather Conditions	55	26	19

These findings indicate a priority for information content and relevance. Accident locations are by far the most likely information to encourage route switching, followed by road work, then lane closures. Clearly all of these are likely to result in congestion and delays, confirming that drivers want to avoid delays and/or save time. Recommended alternate routes are also highly valuable information, followed by road hazards. Surprisingly, estimated travel time ranks somewhat low as an incentive to switch. It is possible that drivers are now used to getting this information (as with weather information), and are deliberately ranking the less accessible information more highly.

In addition to content and relevance/timeliness, message design is also important. It will be critical that systems meet human factors objectives to ensure safety, efficiency, and usability. Dingus and Hulse (1993) specify human factors-related objectives for such systems. Desirable features include:

- *Navigate More Effectively*. The primary purpose of automatic navigation assistance is to allow the driver to locate unknown destinations and assist in error-free planning and route following. In addition, systems will have the capability to provide detailed, relevant information about traffic, obstacles, and roadways. The system must provide the information necessary in an accurate and timely manner.

- *Navigate More Easily*. A number of studies have found that memorizing a route, either through lists or from maps, is difficult and not done well. Remembering spatial map configurations or mentally reorienting a map is also difficult for people and it conflicts with the spatial task of driving. Other navigation tasks are difficult because the information is not always available or is obscured (e.g., street signs).
- *Navigate and Drive Safely*. Drivers should be able to navigate without jeopardizing driving performance. ATIS systems should be designed to minimize the demands imposed by the system and leave sufficient driver attention, information processing, and response resources for driving in all situations. In addition, information regarding upcoming obstacles or traffic congestion could warn drivers of potentially dangerous conditions. This feature could reduce risk, particularly in low visibility circumstances.
- *Optimize Roadway Use Efficiency*. Since traffic congestion is a problem encountered by many drivers and is expected to worsen, some systems try to distribute traffic more evenly throughout a system. If drivers are advised of congestion while planning their route, it is expected that they will avoid congested roadways. Thus, they would be able to avoid delays and not contribute further to congestion. Also, if drivers are informed of obstacles or congestion that occurs while they are en route, they may be willing to detour to avoid the congestion. The feasibility of this objective depends partly on the amount and detail of information provided to the driver en route.

5.3.2 Information Sources and the Processing Requirements

As part of this research, the capabilities of Texas Traffic Management Centers (TMC) regarding traffic information collection and processing were reviewed. The reviews were supplemented by visits to the TMCs in San Antonio (TransGuide), Houston (TranStar), and Austin (CTECC). In addition, capabilities of traffic centers in other major metropolitan areas were reviewed.

Incident Data collection: Generally, incidents that impact traffic flow are identified by observing changes in normal flows. A variety of sources provide information on traffic flow, from in-road loop detectors that count axles over time, to roadside radar detectors, to overhead video cameras that can pan and zoom in on a desired stretch of roadway. Fiber optic cable provides connectivity to the TMC, although some centers are now exploring wireless links. Detectors typically provide coverage at ramps and frontage road intersections, and the data is processed through algorithms that 'detect' unusual flows. The algorithms are adjusted for special events and holiday periods. Cameras provide coverage of freeway sections, and images are monitored visually at the TMC on a bank of screens. Most TMCs monitor only freeways, but Houston is considering adding arterial coverage. There are now some software for scanning images and detecting unusual flow conditions. Most TMCs have agreements with local TV stations to share video feeds, and in some cases even control the cameras.

There are some other sources for incident data. Many radio and TV stations provide a toll-free number for commuters to call in observed incidents, and some TMCs have started doing the same. With the ubiquitous use of cell phones, every commuter can now be a traffic monitor. Some media outlets also have 'an eye in the sky' during rush hours; a helicopter or light plane that circles the region and reports conditions. In some areas probe vehicles are used to monitor traffic flow and report incidents. It would be useful to have a shared database for pooling incident data.

Incident Data Processing: Since local police and the Department of Public Safety are responsible for handling incidents, they usually have a presence at the TMC. When an incident is detected, messages are exchanged via police radio to dispatch officers and emergency vehicles as appropriate. In San Antonio an "Accident Ahead" message is displayed on the upstream DMS if necessary. Incidents are logged in a TMC database/Web site which is now being made available to news outlets and the general public. However, an incident is not 'closed' until officers on the scene give the 'all clear,' which, due to liability concerns, can reportedly be as much as an hour after flow is restored. Therefore, information in the database may not be up-to-date with regard to its effect on traffic flow. It would be desirable to add to the database a field saying that normal flow has resumed, with that field being managed at the TMC.

Congestion Data Collection: Often, there are predictable areas of congestion in a region, varying with time of day, day of week, and time of year (e.g., when school is in session). Frequent commuters are familiar with these recurrent congestion zones. Unusual congestion is of more concern. At the TMC, data on congestion comes from the same sources as incidents, i.e., flow data. In fact, congestion is usually the signal that an incident has occurred. Some newer technologies have been touted for capturing flow data and therefore monitoring congestion. For example, in Houston toll-tagged vehicles are interrogated as they pass specific locations, to provide estimates of the average speed on highway segments. In some jurisdictions public vehicles have been fitted with GPS units that report their location with a time stamp. Software converts flow data to plots of average speeds.

Congestion Data Processing: In Houston, a GIS interface is used to display color-coded average speeds. The map is updated every time a change is detected and confirmed, and is now available on the internet. In San Antonio, a 'Congestion Ahead' message is displayed on DMS when relevant, according to a hierarchy of message urgency. Elsewhere in Texas, little is done to report the presence of, or changes in, congestion other than green/amber/red arrows on lane controllers. In Melbourne, Australia, 'Drive Time' signs provide estimated travel times as well as a color-coded indicator advising where traffic volume is light (green), medium (yellow), or heavy (red). In Japan, commuters see overhead visual displays similar to maps well in advance of congested locations.

Lane Closures Data Collection: Lanes may be closed for a number of different reasons. For emergencies, many jurisdictions have plans in place for road closures, contraflow evacuations, and similar drastic measures. For accidents, the police follow internal guidelines with regard to which lanes are closed and for how long, regardless of the effects on traffic flow. Even for relatively minor incidents, it is not unusual to have lanes closed. TxDOT has espoused a 'Move It' campaign to get motorists to move disabled vehicles off the traveled lanes to reduce congestion. Lane closures can also result from weather and other hazards. Some of these closures are predictable. The most predictable lane closures are those due to scheduled construction.

Since lane closures can result from a variety of events, data sources are also various. Obviously, closures for scheduled road work can be communicated by the contractor or maintenance crew to the TMC in advance. Similarly, weather hazards can be communicated by maintenance crews. Other types of lane closures (and re-openings) ought to be communicated by the party making the decision (e.g., police) as soon as practical. Clearly, the safety of the immediate victims of an incident is paramount, but the safety of approaching motorists and emergency workers makes it essential that lane closures are properly communicated to the TMC, and then effectively disseminated.

Lane Closure Data Processing: Lane closure locations ought to be recorded both as absolute coordinates and as relative positions. GPS coordinates would be ideal, obtained, possibly, from the portable arrow signs used to signal closures. A GIS interface that allows the GPS data to be graphically portrayed as a red line on a map, and 'translated' to a location description, would be useful. Many internet map services, such as Mapquest, have software that ties specific locations such as intersections to maps and text descriptions of relative locations (e.g., 'southbound, half-mile from Exit 259').

Estimated Trip Time Data Collection and Processing: Trip times are derived from average travel speed on each segment of the system. As described earlier, sources of travel speed data include detectors, video, probe vehicles, toll tags, and GPS units. Point-to-point travel speed is chosen as the lower of upstream and downstream sensor speed. Algorithms convert average speeds into estimated point-to-point travel times in minutes. Segment travel time is the sum of point-to-point travel times. Times are typically given in ranges (e.g., 'travel time to IH 10 4-6 minutes'). TransGuide (San Antonio) provides travel times on DMS on all the major routes in the city, updated instantly as data is processed from the central control system. Generally, motorists express satisfaction with this information. One limitation is that it only applies to the next one or two segments. The TransGuide Web site now has a 'Dynamic Route Builder' that allows you to chain segments into a trip, and the estimated travel time is given. The Web site also has links to allow the user to see what message is currently displayed on each DMS.

Alternate Routes Data Collection and Processing: While it is possible to provide data to motorists on alternate routes, most TMCs do not, partly because of liability concerns. Route chains can be derived from digitized maps or GIS files, as is the case for TransGuide's 'Dynamic Route Builder.' The requirements for providing alternate routes are: algorithms for generating a hierarchy of paths for a given trip, lane closures, current travel times for each segment of each path, and estimated total trip time for each path.

Some private sector parties are entering the market to provide information on alternate routes. One such provider is TranSmart Technologies Inc., which is developing a 'routing' service. When the start and end points of a trip are input, the program will output the shortest-time route and driving directions. Dynamic routing is also proposed: as the driver proceeds the service would alert him if conditions on the current route change, and provide a new route from current position, using GPS and cell phone.

Weather Data Collection and Processing: Sources of weather data include the National Weather Service (NWS) and local news outlets. The NWS provides radar images of recent, approaching and future weather patterns, and alerts, watches, and warnings of dangerous conditions. TV outlets often have their own radar services and meteorologists who provide information to radio and print media as well. Weather data is therefore sufficient in most locations for semi-dynamic updates. For example, many radio stations provide weather updates every ten minutes. Cell phones now have the capability to provide a visual display of weather radar images.

Road Hazards and Road Work Data Collection and Processing: The sources of data on road hazards and road work have already been discussed under 'Lane closures.' In the U.S., commuters using cell phones are a growing source of data on road conditions. Mechanisms are needed to allow such information to be captured, verified, and in turn fed back to oncoming traffic. For example, on the toll roads in France, there is a dedicated FM channel that provides motorists with such information in addition to music and news. The station continually urges drivers to call a toll-free number to report useful information.

5.3.3 Information Delivery Technologies

According to the National ITS Architecture for the U.S., several systems are potentially capable of disseminating traveler information. Commuters currently obtain information from several sources but would prefer alternatives. Table 5.10 shows the responses of 706 commuters in the Austin area regarding technology preferences for traffic information (they could select more than one). Some commuters also added 'cell phone' as a category for receiving information. The differences between current sources and preferred sources, with increasing preference for 'high-tech' in-vehicle systems, suggest that there is a growing potential market for in-vehicle information delivery.

Table 5.10: Commuters' Technology Preferences for Traveler Information

Question	Radio	TV	Newspaper	DMS	Internet
How do you *currently* receive traveler information on the local roadway system?	89%	36%	4%	12%	15%
Which of the following would you *prefer* to use to receive traveler information on the local roadway system?	78%	19%	2%	37%	18%

Broadcast Systems: Broadcast technologies are those that broadly disseminate information through existing infrastructure and low cost user equipment. These applications are already in wide use, and the public expects not to have to pay extra for the information. Alternatives include:

- Highway Advisory Radio (HAR)
- Commercial radio
- Satellite radio traffic channel
- Commercial and cable TV
- Roadside dynamic message signs (DMS)

Highway Advisory Radio: For these systems traffic information is processed only to the extent necessary to conform to the medium, and is generic, i.e., not tailored to a specific user. HAR is usually a loop of pre-recorded messages notifying motorists of 'static' conditions such as construction and lane closures, and perhaps regional weather forecasts. Typically, it is a low power signal available in a limited area, and the messages are refreshed once a day. Due to the 'staleness' of the information, HAR has a very limited audience compared to commercial radio.

Commercial and satellite radio: Commercial radio is currently heavily favored by in-vehicle users as a source of traffic information. Radio stations obtain data from the TMC database/ Web site, from police, fire, and EMS radio transmissions, from flyover services, and/or from commuter phone calls. Typically, traffic updates are provided every ten minutes during rush hour. Satellite radio is starting to penetrate the radio market, but is just beginning to tap into user desire for traffic information. Satellite radio is geared to users who want to listen to a favorite station 'coast-to-coast,' and is has yet to design a traffic information service that is specific to the user's location.

Commercial and cable TV: Commercial and cable TV play to a different market from radio: pre-trip users who are interested in unusual conditions on their usual routes. Most TMC provide video feed from their cameras to local TV stations. For example, the Austin CTECC provides local cable channel 8 with feeds from 22 of its cameras. The stations can choose which feed to show. Many stations also display map graphics of the locations of incidents. Most TV traffic reports are delivered in the morning, at about ten minute intervals, to commuters who will be traveling in rush-hour traffic.

Dynamic message signs: DMS is classified as a broadcast medium for traffic information, since the message is not targeted to a specific user's needs. The main advantage of DMS over radio and TV is that the message can be tailored to the location. TMC operators are able to access each DMS individually, select from a set of message designs, customize if needed, and sent directly to the DMS. Messages can be set to display for a fixed period then be replaced by automatically generated travel times or other default message. Disadvantages of DMS are that the signs are costly to install (over $30,000) and maintain, the message is very brief, and in most cases the information is not provided early enough for the driver to switch routes.

Driver Assistance Systems: This category of technologies relates to providing assistance to drivers based on location devices. The two main types are:

- In-vehicle driver assistance system
- On-board GPS navigation device

For these systems, the driver purchases a device that uses his location or destination information as input to an in-vehicle or external database, and outputs guidance on routing, navigation, attractions, etc. Most current systems have static data, although some are now becoming interactive, providing 'live' data.

In-vehicle assistance: The private sector is active in promoting driver assistance systems. One provider is OnStar, a General Motors subsidiary. Equipment consists of a sensor system, a GPS unit, and a built-in cell phone link to the OnStar call center. If the sensor system detects an unusual event such as an accident, a voice link is established between the car and an OnStar center operator, who tries to talk to the driver. If the driver responds, information is exchanged to determine the appropriate action. If there is no response, OnStar determines the vehicle location via GPS and notifies local 911 services. The link is active until emergency services arrive. This 'Safe and Sound' plan costs $17 per month. OnStar is now offering additional services, including email of vehicle diagnostics, voice navigation, stolen vehicle location, etc., for $35 per month.

GPS navigation: High-end new vehicles now have in-vehicle navigation systems as standard equipment, but there are also a number of manufacturers providing portable units (e.g., Garmin, Magellan, Sony, Pioneer, etc.). Prices are in the $250- $500 range. The unit requires a power source. A GPS unit determines the vehicle location, accesses the built-in database, and displays a map of the area to an adjustable level of detail. Some units provide 3-D and perspective views, and some provide voice driving directions when a destination is selected (e.g., 'Turn right at Maple Street', or 'You have passed your exit. Please execute a U-turn at the next safe location.'). Additional services include area attractions such as hotels and restaurants. Some units have a satellite receiver that, instead of using a static database, downloads data relevant to the location, even local traffic and weather reports.

These driver assistance technologies are establishing a market for themselves. They are especially marketable to women and drivers making trips to unfamiliar regions. Because they are creating their own market and adding services as customers request them, these technologies have viable prospects.

Interactive Systems: These are systems that provide tailored information in response to a traveler request. There are two types: real-time interactive systems that are able to respond to requests, and systems that "push" a tailored stream of information to the traveler based on a submitted profile. The technologies in this category include:

- Traffic information kiosk
- Internet-based system accessible by personal computer
- 511 system
- Personal Digital Assistant

Interactive systems require that traffic data, such as collected by a TMC, be messaged and 're-packaged'.

Kiosks: Traffic information kiosks typically provide a limited menu of options and generate a fixed set of outputs. They are especially of use to tourists and low-income citizens who do not have ready access to more sophisticated systems. One shortcoming is that the information provided sometimes assumes some knowledge of the region's transport links, which is not always the case for tourists. Another drawback is that the information may be stale by the time the user makes the trip.

Web sites: Internet-based systems are gaining popularity. Many of the TMCs now have their own Web site, with displays of traffic conditions and interactive query-response options. Private providers are also entering this arena. One example is Traffic.com, a service now available in several large metropolitan areas. As their Web site states: "Traffic.com has a network of advanced roadside sensors deployed along the highways in many areas. These sensors allow us to accurately measure and update the actual speed of traffic flow–around the clock, regardless of the weather. We also gather data from many state and local Departments of Transportation and combine this with our own sensor information. And, we have our own Traffic Operations Center staff covering each of the markets we serve–listening to police and fire department activity on scanners, monitoring video cameras, talking to transportation and other government agencies, and even driving our own cars and flying our own aircraft–to get the latest updates." One disadvantage of internet-based systems is that they are rarely accessible en-route, so are of use mainly for pre-trip planning.

511: Since July 2000, the FHWA and state DOTs have been deploying 511, a nationwide road conditions phone number analogous to 911. As of April 2006, about 50% of the U.S. population has access; 511, however, is still in the planning process in Texas. Messages on incidents, congestion, road construction, etc., are recorded into the 511 system by designated local agencies. Calls are routed to a local center as for 911 calls, and users can access a voice-command menu. The system is still in its infancy, and usage is expected to grow over time. A significant shortcoming is the difficulty local agencies have experienced in providing the data, usually a ‘double entry’ exercise for them. The voice recognition system is still limited, with as much as 37% of user inputs not recognized. A premium service for paying customers has been suggested, but private providers have not evinced interest.

Personal Digital Assistant: PDAs are a hybrid of the phone and the computer, being able to access phone services such as 511 as well as internet services such as Traffic.com. They are currently the most versatile interactive traveler information device, useful for both pre-trip and en-route information. They can also submit queries based on the user profile and download updates without user handling, making them safer during driving than cell phones and similar interactive devices. With a text-to-voice converter, they are like a co-pilot. For example, ALK Technologies is offering ‘Co-pilot Live,’ an interactive system feeding audio and video to PDAs. As data sources, push technologies, and in-vehicle devices improve, en-route traveler information is likely to gain in popularity.

Vehicle-Vehicle-Infrastructure Communication: The next generation of ATIS is expected to include direct communications between vehicles and infrastructure. On-the-go communication between vehicles could significantly increase highway safety. In addition, traffic delays could also be significantly reduced. Potential technologies include:

- Dedicated Short Range Communication (DSRC)
- Wireless networks
- Cell phone tracking.

