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Impacts of Traveler Information on Transportation Network Operations and Potential Deployment Technologies

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Use of Traveler Information to Enhance Toll Road Operations

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Abstract:	**Keywords:**	No. of Pages: 68
This research product provides in-depth analysis of the impact of traveler information on commuters' route choices in the toll road context. The details of a case study of the Austin, Texas metropolitan area are presented, showing impacts on the non-tolled network as well as on proposed toll roads. Technologies for deploying traveler information systems are outlined, along with system design and scoping issues.	Traveler information, route choice, dynamic traffic assignment, traffic diversion, toll road choice, ATIS technologies.	

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1 Introduction

Texas tolling history: In Texas, toll roads were first introduced in 1953 when the Texas Legislature created the Texas Turnpike Authority to oversee toll road construction. The following year, construction began on the Dallas-Fort Worth Turnpike. The turnpike was completed in 1957, was paid off 17 years ahead of schedule, and was debt-free when it was turned over to the State of Texas. In 1983, Harris County approved a referendum to create the Harris County Toll Road Authority, which has built more than 80 miles of toll roads around the Houston metropolitan area. However, the majority of roads in Texas have been built with the gas tax and are toll-free.

Tolling in the future: Over the last 30 years, revenues have not kept up with the demand for transportation. Thus, the primary strategy of the Texas Department of Transportation (TxDOT) for adding capacity to the Texas transportation network has shifted in the last 10 years to supporting the development of new toll roads. Instead of waiting for 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 a 2020 completion date if paid for by traditional financing.

Financial risks: To repay bond debt for new toll roads, investors will depend on toll revenue, an uncertain source. However, the financial risks of toll road projects can be significant. On one hand, costs for toll road construction can be higher than for non-toll roads. On the other hand, toll road traffic could initially be lower than anticipated, growing 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. As a result of high costs and uncertain revenue, many toll road projects may face high financial risks.

Benefits of traveler information: Before this research study, anecdotal evidence showed that toll road prospects could be enhanced if motorists received timely information about traffic conditions in the region. For example, the growth in traffic on the tolled Melbourne City Link in Australia has been partially attributed to aggressive provision of information regarding delays on competing routes (Lay et al, 2002).

Greater diversion of traffic to toll roads would have two benefits: increase toll collections, and reduce traffic 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 toll roads: namely, greater mobility, better travel time reliability, improved safety, and reduced pollution for the entire system.

Route choice: The important factors that affect commuters' en-route diversion behavior are travel time on current and alternative routes, awareness of congestion levels, travel distance, and trip purpose (Hall 1999). Among these attributes, travel time reliability 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 a driver’s choices are based (Fuji and Kitamura 2000). These studies suggest that travel information will influence drivers’ judgments of anticipated travel times and finally, influence drivers’ route choices.

The Advanced Traveler Information System (ATIS) is a system designed for using travel information to enhance the operations of a transportation system. ATIS’s purpose is to provide the traveling public, businesses, and commercial carriers with the right information at the right time to improve the quality and convenience of their trips and the overall performance of the transportation system (ITS America 1998). With the assistance of traveler information, travelers are able to make intelligent choices regarding mode, travel time, and route, including toll roads.

ATIS initiatives: ITS America has established a National ITS Program Plan since the mid-1990s. Many versions of ATIS are in development or trial, most are telephone or internet-based. For example, in California, 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, Wash. ADVANCE®, FAST-TRAC®, and SmarTraveler® (Boston, Mass.) have also been in use. Private initiatives include Pathfinder, which displays maps of area highway conditions, and TravTek®, which provides *yellow pages* of area services.

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, the City of San Antonio (police, fire, and EMS), and the city’s 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.

This research product: The premise of this research 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. This document is an illustration of the impact traveler information has on commuters’ route choices in the toll road context, as well as recommendations for ATIS implementations. Section 2 describes the research objectives and Section 3 details the research approach and experiment design. Section 4 presents the results of the traffic simulations of the impacts of traveler information on network operations. Section 5 outlines traveler information technologies and system design issues. Section 6 provides preliminary conclusions of the research to date.

2 Objective

Research on the impact of information on system operations is relatively sparse. 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. Evaluation of the dual potential of traveler information in the toll road context is the essence of the research project 0-5079, as originally proposed by the Center for Transportation Research (CTR) at The University of Texas at Austin (UT Austin). In order to understand the impact of traveler information on commuters' route choices between toll roads and non-tolled roads, the resulting benefits of traffic diversion, and the implementation issues of ATIS, the research team at CTR have identified two specific tasks:

a. A case study to examine the impact of traveler information on traffic operations and resulting benefits using simulation. The objective of this simulation experiment is to analyze the impacts of traveler information deployment on a real network. The traffic operations on toll roads, non-tolled alternative routes, and the overall performance of the entire transportation network are examined. Considering TxDOT's interest and available data resources, the research team selected the Austin area (IH-35 corridor/SH 130/SH 45) to conduct the case study. The timing of this case study is very appropriate, since SH 130 will open in late 2007. With a 9-month effort, CTR coded the Austin network into the DYNASMART-P simulation program. The SH 130 and SH 45 toll road segments were added to the network. Traffic volumes, travel speeds, total vehicle miles traveled (VMT), total delays, and network level performance were simulated with and without traveler information in the DYNASMART-P program.

b. An analysis of implementation issues of ATIS. While the potential of ATIS to divert traffic has been demonstrated, its application in the toll road context has not been researched prior to this effort. Specifically, technical and financial issues were addressed. The objective of this task was to review the evolution of ATIS, and to provide recommendations to TxDOT on ATIS strategies.

3 Research Approach and Experiment Design

3.1 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 newly emerging 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).

3.2 DYNASMART 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, which integrates traffic flow models, behavioral rules, and ATIS into a simulation-assignment process. DYNASMART-P 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. Figure 3.2-1 is a screenshot.