Vehicle Infrastructure Initiative (VII): This initiative undertaken by the U.S. Department of Transportation will deploy advanced vehicle-vehicle and vehicle-infrastructure communications (US DOT, ITS: Vehicle Infrastructure Initiative, 2005). This wireless communication is supported by DSRC. The VII aims for the coordinated deployments of communication technologies:

- In all vehicles by the automotive industry, and
- On all major U.S. roadways by the transportation public sector.

A VII consortium has been established to determine the feasibility of widespread deployment and establish an implementation strategy. The consortium consists of the vehicle manufacturers already involved in the VII, AASHTO, ten State Departments of Transportation, and the USDOT. Vehicles could serve as data collectors and anonymously transmit traffic and road condition information from every major road within the transportation network. Such information would provide transportation agencies with the information needed to implement active strategies to relieve traffic congestion. The VII vision is that every car manufactured in the U.S. would be equipped with a communications device and a GPS unit so that data could be exchanged with a nationwide, instrumented roadway system. According to the USDOT, a well functioning vehicle-vehicle-infrastructure communications system could halve the 43,000 annual U.S. traffic deaths.

Dedicated Short Range Communication: An example of a DSRC device is ‘Otto,’ a 5.9 GHz RFID unit from Canadian technology integrator MARK IV, designed to provide warnings to drivers, allowing them to take evasive actions, as well as providing real time information such as weather conditions, congestion, and traffic accidents. Otto uses a digital radio technology to pass information over distances of up to 1 km between roadside communicators and the on-board imbedded DSRC device on the vehicle. The technology uses WAVE (Wireless Access in a Vehicular Environment).

Wireless systems: An example of a wireless system is DaimlerChrysler's experimental radio network system derived from the IEEE 802.11 standard, also known as Wireless LAN. As soon as two or more vehicles are in radio communication range, they connect automatically and establish an ad hoc network (Figure 5.2).

As the range of a single Wireless LAN link is limited to a few hundred meters, every vehicle acts as a router, sending messages over multi-hop to vehicles farther away. The routing algorithm is based on the position of the vehicles and is able to handle fast changes of the ad hoc network topology. Motorola is also implementing wireless technologies, and is considering delivery of roadside camera images to PDAs.

Figure 5.2: Car-to-car ad hoc Networks

Cell phone tracking: Cell phones periodically send signals to their network in order to track their location and quickly route a call. The accuracy of location can be within in few yards in full-coverage urban areas to a few hundred yards in rural areas. This tracking feature makes it relatively easy to overlay cell phone locations on a highway network, determine on which roads the phones are moving, and how fast they are moving. Early in 2006, the Maryland DOT signed a contract with Delcan, a Canadian software company, to monitor Cingular cell phone signals and use the data to estimate traffic speeds in the Baltimore area. The project is now being expanded statewide. Similar projects are getting underway in Norfolk, Virginia, and a stretch of I 75 between Atlanta and Macon, Georgia, conducted by the Atlanta-based company AirSage in conjunction with Sprint Nextel.

The 'Sausage Diagram:' At present, US DOT and several state DOTs have attempted to incorporate vehicle needs, roadside requirement, travelers needs and different transportation centers into an all inclusive web connected by DSRC. The idea is that every user on every step of the transportation system will be interconnected, resulting in greater safety, efficiency and the maximization of utility for the traveler and transportation system alike. Figure 5.3 provides an overview of the interconnections between travelers, vehicles, roadside facilities, and traffic management centers. It also identifies the information flow and data exchange among different sub-systems.

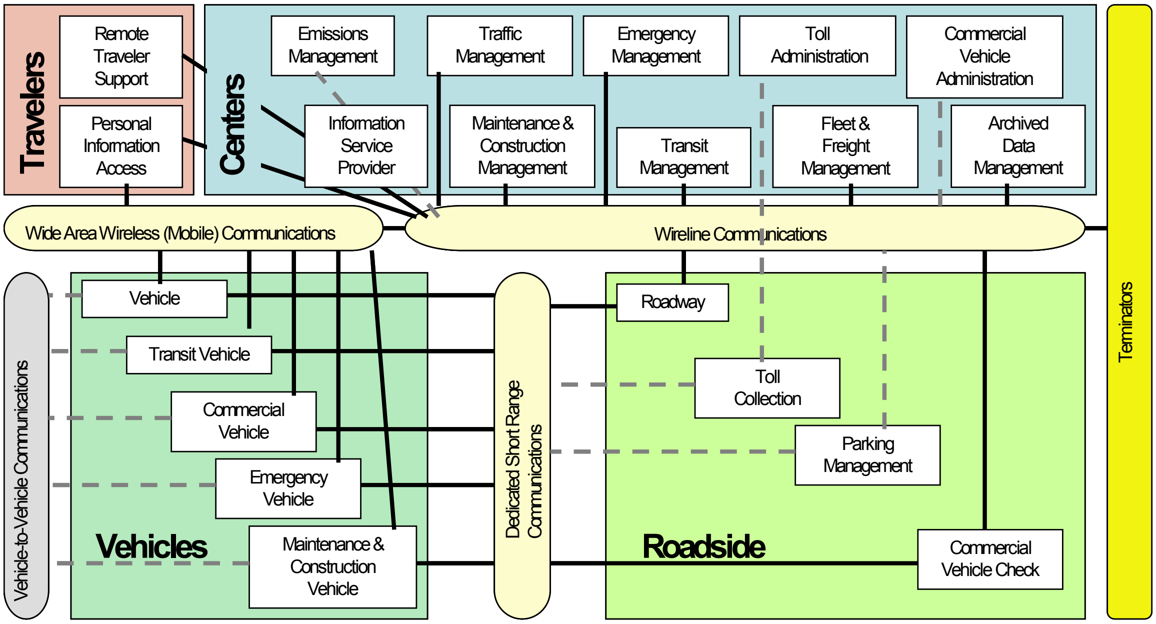


Figure 5.3: Partial "Sausage Diagram" for ITS Architecture
(from Kimley-Horn & Assoc., 2005)
http://www.dot.state.pa.us/ITS/architecture/definitions/def-subterm.htm

5.3.4 The Evolution of Traveler Information Technologies

As with most technological developments, pioneers are proving the technology, and 'settlers' are starting to adopt it. In the early stages, the emphasis has been primarily on providing travelers with information to improve their trip planning. The emphasis is now changing to supplementing static information with dynamic information collected and transmitted from other segments to optimize individual travel. The evolution of ATIS systems can be traced through three stages:

- <u>1990 to 2000:</u> This stage focused on improving information access and timeliness. Most of these systems relied on existing technologies and drivers' knowledge of the network.
- <u>2000 to 2010:</u> This stage focuses on en-route information systems, with increasing interactive content. Drivers are becoming part of the feedback loop.
- <u>2010 to 2020:</u> This stage will see the development of communication between the infrastructure and vehicles. Vehicles will be used to report conditions, and the infrastructure will process the data and use it to manage traffic and inform drivers. A variety of integrated in-vehicle devices will be available.

Figure 5.4 presents an overview of the evolution of ATIS technologies and trends.

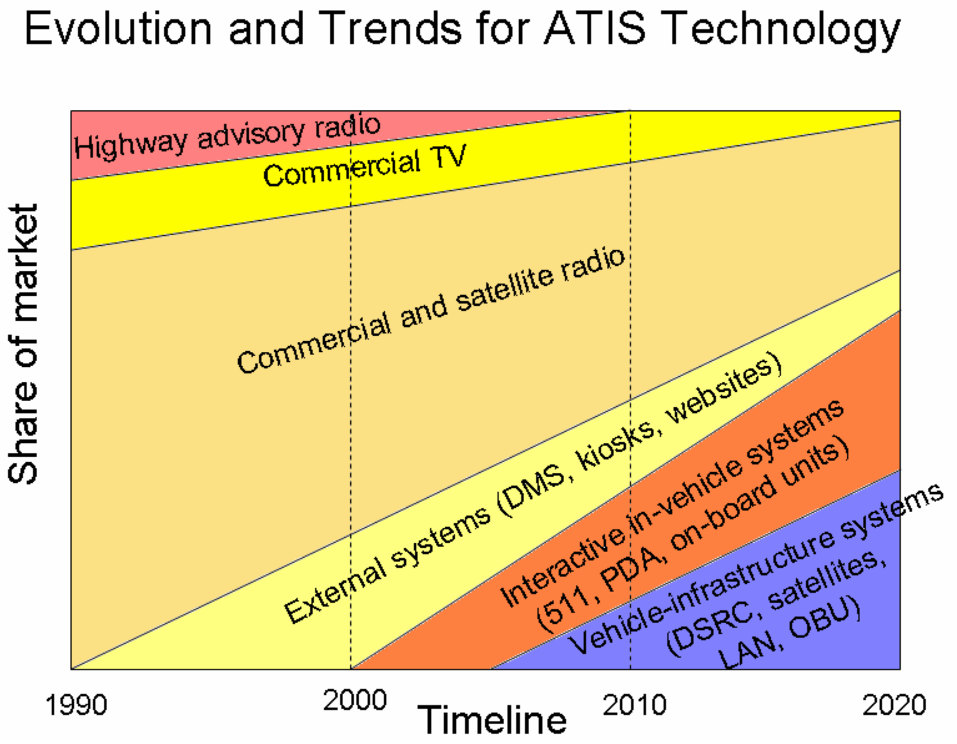


Figure 5.4: The Evolution of ATIS Technology and Trends

5.3.5 A Practical Framework for ATIS Deployment

ATIS use advanced technologies that collect and process travel-related data and disseminate useful information to travelers. These technologies include sensors for monitoring travel conditions, communications for sending and receiving information, data processing, geo-location technologies, microprocessors, and other technological advances.

An ATIS system may cover a single metropolitan area, an entire state, or an even larger area such as a multi-state corridor. The types of information and the modes covered can also vary widely. A system might use data from a single transportation entity, such as a state department of transportation (DOT), or it may cover multiple modes of travel with data from several agencies and even private entities. Although ATIS systems may vary in coverage, technologies, and information handling capabilities, they share some common features. Namely, all ATIS systems must provide accurate, timely, and reliable information desired by travelers in a form that is convenient to use. Based on the working mechanism of ATIS, a practical framework, as shown in Figure 5.5, was developed to meet the commuter needs in Texas. Users' requirements for information and their preferences for receiving it are integrated into the framework.

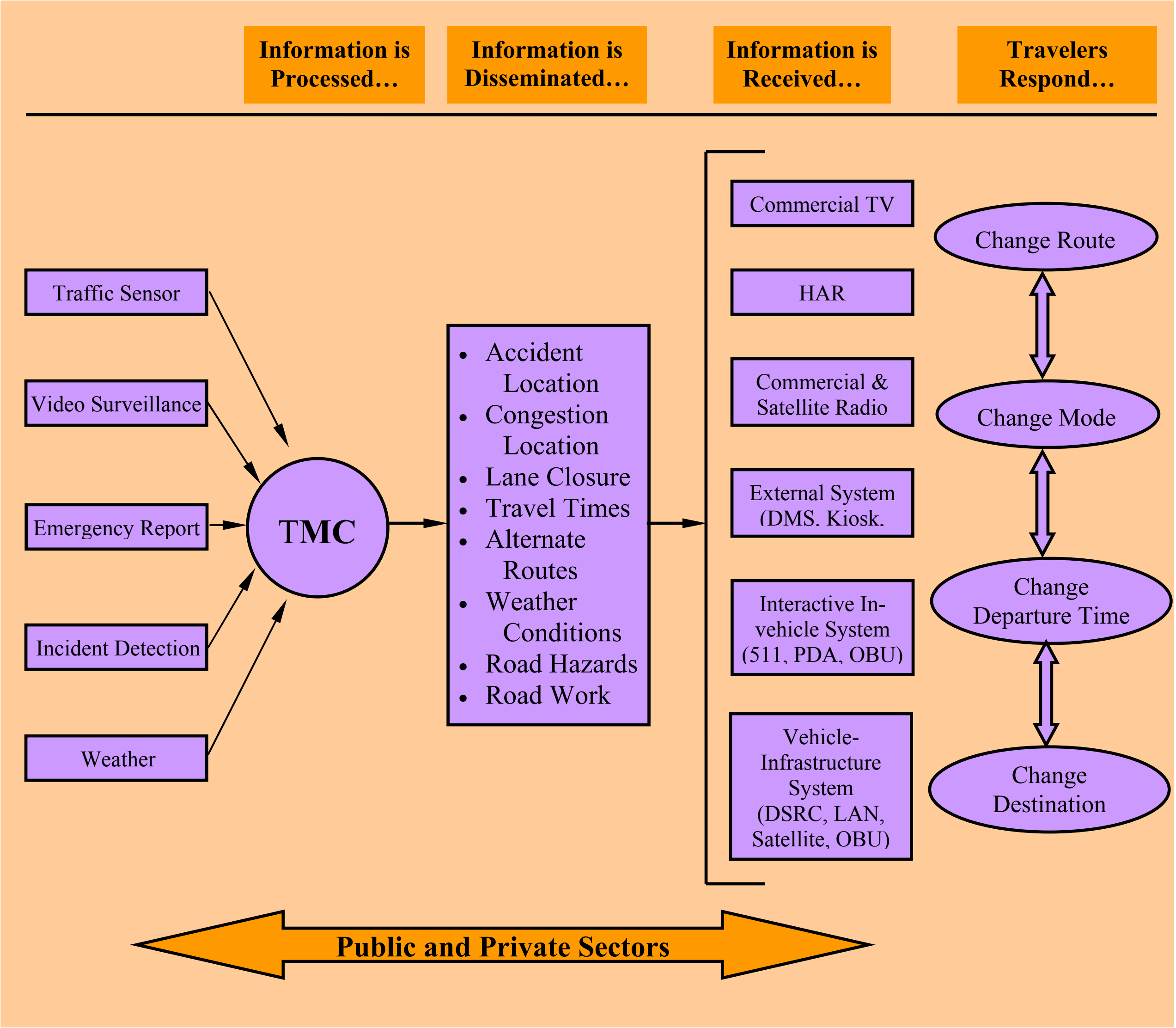


Figure 5.5: A Practical Framework for ATIS Deployment in Texas

5.4 Potential Implementation Issues

ATIS can be a promising method to enhance both tolled and non-tolled road operations. However, there are a number of specific issues associated with ATIS that need to be addressed in ATIS implementation. These issues are listed here with a brief description.

Measurement of Benefits: A significant amount of data is necessary to evaluate the benefits of an ATIS system. In most cases, information may not be available or sufficient for decision-making purposes. IDAS provides the analyst with a practical tool to measure the benefits and costs of an ITS alternative, including various ATIS deployments. However, it requires users to predict the potential impact of traveler information on traffic operations, which could be very difficult. In this study, the research team used the DYNASMART-P model, which is a good tool for that purpose. The data preparation and modeling process are still hard to go through. Improvements in these evaluation tools may help transportation agencies better assess various ATIS deployments and make wiser investments.

Integration with Existing ITS System: An important issue in planning for future deployment of ATIS is the constantly changing technology. The research has examined which technologies will still be in use and what new technologies need to be accommodated. Trends in ATIS clearly indicate that information dissemination is shifting to the private sector. A number of traffic information sources which are available on the internet, and in-vehicle technologies such as General Motors' On-Star system, are rapidly providing additional opportunities for dissemination. It is also clear, however, that TxDOT will continue to play a key role in both data collection and dissemination. The integration of information collection, processing, and dissemination may be a critical issue that requires strong private-public partnerships.

National ITS Standards: The National ITS Standards is one of the most researched area in ITS. Keeping ATIS deployments compliant with national ITS standards would ensure system integration, room for upgrade, interoperability, and the emergence of the wider information services.

Prospective Participants: It is important to involve all potential participants in ATIS to maximize the potential benefits. Both private and public sector groups can collect data, add value to it then disseminate information to customers. So deciding what groups to include in the ATIS is more an "inclusive" than "exclusive" process, with the selection process coming down to the question, 'Who adds net value?' (ITS-America, 1998).

Institutional Issues: Information exchange between existing TMCs and various agencies will be important in achieving maximum benefits of ATIS deployment. As ITS systems emerge in various metropolitan areas in Texas, strategies for coordination between TMCs need to be developed. Also, the coordination between state DOT and counties, state patrol, EMS, fire department, and police also need to be developed or improved. It is important to define each agency's roles and expectations, to identify the issues requiring the most coordination, and to create a management structure to resolve conflicts and carry out this coordination.

The Target Market and Revenue: Generally, there is a market for each type of information dissemination methods. For instance, the in-vehicle route guidance system is targeting vehicles that are equipped with in-vehicle devices and DMS is targeting frequent freeway users. The potential for revenue from the private sector is determined by the size of the ATIS market. Understanding the user market would help to improve ATIS implementations.

Funding Strategies: Development of a comprehensive funding plan for both new deployments and ongoing operations and maintenance usually remains a great challenge for any ITS deployment. The funding for operations and maintenance activities at the Texas TMCs are not likely to be available indefinitely. There is recognition that a more stable and diverse funding program is needed. Alternatives include allocation of funds from other federal and state sources, many of which are eligible for ITS.

Legal/Administrative Issues: State departments of transportation generally have broad expressed authority to contract for construction, perform maintenance and planning, or for developing and improving roads. Implied authority may exist to carry out these functions, but it is not always clear how far that implied authority extends. For example, the idea of using cell phones to collect traffic information has been proposed. It could be a very effective and economic method to achieve data collection goals. Legal issues are inevitably involved however. Are transportation agencies allowed to do this? In private-public partnerships, much of the legal concerns concentrate on who pays for what and how, who owns what and who has access to that knowledge, and who can access public information and how?

5.5 Funding Opportunities for ATIS Implementations

5.5.1 Potential User Market for Traveler Information

The commuter survey done for this project showed that drivers are willing to pay to save time. The survey questions were couched to gauge route switching propensity for time savings, and value of those time savings. Figure 5.6 shows the threshold time savings likely to stimulate route switching.

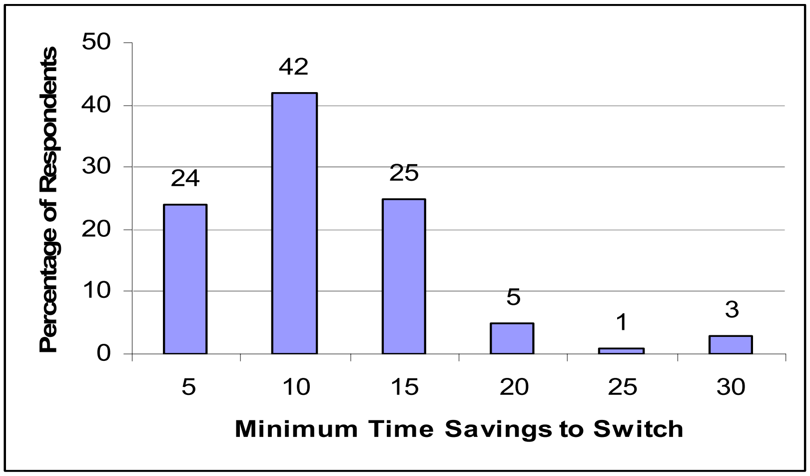


Figure 5.6: Threshold Time Savings to Stimulate Route Switching

The average desired time saving is 12.5 minutes, but the median is only about 8 minutes, i.e., 50% of commuters would switch routes for an 8-minute time saving. About 40% of respondents indicate they are willing to pay to save that time, ranging from $0.05 up to $275.50, with an average of $2.07 and a median of about $1.00 for each instance. These figures indicate that there is a potential market for systems that provide commuters with travel information that would save them time.

In the toll road context, there is an opportunity to combine tolling technology with on-board units. For example, Toll Collect in Germany uses a GPS unit on trucks to measure their mileage and apply tolls (in Germany trucks are tolled for the mileage they travel on the Autobahn system). Other European countries such as Switzerland and Poland are implementing similar tolling systems. Tolling in the U.S. is predicted to evolve from current corridor and cordon tolls, to area-wide or road user tolls as a replacement for the gas tax (Persad et al., 2006). Tolling technology is on the leading edge of ITS implementation, e.g., providing flow data for Houston TranStar. Ultimately, tolling is predicted to be a major component of integrated transportation system management, in which each vehicle carries an on-board unit that reports its location as well as road conditions to the vehicle-infrastructure network. As shown earlier, traveler information can enhance toll road revenues. Toll agencies can tap into this revenue by partnering with technology integrators to deploy toll collection systems that use multi-function on-board units.

5.5.2 Funding Opportunities from Public Sector

In this research, funding opportunities have been identified for ITS program in Texas. Funding opportunities include:

SAFETEA-LU: The bill contains a new real-time system management information program that directs the Secretary of Transportation to establish a program to provide, in all states, the capability to monitor, in real time, the traffic and travel conditions of the major highways in the United States. Appropriations in FY 2005 designated over 100 ITS deployment projects including ATIS. SAFETEA-LU has funds to cover these projects. After that, there are no dedicated ITS deployment funds. Although the ITS integration program is no longer available, ITS' are an eligible capital expense in FTA Federal funding programs.

New/Ongoing Federal Initiatives: USDOT recently announced nine new focal areas for ITS deployment that represent new sources of ITS funding. There also continues to be federal support and interest in ITS deployments related to safety and rural applications.

North American Free Trade Agreement (NAFTA) Transportation Corridors and Related ITS Strategies: As a state that facilitates a significant amount of the nation's trade—particularly in the form of providing safe and efficient routes for commercial trucks—Texas is well positioned to bring forward plans for ITS deployment that should receive significant federal support and be the source of innovative public-private partnering projects. ATIS deployments well suit that scope.

Homeland Security/Evacuations: As a state that is home to targets at high risk of terrorist attacks, contains several of the nation's largest metropolitan urban areas, and has the second-largest coastline in the nation that is prone to hurricanes, Texas is also well positioned to receive federal support for ITS deployment that addresses any/all of these issues. Regardless of federal support, ITS deployment projects that can offer multiple benefits by addressing many of these issues simultaneously should be considered. ATIS is no-doubt such type of deployment.

Cost-Sharing of ITS Deployment with New Toll Road Construction: In areas where new toll roads will interchange with existing roadways, there will be opportunities to co-deploy new ITS technologies and thereby accomplish increased ITS deployment at a reduced cost to TxDOT. ATIS should fall into this category.

5.5.3 Funding Opportunities from Private Sector

The funding opportunities from private sectors are very limited and generally require substantial marketing efforts. The funding opportunities from private sectors include:

Traveler Information Usage or Subscription: The commuter survey in Austin indicates that about 50% of respondents are willing to pay a fee if the information helps them save time. Therefore, opportunities to create new sources of revenue for ITS funding appear to exist in several areas such as subscription services, data exchange, naming rights, sponsorships, and 511 information fees.

Multi-function, on-board units: In the toll road context, there is an opportunity to combine tolling technology with on-board units (OBU). As shown earlier, traveler information can enhance toll road revenues. Toll agencies can tap into this revenue by partnering with technology integrators to deploy toll collection systems that use multi-function, on-board units.

5.5.4 Potential Business Models for ATIS Implementations

The earliest commercial traveler information system appeared during morning commute radio shows in major U.S. cities, such as Los Angeles, New York City, and Chicago, in the mid-1950s. The traffic report programs at that time were produced by the commercial radio stations themselves and paid for by program advertisers (Lappin et al, 1994). Since the inception of the commercial traffic information business, traffic surveillance technology and information delivery technologies have improved. With rapid development in ITS technologies, ATIS becomes more powerful in collecting, processing, and disseminating information. Information provision, processing, and dissemination become more and more complicated requiring stronger partnerships between different sectors. According to a statement of ITS-America, sorting out the roles, responsibilities and relationships of the public and private sectors is the key challenge to successfully launching ATIS (ITS-America, 1998).

In general, a business plan should address the following five issues:

- Define the target market.
- Define the data to be collected.
- Determine how to disseminate the consolidated information.
- Show where the funding will come from and how it will be used.
- Estimate the costs of doing business.

Based on the suggestion of ITS-America, there could be five types of business models that can be applied for ATIS implementations.

Public-Centered Operations: This business model gives the public sector the greatest measure of control over ATIS, helping direct its benefits toward meeting public policy goals, but generates the least amount of revenue while requiring the greatest amount of public expenditure. Figure 5.7 illustrates the concept of Public-Centered Operations model.

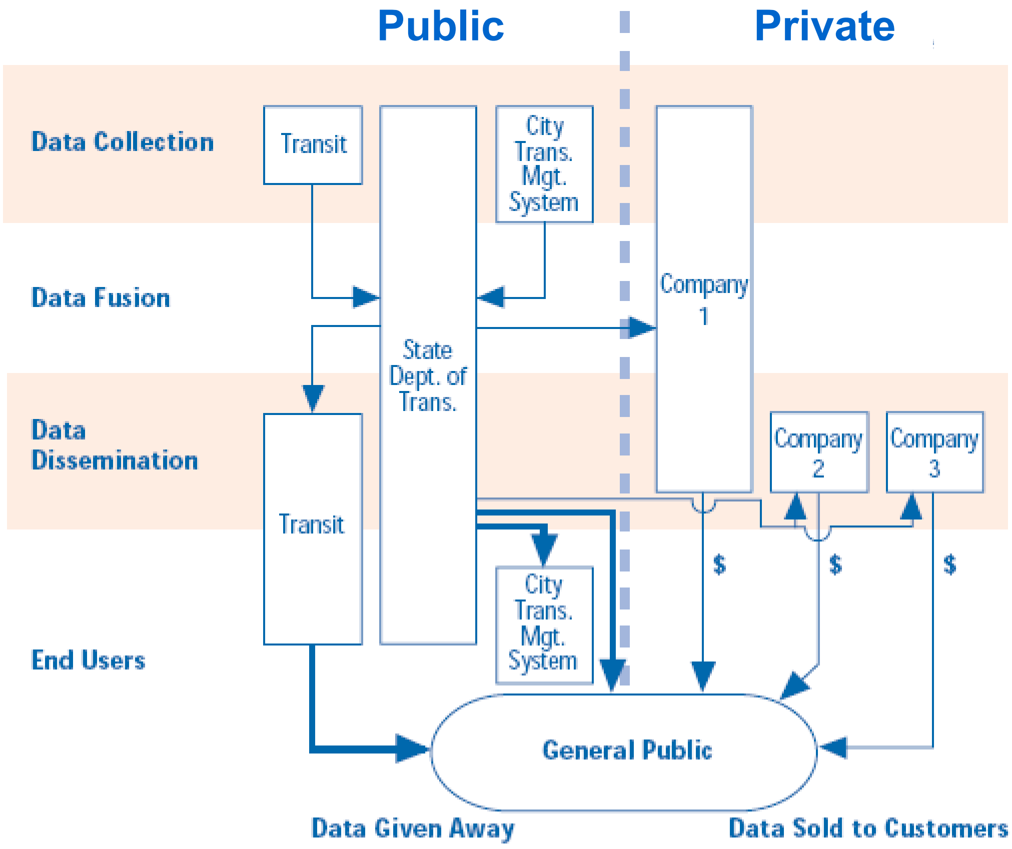


Figure 5.7: ATIS Business Model — Public-Centered Operations

This plan requires the state DOT has the expertise and interest to operate the data fusion process. Private companies have opted to obtain the data, repackage them and sell them to customers.

Contracted Operations: This business plan enables the public sector to maintain overall control of an ATIS system. It provides improved access to the private sector's technical expertise and staffing, but gives the DOT freedom to apply the constraints it believes are important for the system. Figure 5.8 illustrates the concept of Contracted Operations model.

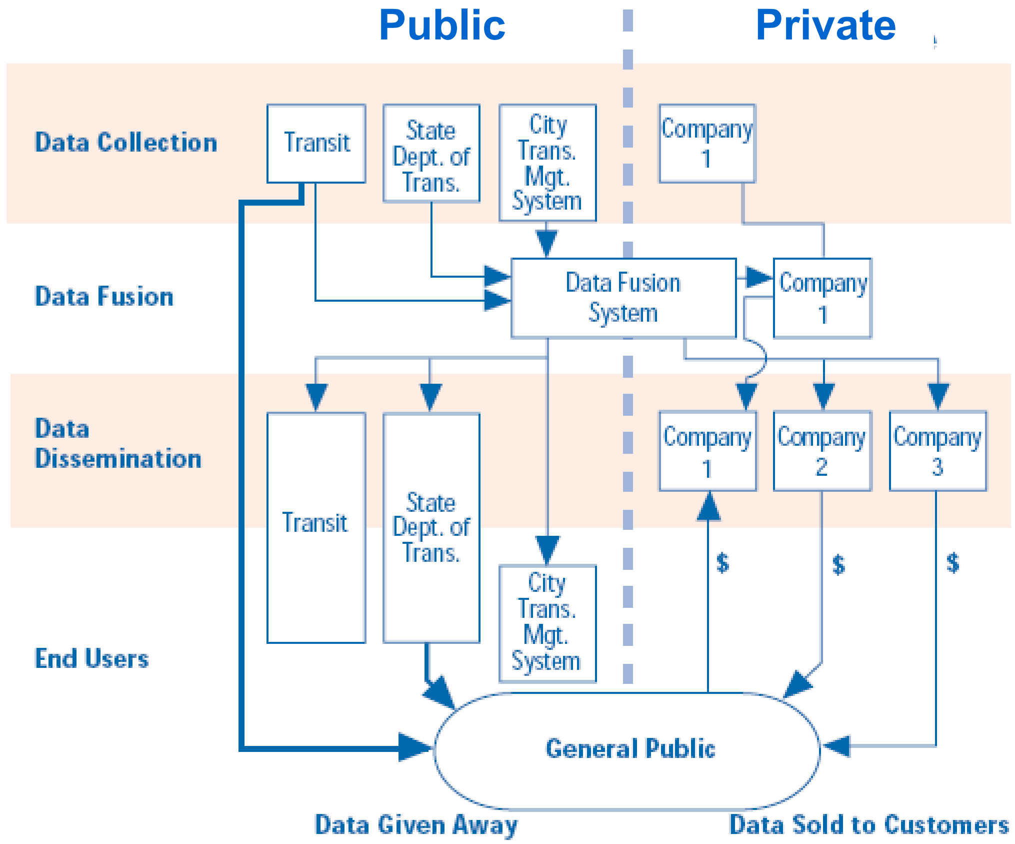


Figure 5.8: ATIS Business Model — Contracted Operations

With this business plan, the data collection and data fusion processes can be contracted to the private sector —possibly through some sort of agreements. The public sector, however, still collects, processes, and provides large amounts of traveler information to the general public. So aside from the data collection and data fusion service, the potential for revenue for the private sector might be limited.

Contracted Fusion with Asset Management: This business model adopts the same basic business structure as the Contracted Operations model, but has different emphases. First, there is a significant reduction in the amount of information provided to the public. Second, an "asset manager" function, which combines product development, marketing and sales functions, is added in addition to the data fusion function. Figure 5.9 illustrates the concept of Contracted Fusion with Asset Management model.

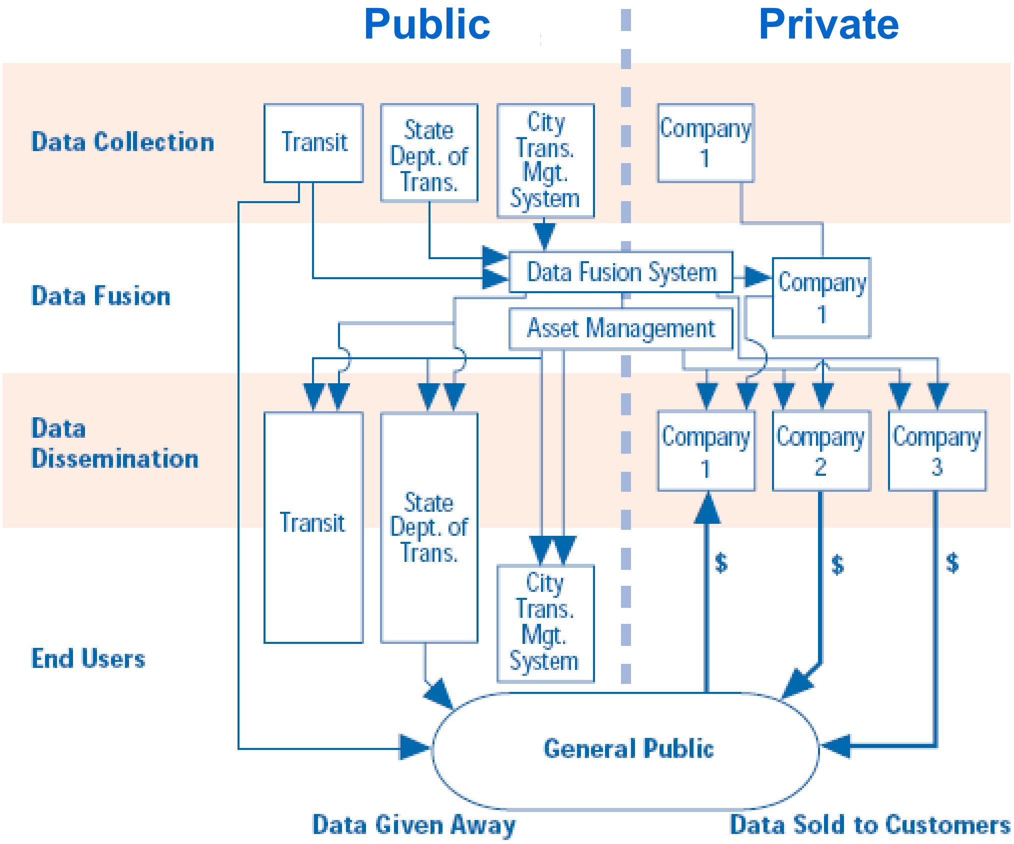


Figure 5.9: ATIS Business Model — Contracted Fusion with Asset Management

With this plan, the "asset manager" will undertake the task of finding and exploiting new uses and revenue sources of the available public sector data. It will work with the data fusion provider to create data products that meet user requirements, and sell those public sector data products to clients (private companies). The private companies will then create new services that can use these data products and maximize the revenue. The advantage of this model is that the revenue generated for public sector use can be increased.

Franchise Operation: In this business model, the public sector essentially removes itself from the data fusion process. The private sector takes over data fusion with their technical skills and marketing capabilities. Figure 5.10 illustrates the concept of the Franchise Operation model.

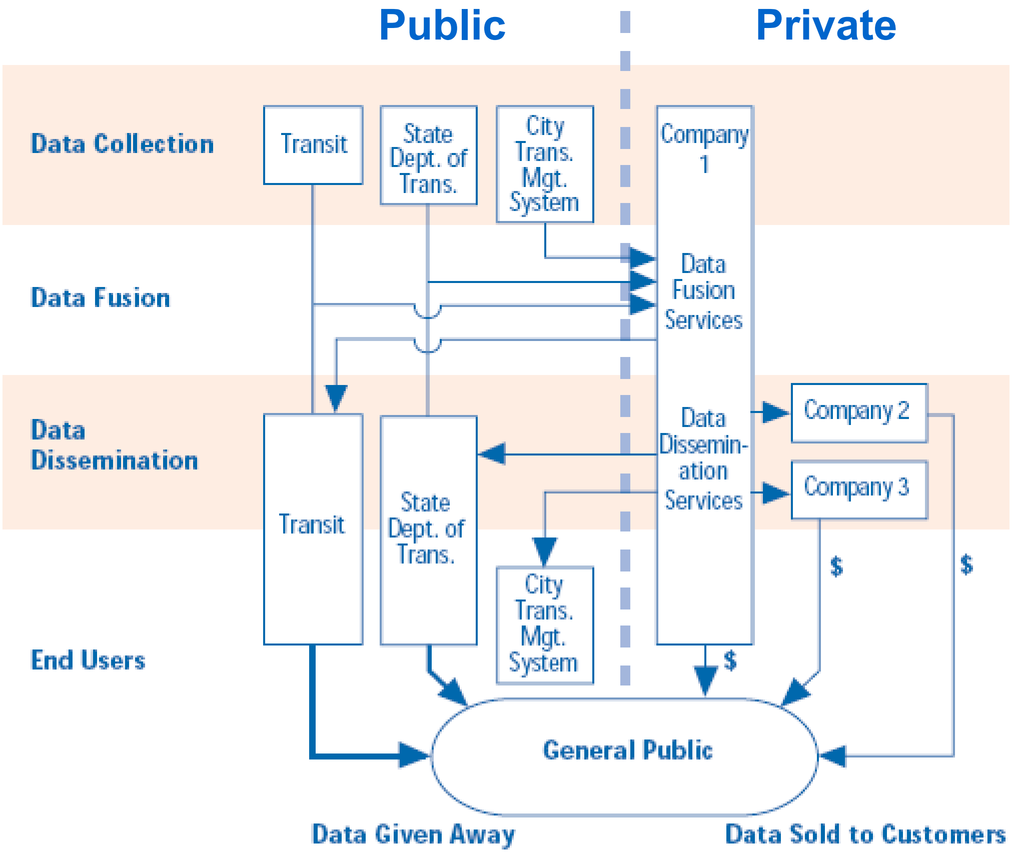


Figure 5.10: ATIS Business Model — Franchise Operation

A designated company may be granted exclusive data access to the public data. In return for the exclusive access, the private sector company that is fusing the data must provide data back to the public sector free of charge. However, the company can sell the data to other private sector partners. With this approach, the public sector's cost can be significantly reduced and the private sector's revenue maximized. The public has to pay for most of the information. With this approach, the public sector agencies are totally reliant on the private sector for the fused data.

Private, Competitive Operations: This approach helps to maximize the competition within the ATIS market, and is aimed at lowering consumer costs and maximizing private sector innovation. Private companies have to compete in data fusions. Figure 5.11 illustrates the concept.

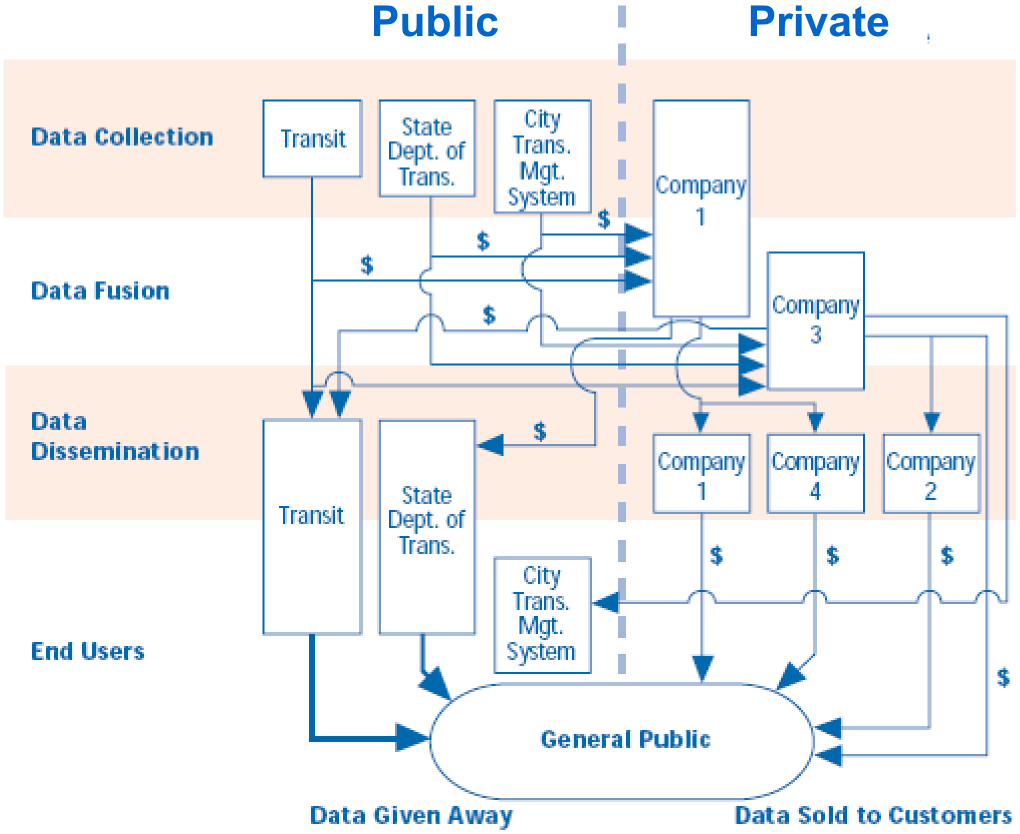


Figure 5.11: ATIS Business Model — Private, Competitive Operations

The advantage of this approach is that the competition should intensify the companies' incentives to provide better, lower-cost services. The disadvantage is that if the market is not large enough to sustain multiple companies, the revenue stream may be too small to achieve the growth needed to bring about better, lower-cost services.

A review of current Texas TMCs data collection, processing, and disseminating shows that most TMCs are using the approach of Public-Centered Operations. In general, TMCs have overall control of the infrastructure and data. TMCs provide information to the public and other information providers such as TV stations and radio stations, mostly for free. It helps transportation agencies meet public policy goals, but generates the least amount of revenue while requiring the greatest amount of public expenditure. In addition, all TMCs must maintain the expertise and technical staff to operate the data fusion process.

The five business models differ as to the involvement of public sectors and private sectors in data collection, access, fusion, and information dissemination. It is recommended that

Texas TMCs should adopt the business plan according to their primary objectives and policy. The decision of which business model to adopt, eventually becomes a policy issue.

5.6 Summary of Findings

This chapter focuses on the following three issues with respect to ATIS:

- Benefits and costs of ATIS deployments
- A framework for ATIS implementation
- Funding opportunities and business models for ATIS

Major findings and recommendations are summarized as follow:

1) ATIS benefits both travelers and transportation agencies. When estimating the costs of ATIS deployments, the capital costs of ATIS equipments and the O&M costs are major concerns. The IDAS program is a good tool to evaluate the benefits and costs of ATIS deployments. It is capable of analyzing the benefit and cost of multiple types of ATIS. However, it may require users to provide the operational impact of ATIS on traffic flow.
2) Since traffic operations are dynamic, it is recommended to use a dynamic traffic assignment tool to estimate the impact of ATIS on traffic operations. The DYNASMART model represents the state-of-the-art of dynamic traffic assignment methodology. It is capable of evaluating several ATIS deployments such as DMS and in-vehicle navigation system. This model might well fit TxDOT's needs in evaluating ITS deployments. Adopting the model and providing necessary training to TxDOT staff are recommended.
3) The IDAS evaluation results show that the DMS deployments in previous simulation study are cost-effective, with a benefit-cost ratio of 4.84. Deploying DMS' at major diversion points are recommended to enhance both toll road and non-tolled road operations.
4) The desired traveler information contents were identified through a commuter survey in Austin, TX. The information providing capabilities of Texas TMCs were reviewed. It was found that most TMCs in Texas are capable of providing the commuter-desired traffic information.
5) Various information delivery technologies were evaluated. These technologies include highway advisory radio (HAR), commercial radio, satellite radio traffic channel, commercial and cable TV, roadside dynamic message signs (DMS), in-vehicle driver assistance system, on-board GPS navigation device, internet-based system accessible by personal computer, 511 system, personal digital assistant (PDA). Based on a review of evolution of ATIS technologies, it was found that an on-board unit was the most promising information receiving method for users. It is recommended that TxDOT explore funding opportunities and public-private partnerships in disseminating traveler information to users through on-board units.

6) A practical framework was developed for ATIS implementations. The elements and their relationships were identified for information collection, information processing, information disseminating, information receiving, and traveler response. The potential implementation issues such as system integration, national ITS standards, system evaluation, funding, institutional and legal issues were identified and reviewed.
7) Funding opportunities for ATIS deployments were explored in this study. It was found that ATIS deployments were generally reliant on funding from the public sector. There is a market for traveler information and it is found that about 50% of commuters are willing to pay. However, the market is still immature. Funding opportunities in private sectors are limited and need substantial marketing effort. It requires public-private partnerships to create and promote the traveler information market.
8) Several business models for ATIS implementations were reviewed. It was found that most TMCs in Texas are using the Public-Centered Operations approach. There is significant scope for private sector involvements. Choosing which business model to apply eventually becomes a policy issue. It is recommended that TMCs choose the most effective approach according to their primary objectives and policies.

6. Conclusions and Recommendations

6.1 Conclusions

The primary assumption of this research is that commuters would be willing to pay a toll in exchange for avoiding congestion or for saving time. When a driver is faced with a choice between a tolled route and a non-tolled alternative route, the toll road is normally less attractive because of the obvious extra cost. However, in many situations, the toll road can actually save users time and cost. To examine how the use of traveler information would affect commuter travel behavior and traffic operations, this study was initiated by TxDOT in September 2004 and completed by the CTR team in August 2006. The primary objective of this study is to examine the benefits of providing traveler information in increasing toll road usage and reducing congestion on non-tolled network. Specifically, four research questions have been addressed:

- What information would help users choose a toll road?
- What is the potential increase in toll road share of traffic?
- What are the operational effects on the non-tolled network?
- What are the technical and financial considerations for deployment?

To accomplish the project objectives in a comprehensive manner, the research team completed the following research tasks in a two-year schedule:

- Leverage industry expertise
- Synthesize state-of-the-art in travel information deployment
- A commuter survey in Austin, Texas to determine effect of information on route choice and user requirements
- Analyze potential users, types of information desired, possible sources, delivery technology
- A simulation case study in Austin, TX to estimate the impacts of traveler information on commuter's toll road usage and traffic operations
- Analyze ATIS technology, cost, potential sources of funding, implementation issues

Through the literature review, it was found that ATIS has the potential to reduce travel time, increase travel time reliability, increase vehicle throughput in the transportation network, and reduce fuel and environmental cost. These benefits are achieved because ATIS can change driver's behavior, especially route choice. As reported in different studies and in different regions, 15%–34% of travelers changed their routes in response to travel information. Uncertainty in travel time on commuters' usual commute routes will significantly encourage them to use pre-trip traffic information. Longer-distance commuters are more likely to switch routes on the basis of pre-trip travel information. Freeway users tend to switch routes more frequently on the basis of en-route information. The amount of time savings is greatest when traffic flows average 95% of capacities. Potential users of ATIS are characterized by high income, high education, frequent driving, frequency of long-distance trips, facing unexpected delay, young, female, employed, and having a cell phone. Customers of toll roads tend to have similar demographics. Therefore, use of ATIS to enhance toll road operations is a natural convergence. However, ATIS is a double-edged sword in congestion management. If the messages are not well understood or properly responded, ATIS may lead to either a spatial transfer of congestion or even a worsen congestion level. On the other hand, when properly designed, ATIS will result in a better usage of system capacity.

Findings of the commuter survey in Austin, Texas verify that:

1) Most respondents, around 90%, indicate they are familiar enough with the local road network to find an alternate route if necessary. Forty-six percent of respondents said they would choose a toll road when traveler information indicates that maybe they could save time by doing so. Hence there is a tremendous opportunity to use automated traveler information systems (ATIS) to improve the operations of both tolled and non-tolled roads.
2) Commuters have more pressure on travel time during the morning rush hour. As a result, commuters seek traveler information more often during the morning rush hour than evening rush hour. Nevertheless, the majority of commuters seek traveler information during both morning rush hour and evening rush hour.
3) The traveler information sought by the majority of commuters includes accident locations, congested roads, road work, weather conditions, and lane closures. This finding is particularly useful for ATIS marketing.
4) Although radio and TV are currently most often used by Austin commuters to receive traveler information, DMS is the most "under-marketed" means of information delivery. The survey results show that DMS, internet, and in-vehicle technologies have great potential in delivering traveler information to commuters.
5) The majority of survey participants, 67%, cite "choose an alternate route" as the response to traveler information. This percentage is far higher than those citing "choose an alternate transportation mode," "change departure time," "cancel trip," and "no impact."
6) Most respondents, about 91%, indicate that they expect to save 5 to 15 minutes by changing their routes. The anticipated time saving accounts for 36% of commuters' regular one-way commute time. About 40% of respondents indicate they would pay for saving travel time. For those respondents who are willing to pay, the average amount is $2.07, with an average anticipated time saving of 12.5 minutes. It is equivalent to about $10 for 1 hour. This figure represents the value commuters in the Austin area place on personal travel time.
7) Forty-six percent of respondents said they would choose a toll road if traveler information indicated that they could save time. It was confirmed that income level and gender have effects on commuters' willingness to choose toll roads.

Based on the commuter survey, the simulation case study in Austin, TX indicates that providing congestion information on IH-35 through DMS would:

- Improve the entire network performance in travel time, delay, and number of stops.
- Reduce traffic on the non-tolled alternative route (IH-35 in the case study) and improve its main-lane performance.
- Significantly increase the SH 130-SH 45 toll road users. As a result of toll road usage increase, the toll road revenue from DMS deployment increases significantly as well.

The investigation of ATIS benefits and costs, implementation, funding opportunities, and business models indicates that:

- ATIS is one of the most promising ITS strategies in meeting travelers' needs and enhancing transportation system operations. It benefits both travelers and transportation agencies. The ATIS technology has evolved very rapidly since the 1990s. Although a mixed use of various ATIS technologies will exist for some time in the future, the technology is expected to merge towards an on-board audio/video system using satellite/GPS technology combined with toll collection capabilities.
- The IDAS evaluation results show that the DMS deployments in the simulation case study are cost-effective, with a benefit-cost ratio of 4.84.
- The commuter survey in Austin, TX indicates that the desired traveler information contents include accident locations, congestion locations, lane closures, estimated trip time, alternate routes, weather conditions, road hazards, and road work. Most TMCs in Texas are capable of providing these information contents.

6.2 Recommendations

Based on findings and conclusions from this study, following recommendations are made to TxDOT:

- Deploying DMSs at major diversion points are recommended to enhance both toll road and non-tolled road operations.
- Based on a review of evolution of ATIS technologies, it was found that on-board unit was the most promising information receiving method for users. It is recommended that TxDOT explore funding opportunities and public-private partnerships in disseminating traveler information to users through on-board units.
- A practical framework was developed for ATIS implementations in this study. It is recommended for TxDOT use in the future.
- It was found that ATIS deployments were generally reliant on funding from the public sector. There is a market for traveler information and it is found that about 50% of commuters are willing to pay. However, the market is still immature. Funding opportunities in private sectors are limited and need substantial marketing effort. It requires public-private partnerships to create and promote the traveler information market. TxDOT should play a leading role in this effort.

- It was found that most TMCs in Texas are using the Public-Centered Operations approach to fund the ATIS implementations. There is significant scope for private sector involvements. Choosing which business model to apply eventually becomes a policy issue. It is recommended that TMCs choose the most effective approach according to their primary objectives and policies.
- Since traffic operations are dynamic, it is recommended to use a dynamic traffic assignment tool to estimate the impact of ATIS on traffic operations. The DYNASMART model represents the state-of-the-art of dynamic traffic assignment methodology. It is capable of evaluating several ATIS deployments such as DMS and in-vehicle navigation system. This model might well fit TxDOT's needs in evaluating ITS deployments. Adopting the model and providing necessary training to TxDOT staff are recommended.

References

Abdel-Aty, M., and H. Abdelwahab. 2001. Toll road origin-destination travel survey. *Transportation Research Board* 1768: 61-70.

Abdel-Aty, M., Vaughn, K.M., Kitamura, R., and Jovanis, P., 1996. Understanding the effects of ATIS on Commuters' Route Choice Decisions. Proceedings of ITS America Conference, Houston, TX.

Algers, S., Bernauer, E., Boero, M., Breheret, L., di Taranto, C., Dougherty, M., Fox, K., and Gabard, J., 1997. Review of micro-simulation models. Smartest Project deliverable D3. Leeds.

Autoroutes, 2002. The French Toll Road Operators 2002, Chapter 4. Website:http://www.autoroutes.fr/pdf/RA_Chapitre4_gb.pdf

Balke, K.N., et al., 1995. Benefits of Real Time Travel Information in Houston, Texas. SWUTC/95/60010-1.

Bhat, C. 2004. Austin commuter survey: Findings and recommendations. Survey report. http://www.ce.utexas.edu/prof/bhat/REPORTS/austin_commuter_survey_report.doc

Byrne, A., de Laski, A., Courage, K., and Wallace, C., 1982. Handbook of computer models for traffic operations analysis. Technology Sharing Report FHWA-TS-82-213. Washington, D.C.

Cambridge Systematics Inc., 2001. ITS Deployment Analysis System (IDAS) User's Manual.

Carter, et al. Metropolitan Model Deployment Initiative: San Antonio Evaluation Report (Final Draft). Federal Highway Administration (FHWA-OP-00-017). Washington, DC. May 2000.

Dingus, T.A. and Hulse, M.C., 1993. Human factors research recommendations for the development of design guidelines for advanced traveler information systems. Proceedings of the Human Factors Society 37th Annual Meeting, pp1067-1071. Santa Monica, CA: Human Factors and Ergonomics Society.

Drew, D.R., 1968. Traffic flow theory and control. New York: McGraw-Hill.

FHWA, 2000. "What Have We Learned About Advanced Traveler Information Systems and Customer Satisfaction?", Chapter 4 of *What Have We Learned About ITS?* (US DOT, FHWA, December 2000).

Fujii, S., and R. Kitamura. 2000. Anticipated travel time, information acquisition, and actual experience: Hanshin Expressway route closure, Osaka-Sakai, Japan. *Transportation Research Record: Journal of the Transportation Research Board* 1725: 79-85.

Gerlough, D., and Huber, M., 1975. Traffic flow theory. A monograph. TRB Special Report 165. Washington, D.C.

Hall, R.W. 1999. *Handbook of transportation science.* Massachusetts: Kluwer Academic Publishers.

Hobeika, A., Sivanandan, R., Jehanian, K.M., and Ameen, M.D., 1996. Advanced Traveler Information System: User's Needs in I-95 Northeast Corridor. Transportation Research Record 1537, pp.55-62, Washington, D.C.

ITS-America, 1998. Choosing the Route to Traveler Information Systems Deployment-Decision Factors for Creating Public-Private Business Plans: An Action Guide.

Kallberg, H., 1971. Traffic simulation (in Finnish). Licentiate thesis, Helsinki University of Technology, Transportation Engineering. Espoo.

Khattak, A.J. and Khattak, A.J., 1998. Comparative Analysis of Spatial Knowledge and En Route Diversion Behavior in Chicago and San Francisco: Implications for Advanced Traveler Information Systems. Transportation Research Record 1621, pp.27-35, Washington, D.C.

Khattak, A.J., Yim, Y., and Stalker, L., 1999. Does travel information influence commuter and noncommuter behavior? Results from the San Francisco Bay Area TravInfo project. *Transportation Research Record: Journal of the Transportation Research Board* 1694: 48-58.

Kim, K.S. and Vandebona, U., 1999. User Requirements and Willingness to Pay for Traffic Information Systems: Case Study of Sydney, Australia. Transportation Research Record 1694, pp.42-47, Washington, D.C.

Koo, R. and Yim, Y., 1998. Commuter Response to Traffic Information on an Incident. Transportation Research Record 1621, pp.36-42, Washington, D.C.

Lappin, J., Sloan, S., and Church, R., 1994. A Market Analysis of the Commercial Traffic Information Business. Economic Analysis Division, John A. Volpe National Transportation Systems Center, Research Report prepared for FHWA. Cambridge, MA.

Lay, M.G., and Daley, K.F., 2002. "The Melbourne City Link Project". Transport Policy. May 2002.

Lee, D.B., 2000(b). Cost-benefit Evaluation of Traveler Information: Seattle's Washington State Department of Transportation Website. In Transportation Research Record: Journal of the Transportation Research Board No. 1739, TRB, National Research Council, Washington, D.C., pp.25-34.

Levinson, D.M., 2003. The value of advanced traveler information systems for route choic. *Transportation Research, Part C, 11C(1), pp75-87.*

Lockheed Martin Federal Systems, Odetics Intelligent Transportation Systems Division, 1996 . ITS Performance and Benefit Study. Report prepared for FHWA, USDOT, Washington, D.C.

Mahmassani, H.S., Sbayti, H.A., and Zhou, X., 2004. DYNASMART-P Version 1.0 User's Guide. University of Maryland, Maryland.

McDonald, M., Brackstone, M., and Sultan, B., 1998. Instrumented vehicle studies of traffic flow models. Proceedings of the Third International Symposium on Highway Capacity, Volume 2, Ryysgaard, R., ed., pp. 755-774. Copenhagen: Transportation Research Board and Danish Road Directorate.

Mehndiratta, S.R., Kemp, M.A., Lappin, J.E., and Nierenberg, E., 2000. Likely Users of Advanced Traveler Information Systems. Transportation Research Record 1739, pp.15-24, Washington, D.C.

Mustafa, M. A. S. and Pitsiava-Latinpoulou, M., 1995 "Implementation of Driver Information System Using Dedicated Short Range Communication Media." Aristotle University of Thessaloniki, Greece.

Ng, L., W. Barfield, and F. Mannering, 1995. A Survey_Based Methodology to Determine Information Requirements for Advanced Traveler Information Systems. Presented at 74th Annual Meeting of the Transportation Research Board. Washington, D.C.

Orrick 2003. Phyllis Orrick. Institute of Transportation Studies at the University of California at Berkeley. Website: http://www.calccit.org/itsdecision/serv_and_tech/ Traveler_ information/trav_info_overview.html. Accessed February 2005.

Pattern, M.L., Goulias, K.G., Pibyl, O., 2002. User Perceptions of Advanced Traveler Information Systems on the Pennsylvania Turnpike. 9th World Congress on Intelligent Transport Systems, 2002. Chicago, IL, USA.

Peng, Z.R., Beimborn, E., and Neluheni, M.,,2000. A Framework for the Evaluation of the Benefits of Intelligent Transportation Systems. Prepared for the Wisconsin Department of Transportation. Center for Urban Transportation Studies, University of Wisconsin-Milwaukee, Milwaukee, WI.

Persad et al, 2006: Persad, K., Walton, C.M., and Hussain, S., 2006. *Toll Collection Technology and Best Practices*. TxDOT Research Product 0-5217-P1.

Persad, K., and Bansal, S., 2004. Toll roll life cycle: Two case studies. Presented at 83rd Annual Meeting of the Transportation Research Board. Washington, D.C.

Polydoropoulou, A., M. Ben-Akiva, A. Khattak, and G. Lauprete. 1996. Modeling revealed and state en-route travel response to advanced traveler information systems. *Transportation Research Record: Journal of the Transportation Research Board* 1537: 38-45.

Sadek, A.W. and Baah, B., 2003. Cost-Effectiveness of Intelligent Transportation System Deployment in a Medium-Sized Area: Case Study with ITS Deployment Analysis System. In Transportation Research Record: Journal of the Transportation Research Board No. 1826, TRB, National Research Council, Washington, D.C., pp.16-24.

Sanhouri, I.E. and Bernstein, D., 1994. Integrating Driver Information and Congestion Pricing Systems. Transportation Research Record 1450, pp.44-50, Washington, D.C.

Science Applications International Corporation (SAIC), 1999. User's Manual for SCRITS, SCReening Analysis for ITS. Washington, D.C.

Shah, V.P., Wunderlich, K., Toppen, A., and Larkin, J., 2003. Potential of Advanced Traveler Information System to Reduce Travel Disutility. Transportation Research Record No.1826, pp.7-15, 2003. Washington, D.C.

Supernak et al., 2002 "San Diego's I-15 Congestion Pricing Project – Attitudinal, Behavioral and Institutional Issues," Transportation Research Record 1812, pp78-86, Washington, D.C.

Shaheen, S., 2003. ITS Decision. Website: http://www.calccit.org/itsdecision/serv_and_tech/Traveler_information/Pretrip/pretrip_summary.html

Toppen, A.J., Shah, V.P., Larkin, J.J., Wunderlich, K., 2002. Time Management Benefits of ATIS for Unfamiliar Urban Drivers. 9th World Congress on Intelligent Transport Systems, 2002. Chicago, IL, USA.

United States Department of Transportation, 2001. ITS Benefits, 2001 Updates. Washington, D.C.

USDOT, ITS: Vehicle Infrastructure Initiative, 2005. U.S. Department of Transportation, Intelligent Transportation Systems: Vehicle Infrastructure Initiative. http://www.its.dot.gov/vii/vii_concept.htm. Accessed 04/06.

Wolinetz, L.D., Khattak, A.J., and Yim, Y., 2001. Why Will Some Individuals Pay for Travel Information When It Can Be Free?: Analysis of a Bay Area Traveler Survey. Transportation Research Record 1759, pp.9-18, Washington, D.C.

Wunderlich, K., Bunch, J. and Larkin, J., 2000. Seattle Metropolitan Model deployment Initiative Evaluation. Transportation Research Record 1739, pp.35-43, Washington, D.C.

Yang, C.Y., Fricker, J.D., and Kuczek, T., 1998. Designing Advanced Traveler Information Systems from a Driver's Perspective: Results of a Driving Simulation Study. Transportation Research Record 1621, pp.20-26, Washington, D.C.

Yang, C.Y. David, and Fricker, J.D., 2001. Using Human Information Processing Principles to Design Advanced Traveler Information Systems. Transportation Research Record 1759, pp.1-8, Washington, D.C.

Yim, Y., Hall, R.W., and Weissenberger, S., 1997. TravInfo Evaluation: Traveler Response Element Broad Area Survey. PATH Working Paper UCB-ITS-PWP-97-9, California Department of Transportation, CA.

Zavergiu, R., 1996. Intelligent Transportation Systems: An Approach to Cost-benefit Studies. Research Report. Published by Transport Canada. Transportation Development Center, Quebec, Canada.

Appendix A. Survey Questionnaire for Austin Commuters on Use of Traveler Information to Enhance Traffic Operations on both Tolled and Non-Tolled Roads

This questionnaire was developed for a survey with Austin commuters to obtain their opinions on traveler information system and toll roads. The purpose of the survey was to examine commuters’ perspective with respect to ATIS deployments and toll road usage.

(Please see next page for the questionnaire)

SURVEY ON USE OF TRAVELER INFORMATION IN AUSTIN, TEXAS REGION

The Center for Transportation Research (CTR) at the University of Texas, Austin is conducting a survey on traveler information usage in Central Texas. We define traveler information as news or updates on the travel condition of roads you use (for example, news of accidents and general traffic flow). With your feedback we will determine the type of traveler information most useful to the public and develop traveler information systems that will help in alleviating traffic congestion in the Austin metropolitan area. The questionnaire requires approximately 10 to 12 minutes to complete, and your answers will be kept confidential. CTR thanks you for taking the time to let us know your opinion on traveler information. If you have any questions please contact me at the following email address.

Khali Persad, Research Associate
Center for Transportation Research
(kpersad@mail.utexas.edu)

Section I. Your Commuting Patterns

In this section we want to ask about trips you take during rush hours. We define <u>*rush hours*</u> *as the times between 7:00 – 9:00 a.m. and 4:00 – 6:00 p.m. on* <u>*weekdays*</u> *and from 10 a.m.. to 5 p.m. on* <u>*weekends*</u>*.*

1. How many days per week do you commute during peak traffic hours? (Please enter a value in the space provided)

_____ number of days

2. When you typically travel during rush hours, what is your main trip purpose(s)?

	Primary Trip Purpose	**Secondary Trip Purpose**
Work	☐	☐
School	☐	☐
Child care/child's school	☐	☐
Recreation/social	☐	☐
Shopping	☐	☐
Medical	☐	☐
Other:__________________ (specify)	☐	☐

3. What type of transportation do you use most often when traveling during morning and/or evening rush hours? (Please select one answer – if you use more than one mode, please select the one that that you use for the majority of your commute)

a. automobile (including a car, truck, van)
b. public transportation (Capital Metro bus or other transit provider)
c. walk
d. bicycle
e. other ________________ (please specify)

4. Which of the following Austin area highways do you use most often when commuting during rush hours? (Please select all that apply)

	Morning Rush Hours	Evening Rush Hours
IH – 35 (Interstate Highway 35)	☐	☐
US-360 (Capital of Texas)	☐	☐
US-71 (Ben White Boulevard: West - Bee Cave)	☐	☐
US-71 (Ben White Boulevard: East – Bastrop)	☐	☐
US-183 (Research Boulevard - North)	☐	☐
Loop 1 (Mopac)	☐	☐
US-290 East (Elgin/Manor)	☐	☐
US-290 West (Dripping Springs/Oak Hill)	☐	☐
FM-2222	☐	☐
Parmer Lane (FM 734)	☐	☐
Other:___________________ (specify)	☐	☐

5. Do you know the local Austin roadway system well enough to find alternative routes when necessary?

1. yes   2. no

6. When traveling during rush hours, what is the average time in minutes you spend traveling to your final destination? (Please enter a number value in the space provided.)

_____ average number of minutes spent in outbound trip

_____ average number of minutes spent in home bound trip

7. When traveling during rush hours what is the average number of miles you travel? (Please enter a number value in the space provided.)

_____ average number of miles spent in outbound trip

_____ average number of miles spent in home bound trip

8. At what time do you usually need to arrive at your trip destination? (Please use an hour and minute format, for example 08:30 or 10:00, in the space provided.)

weekdays: ____:____ a.m.

weekdays: ____:____ p.m.

Section II. Traveler Information Usage

We now want to ask you about your use of traveler information. We define *__traveler information__* *as news or updates on travel condition of roads you use (for example, news of accidents and general traffic flow).*

1. How often do you typically seek traveler information during <u>morning</u> <u>and</u> <u>evening</u> rush hours? (Please select one rating for morning and for evening rush hours.)

Rush Hours	**Never**	**Sometimes**	**Fairly Often**	**Very Often**
Morning	1	2	3	4
Evening	1	2	3	4

2. How do you currently receive traveler information on the local roadway system? (Please select all that apply.)

a. Radio
b. TV
c. Local newspaper
d. Internet
e. Highway Electronic Message Signs
f. Other __________________ (please specify)

3. Which of the following would you *prefer* to use to receive traveler information on the local roadway system? (Please select one answer.)

a. Radio
b. TV
c. Local newspaper
d. Internet
e. Highway Electronic Message Signs
f. Other __________________ (please specify)

4. When do you seek out traveler information?

a. Before you leave your home/destination
b. While en-route
c. Both

5. How likely are you to seek out the following traveler information to determine traffic conditions? (Please circle a likelihood rating for each type of traveler information)

Traveler Information on:	**Likelihood to Seek Out Traveler Information**				
	Very Unlikely	**Unlikely**	**Neutral**	**Likely**	**Very Likely**
Road work	1	2	3	4	5
Lane closure	1	2	3	4	5
Road hazard warnings	1	2	3	4	5
Accident locations	1	2	3	4	5
Congested roads	1	2	3	4	5
Estimated travel time	1	2	3	4	5
Alternate routes	1	2	3	4	5
Weather conditions	1	2	3	4	5
Other _____________ (please specify)	1	2	3	4	5

6. At what time is the following traveler information most important to you? (Please check a box for each type of traveler information.)

Traveler Information on:	**When Information is Most Important**			
	AM	**PM**	**All the Time**	**None of the Time**
Road work	☐	☐	☐	☐
Lane closure	☐	☐	☐	☐
Road hazard warnings	☐	☐	☐	☐
Accident locations	☐	☐	☐	☐
Congested roads	☐	☐	☐	☐
Estimated travel time	☐	☐	☐	☐
Alternate routes	☐	☐	☐	☐
Weather conditions	☐	☐	☐	☐
Other _________________ (please specify)	☐	☐	☐	☐

7. How does the traveler information you've received impact your travel? (Please select one answer.)

a. choose an alternate form of transportation other than my car such as public transportation, walking or a bus)

b. delay my departure time
c. leave earlier than planned
d. choose an alternate route
e. cancel trip
f. no impact on travel decision
g. other ___________________ (please specify)

Section III. Route Switching and Value of Time

Now we're going to ask you some questions regarding road congestion and switching to an alternate commuting route.

1. For each type of traveler information listed below please indicate how likely you would be to switch to another route if that type of information was **available** to you and you found that it might impact your typical travel. (Please circle a rating for each choice listed below.)

	Likelihood of Switching Route				
Traveler Information on:	**Very Unlikely**	**Unlikely**	**Neutral**	**Likely**	**Very Likely**
Road work	1	2	3	4	5
Lane closure	1	2	3	4	5
Warnings about road hazards	1	2	3	4	5
Accident locations	1	2	3	4	5
Congested roads	1	2	3	4	5
Estimated travel time	1	2	3	4	5
Recommended alternate routes	1	2	3	4	5
Weather conditions	1	2	3	4	5
Other ______________(please specify)	1	2	3	4	5

2. If you knew that you could save time by switching to an alternate route, what is the **minimum** number of minutes of time savings that would encourage you to switch routes? (Please select one answer.)

a. 5 minutes b. 10 c. 15 d. 20 e. 25 f. 30

3. To save the amount of time you circled in Q2 above, how much would you be willing to pay? (Please include a dollar/cents amount in the space provided.)

$__________

4. Would you choose a toll road, if traveler information indicated that you could save time on the toll road?

1. yes 2. no

Section IV. Your Demographic Data

This information will allow us to categorize the survey responses and to make comparisons of results among different demographic groups and areas/regions within Central Texas. The information will not be used to identify respondents.

1. How many people live in your household including yourself?

_____ number of people in household

2. Of the people who live in your household, how many drive?

_____ number of drivers in the household

3. How many vehicles do you have in your household?

_____ number of vehicles in your household

4. Do you have any children ages 0 to 11 years of age in your household?

1. yes 2. no

5. What is your current zip code?

________ zip code

6. What is your gender?

a. female
b. male

7. What is your age?

a. 15 to 19
b. 20 to 24
c. 25 to 34
d. 35 to 44
e. 45 to 54
f. 55 to 59
g. 60 to 64
g. 65+

8. What is the highest level of education you have completed?

a. Less than high school graduate
b. High school graduate (includes equivalency)
c. Some college, no degree
d. Associates degree
e. Bachelor's degree
f. Graduate or professional degree

9. What is your current employment status?

a. employed full-time and work from my home
b. employed full-time and work outside my home
c. employed part-time and work from my home
d. employed part-time and work outside my home
e. unemployed
f. unpaid family worker
g. full time student
h. retired
i. other _____________________________ (please specify)

10. What is your total household income?

Less than $10,000
$10,000 to $14,999
$15,000 to $24,999
$25,000 to $34,999
$35,000 to $49,999
$50,000 to $74,999
$75,000 to $99,999
$100, 000 to $149,000
$150,000 to $199,999
$200,000 or more

11. Would you like to be contacted regarding the survey results/findings? If so, please include your email address here: _________________________ (email address).

❖❖❖❖❖❖

Thank you for completing the questionnaire. The information you have provided will be used to help develop a traveler information system that will improve travel during peak hours in Austin.

Appendix B. DYNASMART-P Simulation Results

Outputs for No-Information Scenario

```
          ***************************************************
          *              D Y N A S M A R T - P              *
          *                                                 *
          *   Intelligent Transportation Network Planning Tool   *
          *                                                 *
          *                  Version (1.0)                  *
          *                                                 *
          *             University of Maryland              *
          *                                                 *
          *          Release Date: September, 2004          *
          ***************************************************


***************************************
 *     Basic Information             *
***************************************

NETWORK DATA
------------
   Number of Nodes                  :    5964
   Number of Links                  :   12421
   Number of Zones                  :     111
***************************************

INTERSECTION CONTROL DATA
-------------------------
   Number of No Control              :    4908
   Number of Yield Signs             :       0
   Number of 4-Way Stop Signs          :       0
   Number of 2-Way Stop Signs          :       0
   Number of Pretimed Control         :       0
   Number of Actuated Control         :    1056
***************************************

RAMP DATA
---------
   Number of Metered Ramps :       0
***************************************

SOLUTION MODE
-------------
  Execute One-Shot Simulation Mode
***************************************
```

```
TIME PERIODS
-----------
  Planning Horizon(min)                  :    100.0
  Aggregation Interval(# of Sim Int)      :     10
  Assignment Interval(# of Sim Int)       :     50
  Max # of Iterations                   :      0
  MUC Threshold (# of Vehicles)           :      0.5
  Convergence Threshold(# of Violation)   :    100
**************************************

CONGESTION PRICING
-----------------
  Cost on Regular Links($)               :      0.0
  Cost of LOV on HOT Links($)             :      0.1
  Cost of HOV on HOT Links($)             :      0.1
  Value of Time($/hr)                   :     10.0
**************************************

VARIABLE MESSAGE SIGNS
---------------------
  No Traffic Management Strategy Was Specified
**************************************

CAPACITY REDUCTION
-----------------
  No Capacity Reduction Scenario Was Specified

***************************************
*      Loading Information            *
***************************************

T:   5.0 Tot Veh:   25020 Gen:  25020 Out_n:      0 Out_t:  1473 In_v:  23547
T:  10.0 Tot Veh:   53671 Gen:  28651 Out_n:      0 Out_t:  6330 In_v:  45868
T:  15.0 Tot Veh:   89463 Gen:  35792 Out_n:      0 Out_t: 11145 In_v:  70515
T:  20.0 Tot Veh:  132388 Gen:  42925 Out_n:      0 Out_t: 15011 In_v:  98429
T:  25.0 Tot Veh:  178905 Gen:  46517 Out_n:      0 Out_t: 17145 In_v: 127801
T:  30.0 Tot Veh:  218299 Gen:  39394 Out_n:      0 Out_t: 18668 In_v: 148527
T:  35.0 Tot Veh:  250477 Gen:  32178 Out_n:      0 Out_t: 19355 In_v: 161350
T:  40.0 Tot Veh:  282683 Gen:  32206 Out_n:      0 Out_t: 18756 In_v: 174800
T:  45.0 Tot Veh:  311344 Gen:  28661 Out_n:      0 Out_t: 18611 In_v: 184850
T:  50.0 Tot Veh:  339965 Gen:  28621 Out_n:      0 Out_t: 17959 In_v: 195512
T:  55.0 Tot Veh:  364981 Gen:  25016 Out_n:      0 Out_t: 17312 In_v: 203216
T:  60.0 Tot Veh:  390052 Gen:  25071 Out_n:      0 Out_t: 16923 In_v: 211364
T:  65.0 Tot Veh:  411484 Gen:  21432 Out_n:      0 Out_t: 16641 In_v: 216155
T:  70.0 Tot Veh:  429348 Gen:  17864 Out_n:      0 Out_t: 15970 In_v: 218049
T:  75.0 Tot Veh:  447269 Gen:  17921 Out_n:      0 Out_t: 15059 In_v: 220911
T:  80.0 Tot Veh:  465157 Gen:  17888 Out_n:      0 Out_t: 14288 In_v: 224511
T:  85.0 Tot Veh:  483057 Gen:  17900 Out_n:      0 Out_t: 13984 In_v: 228427
T:  90.0 Tot Veh:  500951 Gen:  17894 Out_n:      0 Out_t: 12939 In_v: 233382
T:  95.0 Tot Veh:  518798 Gen:  17847 Out_n:      0 Out_t: 12422 In_v: 238807
T: 100.0 Tot Veh:  536696 Gen:  17898 Out_n:      0 Out_t: 11549 In_v: 245156
**************************************
```

```
VEHICLE LOADING MODE
--------------------
   O-D Demand Table
**************************************

MUC CLASS PERCENTAGES
---------------------
   Pre-Specified (Non-Responsive)          :   100.00 %
   Boundedly-Rational(En-route Information) :     0.00 %
   VMS Responsive                          :     0.00 %
   System Optimal                          :     0.00 %
   User Equilibrium                        :     0.00 %
**************************************

VEHICLE TYPE PERCENTAGES
------------------------
   PC                          :     100.0 %
   TRUCK                       :       0.0 %
   HOV                         :       0.0 %
   BUS                         :       0 Buses
AVG.IB-FRACTION = 0.20   BOUND = 1.00

NOTE : There are      245156  target vehicles still in the network

 ******* VEHICLE INFORMATION *******
          TOTAL VEHICLES        :       536696
          NON-TAGGED VEHICLES   :            0
          TAGGED VEHICLES (IN)  :       245156
          TAGGED VEHICLES (OUT) :       291540
          OTHERS                :            0

   Avg. travel time for HOV                    :       N/A

 ******* HOT LANE(S) INFORMATION  **********
   Number of Links with Toll                   :     149

   For the Vehicles Exit the Network

   Number of LOV in HOT lanes                  :    6123
   Avg. travel time for LOV in the HOT lane    :      30.8892

   Number of LOV not in HOT lanes              :  285417
   Avg. travel time for LOV not in the HOT lane :      20.9684

   Number of HOV in HOT lanes                  :       0
   Avg. travel time for HOV in the HOT lane    :       N/A

   Number of HOV not in HOT lanes              :       0
   Avg. travel time for HOV not in the HOT lane :       N/A
```

```
*************************************
*  OVERALL STATISTICS REPORT         *
*************************************

   Max Simulation Time (min)                :      100.0
   Actual Sim. Intervals                    :     1000
   Simulation Time     (min)                :      100.0
   Start Time in Which Veh Stat are Collected :        0.0
   End   Time in Which Veh Stat are Collected :      100.0
   Total Number of Vehicles of Interest       :   536696
                        With    Info       :        0
                        Without Info       :   536696
-----------------------------------------------
TOTAL TRAVEL TIMES (HRS)
   OVERALL    :  259228.6406
   NOINFO     :  259228.6406
   1 stop     :  259228.6406
   2 stops    :       0.0000
   3 stops    :       0.0000
   INFO       :       0.0000
   1 stop     :       0.0000
   2 stops    :       0.0000
   3 stops    :       0.0000

AVERAGE TRAVEL TIMES (MINS)
   OVERALL    :      28.9805
   NOINFO     :      28.9805
   1 stop     :      28.9805
   2 stops    :       0.0000
   3 stops    :       0.0000
   INFO       :       0.0000
   1 stop     :       0.0000
   2 stops    :       0.0000
   3 stops    :       0.0000

-----------------------------------------------
TOTAL TRIP TIMES (INCLUDING ENTRY QUEUE TIME) (HRS)
   OVERALL    :  279742.4062
   NOINFO     :  279742.4062
   1 stop     :  279742.4062
   2 stops    :       0.0000
   3 stops    :       0.0000
   INFO       :       0.0000
   1 stop     :       0.0000
   2 stops    :       0.0000
   3 stops    :       0.0000
AVERAGE TRIP TIMES (INCLUDING ENTRY QUEUE TIME) (MINS)
   OVERALL    :      31.2738
   NOINFO     :      31.2738
   1 stop     :      31.2738
   2 stops    :       0.0000
   3 stops    :       0.0000
   INFO       :       0.0000
```

```
  1 stop     :      0.0000
  2 stops    :      0.0000
  3 stops    :      0.0000

-------------------------------------------------
TOTAL ENTRY QUEUE TIMES (HRS)
  OVERALL    :  20307.3125
  NOINFO     :  20307.3125
  1 stop     :  20307.3125
  2 stops    :      0.0000
  3 stops    :      0.0000
  INFO       :      0.0000
  1 stop     :      0.0000
  2 stops    :      0.0000
  3 stops    :      0.0000
AVERAGE ENTRY QUEUE TIMES (MINS)
  OVERALL    :      2.2703
  NOINFO     :      2.2703
  1 stop     :      2.2703
  2 stops    :      0.0000
  3 stops    :      0.0000
  INFO       :      0.0000
  1 stop     :      0.0000
  2 stops    :      0.0000
  3 stops    :      0.0000

--------------------------------------------------
TOTAL STOP TIME ( HRS )
  OVERALL    : 114640.9531
  NOINFO     : 114640.9531
  1 stop     : 114640.9531
  2 stops    :      0.0000
  3 stops    :      0.0000
  INFO       :      0.0000
  1 stop     :      0.0000
  2 stops    :      0.0000
  3 stops    :      0.0000
AVERAGE STOP TIME ( MINS )
  OVERALL    :     12.8163
  NOINFO     :     12.8163
  1 stop     :     12.8163
  2 stops    :      0.0000
  3 stops    :      0.0000
  INFO       :      0.0000
  1 stop     :      0.0000
  2 stops    :      0.0000
  3 stops    :      0.0000

--------------------------------------------------
TOTAL TRIP DISTANCE ( MILES )
  OVERALL    : 4492723.0000
  NOINFO     : 4492723.0000
  1 stop     : 4492723.0000
```

```
   2 stops    :       0.0000
   3 stops    :       0.0000
   INFO       :       0.0000
   1 stop     :       0.0000
   2 stops    :       0.0000
   3 stops    :       0.0000
AVERAGE TRIP DISTANCE ( MILES )
   OVERALL    :       8.3711
   NOINFO     :       8.3711
   1 stop     :       8.3711
   2 stops    :       0.0000
   3 stops    :       0.0000
   INFO       :       0.0000
   1 stop     :       0.0000
   2 stops    :       0.0000
   3 stops    :       0.0000

--------------------------------------------------
```

Outputs for for Information-Provided Scenario

```
          **************************************************
          *                D Y N A S M A R T - P           *
          *                                                *
          *   Intelligent Transportation Network Planning Tool *
          *                                                *
          *                  Version (1.0)                 *
          *                                                *
          *              University of Maryland            *
          *                                                *
          *          Release Date: September, 2004         *
          **************************************************


***************************************
*    Basic Information          *
***************************************

NETWORK DATA
------------
   Number of Nodes                 :   5964
   Number of Links                 :  12421
   Number of Zones                 :    111
**************************************

 INTERSECTION CONTROL DATA
------------------------
   Number of No Control             :   4908
   Number of Yield Signs            :      0
   Number of 4-Way Stop Signs       :      0
   Number of 2-Way Stop Signs       :      0
   Number of Pretimed Control       :      0
   Number of Actuated Control       :   1056
**************************************

 RAMP DATA
---------
   Number of Metered Ramps :      0
**************************************

 SOLUTION MODE
-------------
  Execute One-Shot Simulation Mode
**************************************

 TIME PERIODS
------------
   Planning Horizon(min)             :    100.0
   Aggregation Interval(# of Sim Int)  :     10
   Assignment Interval(# of Sim Int)   :     50
```

```
  Max # of Iterations                    :       0
  MUC Threshold (# of Vehicles)          :       0.5
  Convergence Threshold(# of Violation)   :     100
***************************************

CONGESTION PRICING
------------------
  Cost on Regular Links($)               :       0.0
  Cost of LOV on HOT Links($)            :       0.1
  Cost of HOV on HOT Links($)            :       0.1
  Value of Time($/hr)                    :      10.0
***************************************

VARIABLE MESSAGE SIGNS
----------------------
  Number of Variable Message Signs:   19

  VMS #     1    Type:  Congestion Warning
  Location 3069  -- 8754   From min   0.0 To min 100.0
  The Best Path is Assigned to Responded Vehicles
    100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

  VMS #     2    Type:  Congestion Warning
  Location 3911  -- 3804   From min   0.0 To min 100.0
  The Best Path is Assigned to Responded Vehicles
    100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

  VMS #     3    Type:  Congestion Warning
  Location 3960  -- 3959   From min   0.0 To min 100.0
  The Best Path is Assigned to Responded Vehicles
    100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

  VMS #     4    Type:  Congestion Warning
  Location 4023  -- 7420   From min   0.0 To min 100.0
  The Best Path is Assigned to Responded Vehicles
    100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

  VMS #     5    Type:  Congestion Warning
  Location 4029  -- 7426   From min   0.0 To min 100.0
  The Best Path is Assigned to Responded Vehicles
    100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

  VMS #     6    Type:  Congestion Warning
  Location 4572  -- 7465   From min   0.0 To min 100.0
  The Best Path is Assigned to Responded Vehicles
    100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

  VMS #     7    Type:  Congestion Warning
  Location 4614  -- 7471   From min   0.0 To min 100.0
  The Best Path is Assigned to Responded Vehicles
    100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS
```

```
VMS #     8    Type:  Congestion Warning
 Location 4581  -- 4582   From min   0.0 To min 100.0
 The Best Path is Assigned to Responded Vehicles
   100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

 VMS #     9    Type:  Congestion Warning
 Location 5280  -- 7459   From min   0.0 To min 100.0
 The Best Path is Assigned to Responded Vehicles
   100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

 VMS #    10    Type:  Congestion Warning
 Location 5310  -- 7419   From min   0.0 To min 100.0
 The Best Path is Assigned to Responded Vehicles
   100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

 VMS #    11    Type:  Congestion Warning
 Location 5323  -- 4567   From min   0.0 To min 100.0
 The Best Path is Assigned to Responded Vehicles
   100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

 VMS #    12    Type:  Congestion Warning
 Location 5999  -- 5998   From min   0.0 To min 100.0
 The Best Path is Assigned to Responded Vehicles
   100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

 VMS #    13    Type:  Congestion Warning
 Location 6247  -- 6248   From min   0.0 To min 100.0
 The Best Path is Assigned to Responded Vehicles
   100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

 VMS #    14    Type:  Congestion Warning
 Location 6349  -- 6350   From min   0.0 To min 100.0
 The Best Path is Assigned to Responded Vehicles
   100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

 VMS #    15    Type:  Congestion Warning
 Location 6361  -- 6354   From min   0.0 To min 100.0
 The Best Path is Assigned to Responded Vehicles
   100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

 VMS #    16    Type:  Congestion Warning
 Location 7095  -- 7087   From min   0.0 To min 100.0
 The Best Path is Assigned to Responded Vehicles
   100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

 VMS #    17    Type:  Congestion Warning
 Location 8744  -- 8753   From min   0.0 To min 100.0
 The Best Path is Assigned to Responded Vehicles
   100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

 VMS #    18    Type:  Congestion Warning
 Location 8761  -- 8757   From min   0.0 To min 100.0
 The Best Path is Assigned to Responded Vehicles
```

```
    100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS

  VMS #    19    Type:  Congestion Warning
  Location 6634  -- 7086   From min   0.0 To min 100.0
  The Best Path is Assigned to Responded Vehicles
    100 % of Out-of-Vehicle Responsive Vehicles Respond to VMS
***************************************

CAPACITY REDUCTION
-----------------
  No Capacity Reduction Scenario Was Specified

****************************************
*      Loading Information             *
****************************************

T:   5.0 Tot Veh:   25020 Gen:  25020 Out_n:      0 Out_t:  1466 In_v:  23554
T:  10.0 Tot Veh:   53671 Gen:  28651 Out_n:      0 Out_t:  6417 In_v:  45788
T:  15.0 Tot Veh:   89463 Gen:  35792 Out_n:      0 Out_t: 11283 In_v:  70297
T:  20.0 Tot Veh:  132388 Gen:  42925 Out_n:      0 Out_t: 14981 In_v:  98241
T:  25.0 Tot Veh:  178905 Gen:  46517 Out_n:      0 Out_t: 17284 In_v: 127474
T:  30.0 Tot Veh:  218299 Gen:  39394 Out_n:      0 Out_t: 18947 In_v: 147921
T:  35.0 Tot Veh:  250477 Gen:  32178 Out_n:      0 Out_t: 19434 In_v: 160665
T:  40.0 Tot Veh:  282683 Gen:  32206 Out_n:      0 Out_t: 19774 In_v: 173097
T:  45.0 Tot Veh:  311344 Gen:  28661 Out_n:      0 Out_t: 19397 In_v: 182361
T:  50.0 Tot Veh:  339965 Gen:  28621 Out_n:      0 Out_t: 19057 In_v: 191925
T:  55.0 Tot Veh:  364981 Gen:  25016 Out_n:      0 Out_t: 18611 In_v: 198330
T:  60.0 Tot Veh:  390052 Gen:  25071 Out_n:      0 Out_t: 18006 In_v: 205395
T:  65.0 Tot Veh:  411484 Gen:  21432 Out_n:      0 Out_t: 17465 In_v: 209362
T:  70.0 Tot Veh:  429348 Gen:  17864 Out_n:      0 Out_t: 17147 In_v: 210079
T:  75.0 Tot Veh:  447269 Gen:  17921 Out_n:      0 Out_t: 16696 In_v: 211304
T:  80.0 Tot Veh:  465157 Gen:  17888 Out_n:      0 Out_t: 15659 In_v: 213533
T:  85.0 Tot Veh:  483057 Gen:  17900 Out_n:      0 Out_t: 15339 In_v: 216094
T:  90.0 Tot Veh:  500951 Gen:  17894 Out_n:      0 Out_t: 14367 In_v: 219621
T:  95.0 Tot Veh:  518798 Gen:  17847 Out_n:      0 Out_t: 13412 In_v: 224056
T: 100.0 Tot Veh:  536696 Gen:  17898 Out_n:      0 Out_t: 12614 In_v: 229340
***************************************

VEHICLE LOADING MODE
--------------------
  O-D Demand Table
***************************************

MUC CLASS PERCENTAGES
---------------------
  Pre-Specified (Non-Responsive)          :    40.13 %
  Boundedly-Rational(En-route Information) :    10.02 %
  VMS Responsive                          :    49.85 %
  System Optimal                          :     0.00 %
  User Equilibrium                        :     0.00 %
***************************************
```

```
VEHICLE TYPE PERCENTAGES
------------------------
  PC                          :    100.0 %
  TRUCK                       :      0.0 %
  HOV                         :      0.0 %
  BUS                         :      0 Buses
AVG.IB-FRACTION = 0.20   BOUND = 1.00

NOTE : There are      229340  target vehicles still in the network

 ******* VEHICLE INFORMATION *******
        TOTAL VEHICLES       :      536696
        NON-TAGGED VEHICLES  :           0
        TAGGED VEHICLES (IN)  :      229340
        TAGGED VEHICLES (OUT) :      307356
        OTHERS               :           0

  Avg. travel time for HOV                  :      N/A

 ******* HOT LANE(S) INFORMATION  **********
  Number of Links with Toll                 :    149

  For the Vehicles Exit the Network

  Number of LOV in HOT lanes                :   6810
  Avg. travel time for LOV in the HOT lane     :     32.0527

  Number of LOV not in HOT lanes            :  300546
  Avg. travel time for LOV not in the HOT lane :      21.3657

  Number of HOV in HOT lanes                :      0
  Avg. travel time for HOV in the HOT lane     :      N/A

  Number of HOV not in HOT lanes            :      0
  Avg. travel time for HOV not in the HOT lane :      N/A

**************************************
*  OVERALL STATISTICS REPORT         *
**************************************

  Max Simulation Time (min)              :     100.0
  Actual Sim. Intervals                  :    1000
  Simulation Time     (min)              :     100.0
  Start Time in Which Veh Stat are Collected :       0.0
  End   Time in Which Veh Stat are Collected :     100.0
  Total Number of Vehicles of Interest      :   536696
                    With    Info       :   53751
                    Without Info       :   482945
----------------------------------------------
TOTAL TRAVEL TIMES (HRS)
  OVERALL    :  254548.5625
  NOINFO     :  229773.0000
  1 stop     :  229773.0000
```

```
  2 stops    :       0.0000
  3 stops    :       0.0000
  INFO       :   24786.1016
  1 stop     :   24786.1016
  2 stops    :       0.0000
  3 stops    :       0.0000

AVERAGE TRAVEL TIMES (MINS)
  OVERALL    :      28.4573
  NOINFO     :      28.5465
  1 stop     :      28.5465
  2 stops    :       0.0000
  3 stops    :       0.0000
  INFO       :      27.6677
  1 stop     :      27.6677
  2 stops    :       0.0000
  3 stops    :       0.0000

------------------------------------------------
TOTAL TRIP TIMES (INCLUDING ENTRY QUEUE TIME) (HRS)
  OVERALL    :  271004.2812
  NOINFO     :  244599.3281
  1 stop     :  244599.3281
  2 stops    :       0.0000
  3 stops    :       0.0000
  INFO       :   26382.0078
  1 stop     :   26382.0078
  2 stops    :       0.0000
  3 stops    :       0.0000
AVERAGE TRIP TIMES (INCLUDING ENTRY QUEUE TIME) (MINS)
  OVERALL    :      30.2970
  NOINFO     :      30.3885
  1 stop     :      30.3885
  2 stops    :       0.0000
  3 stops    :       0.0000
  INFO       :      29.4491
  1 stop     :      29.4491
  2 stops    :       0.0000
  3 stops    :       0.0000

------------------------------------------------
TOTAL ENTRY QUEUE TIMES (HRS)
  OVERALL    :   16263.8174
  NOINFO     :   14666.9824
  1 stop     :   14666.9824
  2 stops    :       0.0000
  3 stops    :       0.0000
  INFO       :    1596.0387
  1 stop     :    1596.0387
  2 stops    :       0.0000
  3 stops    :       0.0000
AVERAGE ENTRY QUEUE TIMES (MINS)
  OVERALL    :       1.8182
```

```
  NOINFO    :      1.8222
  1 stop    :      1.8222
  2 stops   :      0.0000
  3 stops   :      0.0000
  INFO      :      1.7816
  1 stop    :      1.7816
  2 stops   :      0.0000
  3 stops   :      0.0000

------------------------------------------------
TOTAL STOP TIME ( HRS )
  OVERALL   :  102424.9688
  NOINFO    :   95025.2969
  1 stop    :   95025.2969
  2 stops   :      0.0000
  3 stops   :      0.0000
  INFO      :    7399.8745
  1 stop    :    7399.8745
  2 stops   :      0.0000
  3 stops   :      0.0000
AVERAGE STOP TIME ( MINS )
  OVERALL   :     11.4506
  NOINFO    :     11.8057
  1 stop    :     11.8057
  2 stops   :      0.0000
  3 stops   :      0.0000
  INFO      :      8.2602
  1 stop    :      8.2602
  2 stops   :      0.0000
  3 stops   :      0.0000

------------------------------------------------
TOTAL TRIP DISTANCE ( MILES )
  OVERALL   : 4777623.5000
  NOINFO    : 4192201.5000
  1 stop    : 4192201.5000
  2 stops   :      0.0000
  3 stops   :      0.0000
  INFO      :  585904.1250
  1 stop    :  585904.1250
  2 stops   :      0.0000
  3 stops   :      0.0000
AVERAGE TRIP DISTANCE ( MILES )
  OVERALL   :      8.9019
  NOINFO    :      8.6805
  1 stop    :      8.6805
  2 stops   :      0.0000
  3 stops   :      0.0000
  INFO      :     10.9003
  1 stop    :     10.9003
  2 stops   :      0.0000
  3 stops   :      0.0000
```

Appendix C. Analyses of Simulation Results

Traffic Operations on IH-35 with and without Traveler Information

Based on DYNASMART-P simulation results, traffic operations on IH-35 links with and without provision of traveler information are presented as following:

1. Link 10242: IH-35 South main lanes starting at the IH-35/SH 130 junction in northern Austin.

According to the simulation outputs, this link has free-flow speeds, 70 mile/hour, in both scenarios. There is no congestion on this link during the simulation period. Figure C.1 presents a comparison of the link volumes in two scenarios.

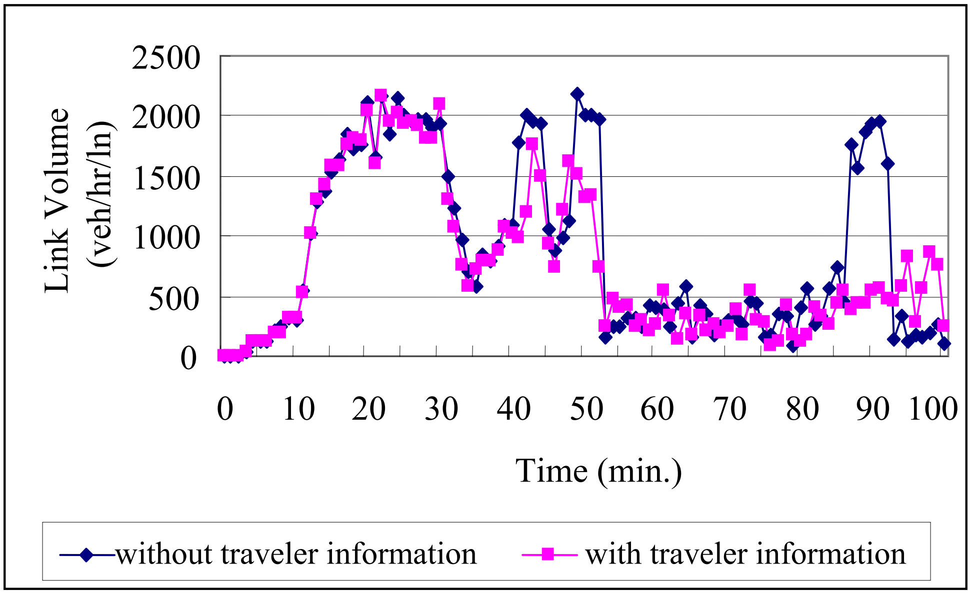


Figure C.1: Traffic Volumes on IH-35 South Main Lanes (Lanes Starting at the IH-35/SH 130 Junction in Northern Austin)

It can be seen that when traveler information is provided, the link volume in ATIS scenario is lower than the volume in no-ATIS scenario. Since there is no congestion, a reasonable explanation is that a portion of the traffic diverts to the SH 130 toll roads. The average volume in no-ATIS scenario is 892 vehicles/hour/lane. When ATIS is deployed, the average volume on this link decreases to 770 vehicles/hour/lane.

2. Link 5266: IH-35 South main lanes at 51st Street

According to the simulation outputs, this link is a heavily congested link in both scenarios. Heavy congestion occurred on this link during the simulation period. Figure C.2 presents a comparison of the link volumes in two scenarios.

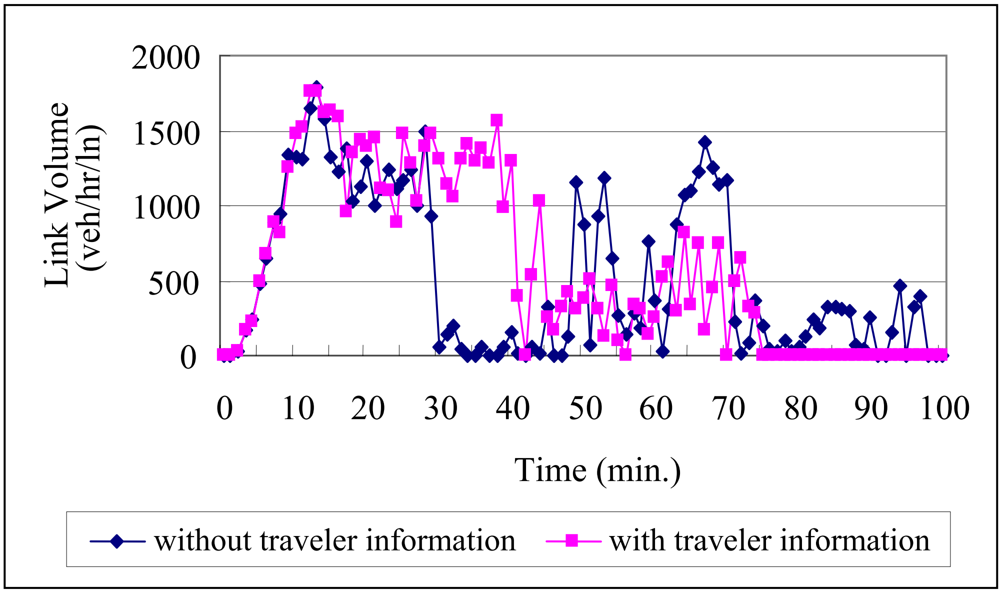


Figure C.2: Traffic Volumes on IH-35 South Main Lanes at 51st St.

It can be seen that as traveler information is provided, the traffic volume on this link is higher than the volume in no-ATIS scenario. The average volume on this link is 519 vehicles/hour/lane in a no-ATIS scenario. It increases to 585 vehicles/hour/lane when ATIS is deployed. The average speed of this link increases when ATIS is provided. Since this link is heavily congested, it means that more vehicles pass through this link in a certain period when ATIS is deployed.

3. Link 5732: IH-35 South upper-level main lanes at 26th Street

This link is a heavily congested link in both scenarios. Figure C.3 presents a comparison of the link volumes in two scenarios.

It can be seen that when traveler information is provided, the link volume on this link is higher than the volume in no-ATIS scenario. The average volume on this link in no-ATIS scenario is 781 vehicles/hour/lane. It increased to 930 vehicles/hour/lane when ATIS is deployed. Because this link is heavily congested, it means that more vehicles could pass through this link in a certain period if ATIS is deployed.

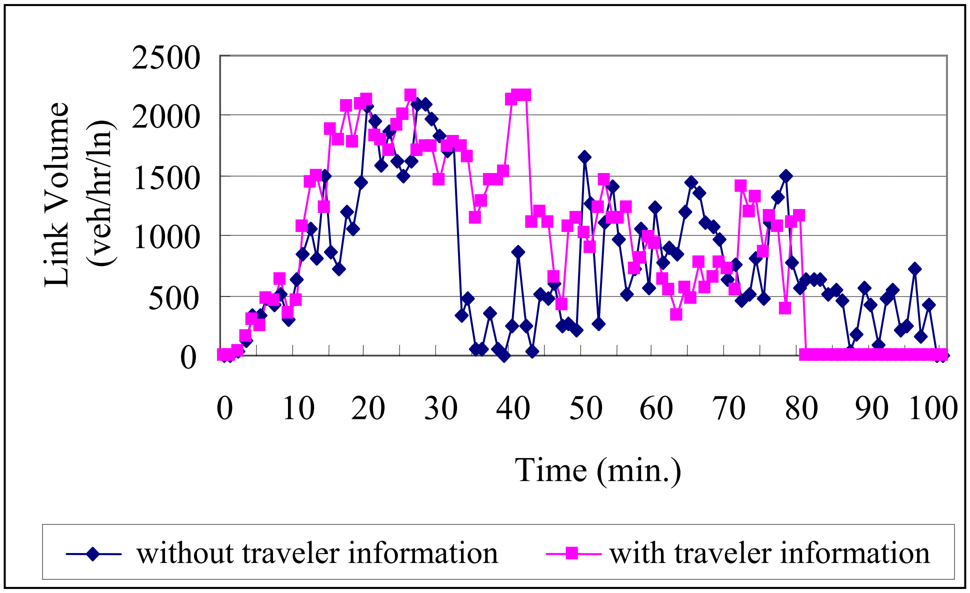


Figure C.3: Traffic Volumes on IH-35 South Main Lanes at 26th St. (Upper Level)

4. Link 3661: IH-35 South main lanes at M.L.K.

This link is another heavily congested link in both scenarios. Heavy congestion occurred on this link during the simulation period. Figure C.4 presents a comparison of the link volumes in two scenarios. It can be seen that when traveler information is provided, the traffic volume on this link is lower than the volume in no-ATIS scenario. The average volume on this link in no-ATIS scenario is 627 vehicles/hour/lane. It decreased to 498 vehicles/hour/lane when ATIS is deployed. Since this link is heavily congested, it means that fewer vehicles pass through this link in a certain period when ATIS is deployed. Although the entire network performance is improved, the congestion on this link becomes heavier when ATIS is deployed.

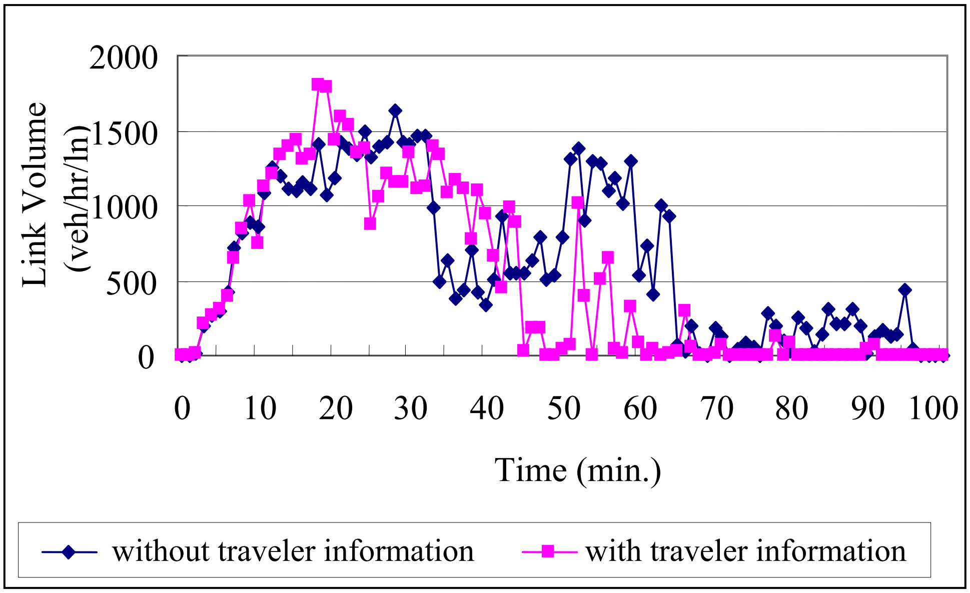


Figure C.4: Traffic Volumes on IH-35 South Main Lanes at M.L.K.

5. Link 10690: IH-35 North main lanes at M.L.K.

Similar to the link of IH-35 South main lanes at M.L.K., this link is also heavily congested link in both scenarios. Heavy congestion occurred on this link during the simulation period. Figure C.5 presents a comparison of the link volumes in two scenarios.

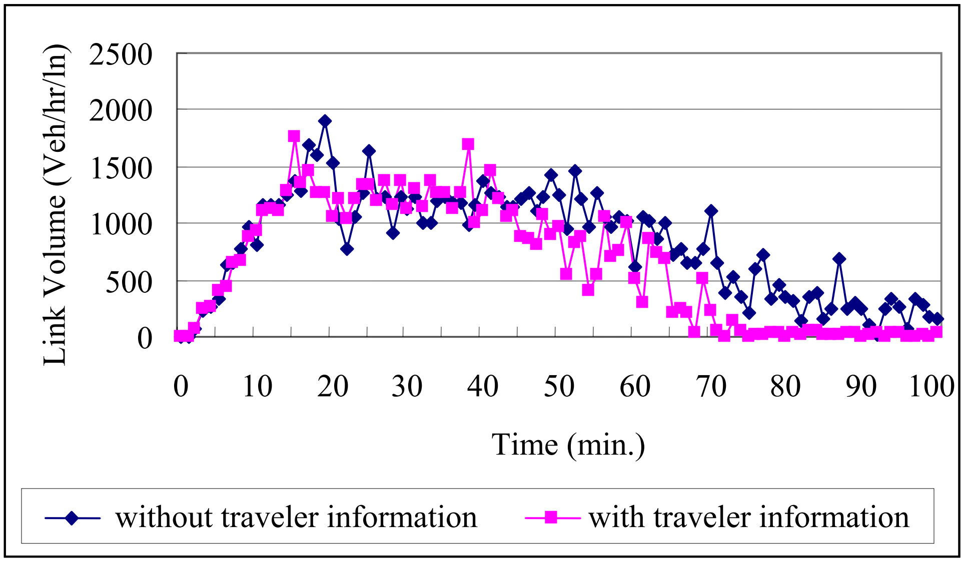


Figure C.5: Traffic Volumes on IH-35 North Main Lanes at M.L.K.

It can be seen that when traveler information is provided, the traffic volume on this link is lower than the volume in no-ATIS scenario. The average volume on this link in no-ATIS scenario is 831 vehicles/hour/lane. It decreased to 646 vehicles/hour/lane when ATIS is deployed. Since this link is heavily congested, it means that fewer vehicles pass through this link in a certain period when ATIS is deployed. Although the entire network performance is improved, the congestion on this link becomes heavier when ATIS is deployed.

6. Link 6500: IH-35 North main lanes at 51st Street

According to the simulation outputs, this link is slightly congested in the no-ATIS scenario. However, there are no congestions in the ATIS scenario. Figure C.6 presents a comparison of the link volumes in two scenarios.

It can be seen that when traveler information is provided, the traffic volume on this link is lower than the volume in no-traveler-information scenario. Since there is only slight congestion in the no-ATIS scenario, a reasonable explanation is that a portion of the traffic diverts to toll roads and other routes. The average volume in the no-ATIS scenario is 1037 vehicles/hour/lane. When ATIS is deployed, the average volume on this link decreases to 961 vehicles/hour/lane.

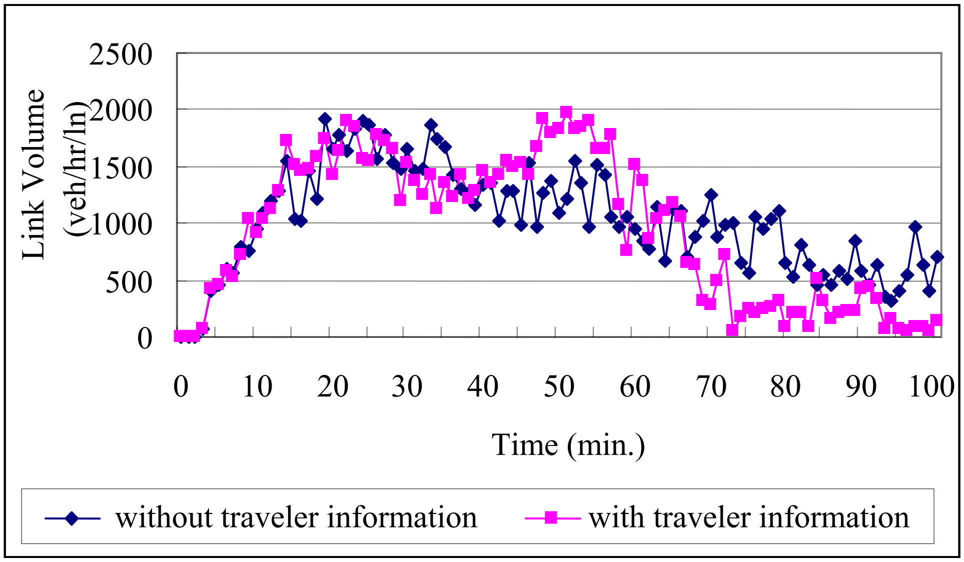


Figure C.6: Traffic Volumes on IH-35 North Main Lanes at 51st St.

Simulation Results: Traffic Operations on SH130 Toll Road with and without Traveler Information

Based on DYNASMART-P simulation outputs, traffic operations on SH 130 toll road links with and without provision of traveler information are presented as following:

1. Link 10278: SH 130 South main lanes starting at the IH-35/SH 130 junction in the north

This link has free-flow speed whether traveler information is provided or not. There was no congestion on this link during the simulation period. Figure C.7 presents a comparison of the link volumes in two scenarios. It can be seen that when traveler information is provided, the traffic volume on this link is significantly higher than the volume in the no traveler information scenario. It verifies that the ATIS deployment is effective in diverting traffic from the congested IH-35 to toll road SH 130. A portion of the traffic will divert to the SH 130 toll road if drivers know there is congestion on IH-35 and no congestion on SH 130 toll road. The average volume in the no-ATIS scenario is 114 vehicles/hour/lane. When ATIS is deployed, the average volume on this link increases to 195 vehicles/hour/lane.

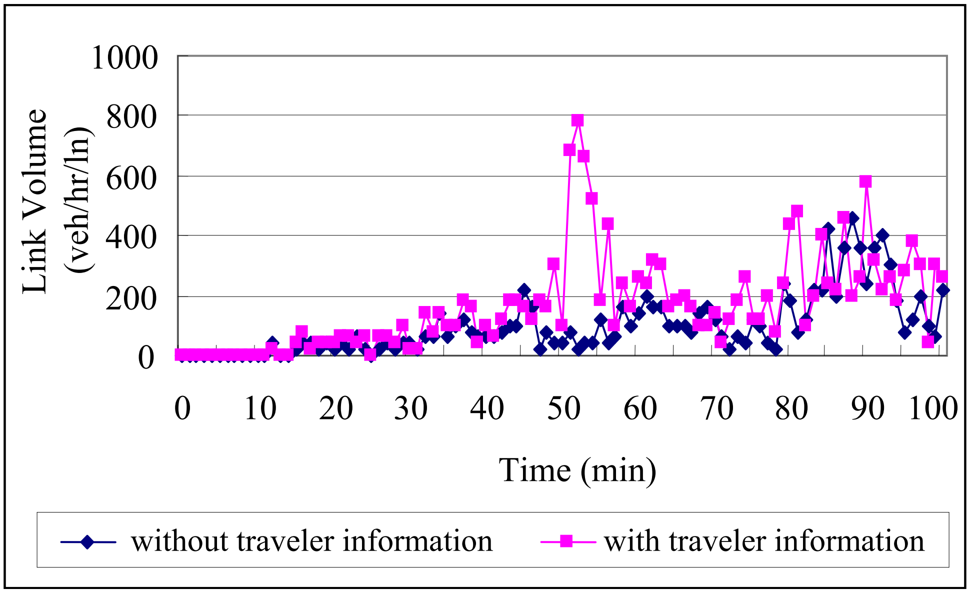


Figure C.7: Traffic Volumes on SH 130 South Main Lanes (Lanes Starting at the IH-35/SH 130 Junction in the north)

2. Link 12050: SH 130 South main lanes starting at the SH 130/US 79 junction

This link has free-flow speed in both scenarios. Figure C.8 presents a comparison of the link volumes in two scenarios.

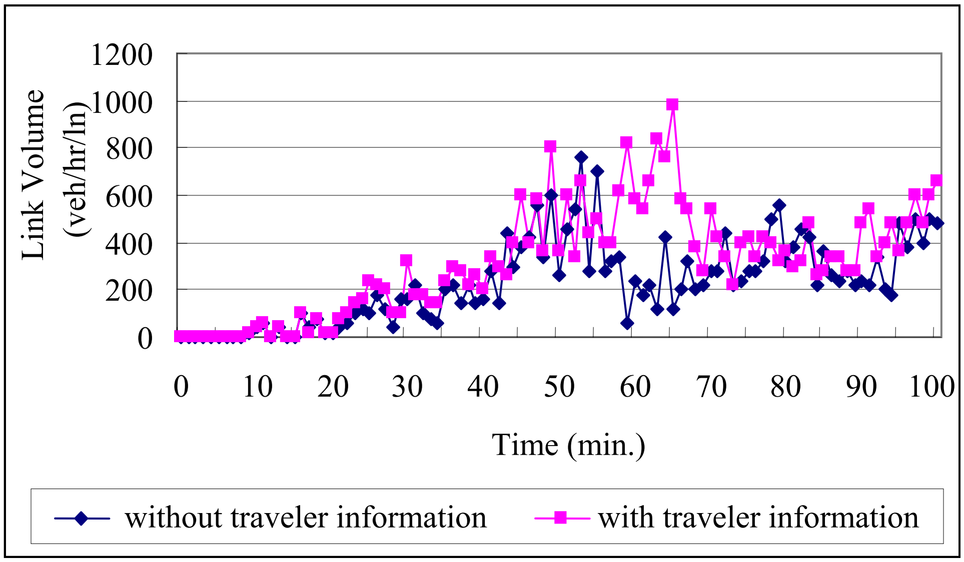


Figure C.8: Traffic Volumes on SH 130 South Main Lanes (Lanes Starting at the IH-35/US 79 Junction)

It can be seen that when traveler information is provided, the traffic volume on this link is significantly higher than the volume in the no-ATIS scenario. A portion of the traffic diverts to the SH 130 toll road from the free but congested alternative route IH-35. The average volume in no-ATIS scenario is 232 vehicles/hour/lane. When ATIS is deployed, the average volume on this link increases to 320 vehicles/hour/lane.

3. Link 12142: SH 130 South main lanes between SH 45 North and US 290

Figure C.9 presents a comparison of the link volumes in the two scenarios. This link has free-flow speed in both scenarios. It can be seen that when traveler information is provided, the traffic volume on this link is significantly higher than the volume in the no traveler information scenario. The average volume in no-ATIS scenario is 193 vehicles/hour/lane. When ATIS is deployed, the average volume on this link increases to 405 vehicles/hour/lane. The number of vehicles using toll roads almost doubles on this link in this scenario.

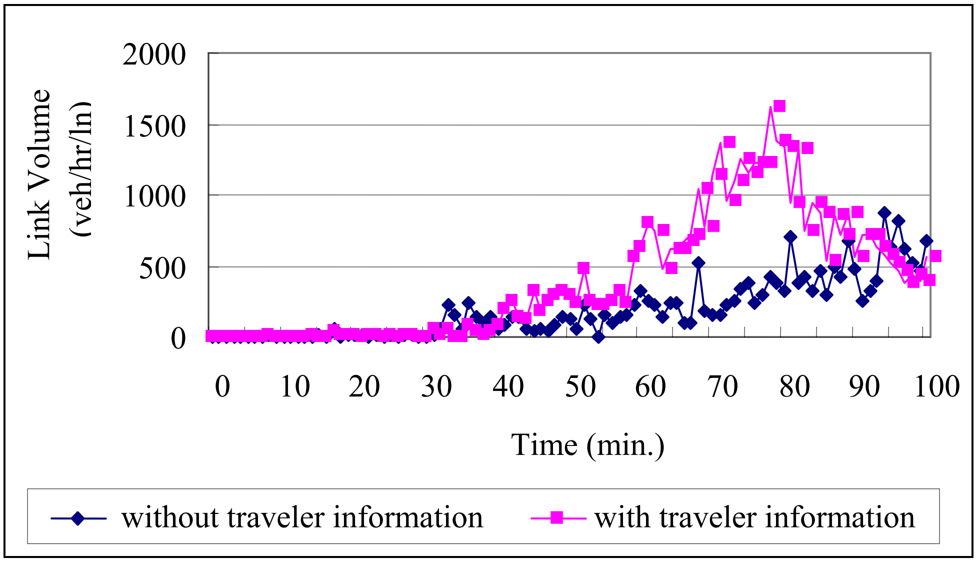


Figure C.9: Traffic Volumes on SH 130 South Main Lanes (between SH 45 North and US 290)

4. Link 12210: SH 130 South main lanes between US 290 and US 71

This link has free-flow speed in both scenarios. Figure C.10 presents a comparison of the link volumes in two scenarios.

It can be seen that when traveler information is provided, the traffic volume on this link is significantly higher than the volume in the no traveler information scenario. The average volume in no-ATIS scenario is 110 vehicles/hour/lane. When ATIS is deployed, the average volume on this link increases to 204 vehicles/hour/lane. The number of vehicles choosing toll roads almost doubles on this link.

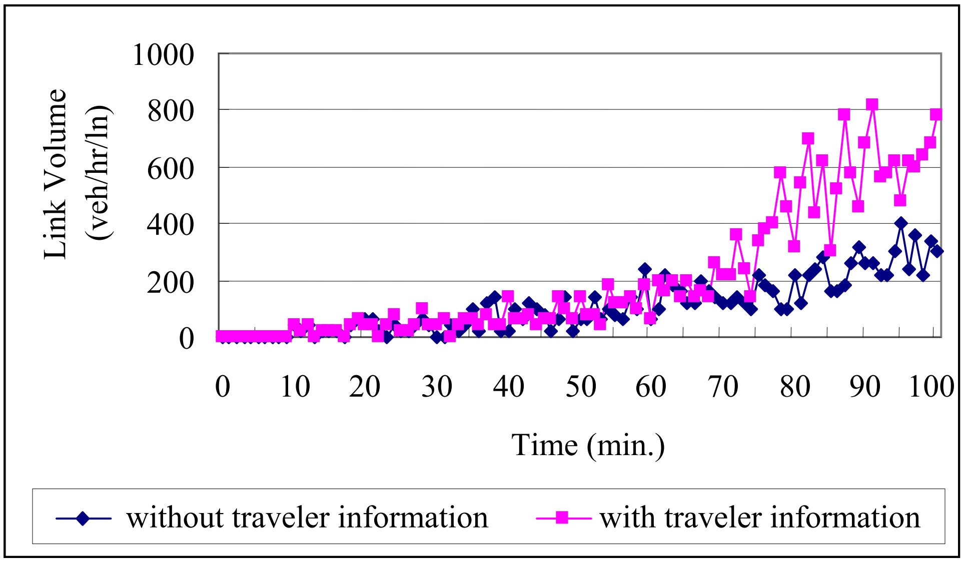


Figure C.10: Traffic Volumes on SH 130 South Main Lanes (between US 290 and US 71)

5. Link 11857: SH 45 South main lanes starting at the IH-35/SH 45 South junction

This link also has free-flow speed in both scenarios. Figure C.11 presents a comparison of the link volumes in two scenarios.

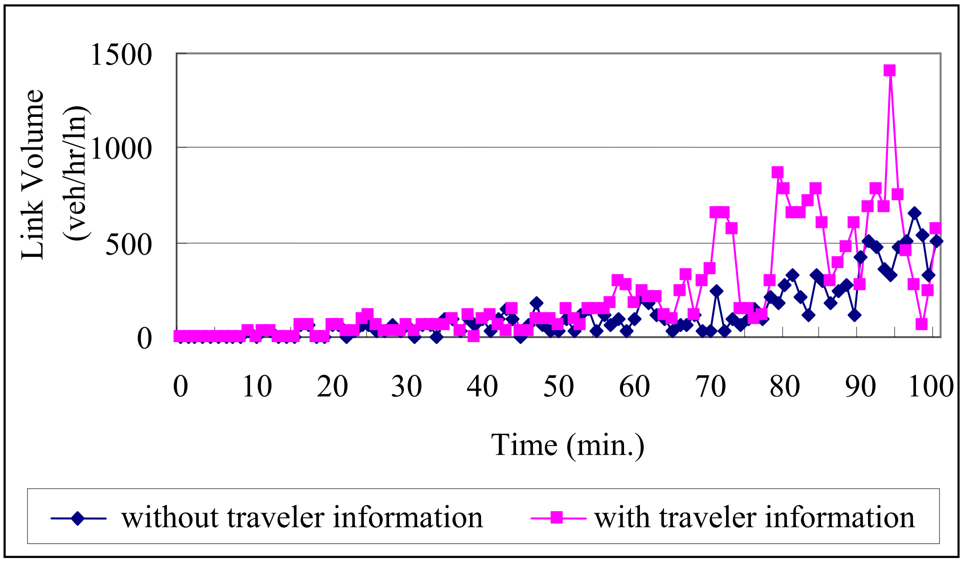


Figure C.11: Traffic Volumes on SH 45 S. Main Lanes (Lanes Starting at the IH-35/SH 45 S. Junction)

It can be seen that when traveler information is provided, the traffic volume on this link is significantly higher than the volume in the no traveler information scenario. The average volume in no-ATIS scenario is 124 vehicles/hour/lane. When ATIS is deployed, the average volume on this link increases to 218 vehicles/hour/lane.

6. Link 12229: SH 130 North main lanes between US 71 and US 290

Figure C.12 presents the link volumes on link 12229. This link has free-flow speed in both scenarios. It can be seen that when traveler information is provided, the traffic volume on this link is higher than the volume in the no-ATIS scenario. The average volume in no-ATIS scenario is 57 vehicles/hour/lane. When ATIS is deployed, the average volume on this link increases to 82 vehicles/hour/lane.

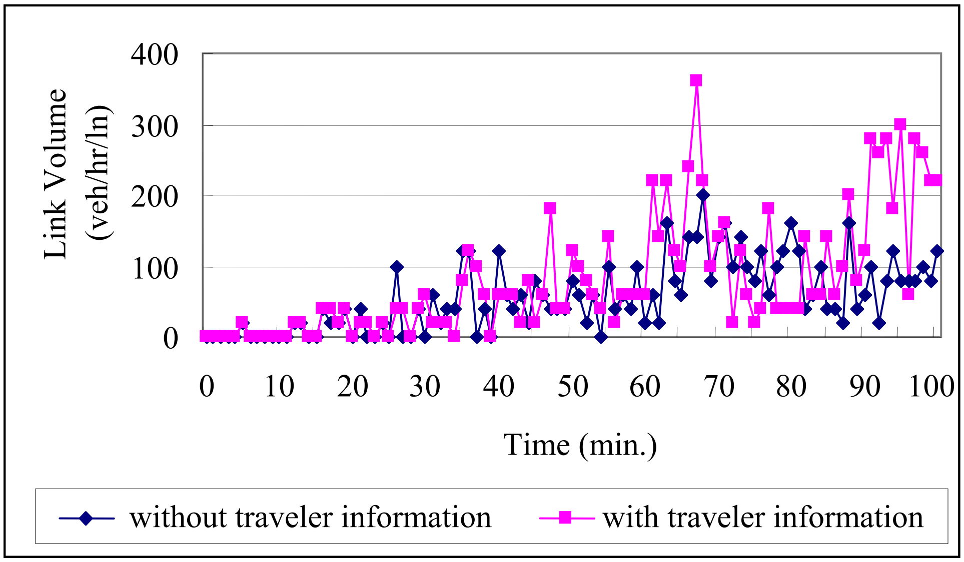


Figure C.12: Traffic Volumes on SH 130 N. Main Lanes between US 71 and US 290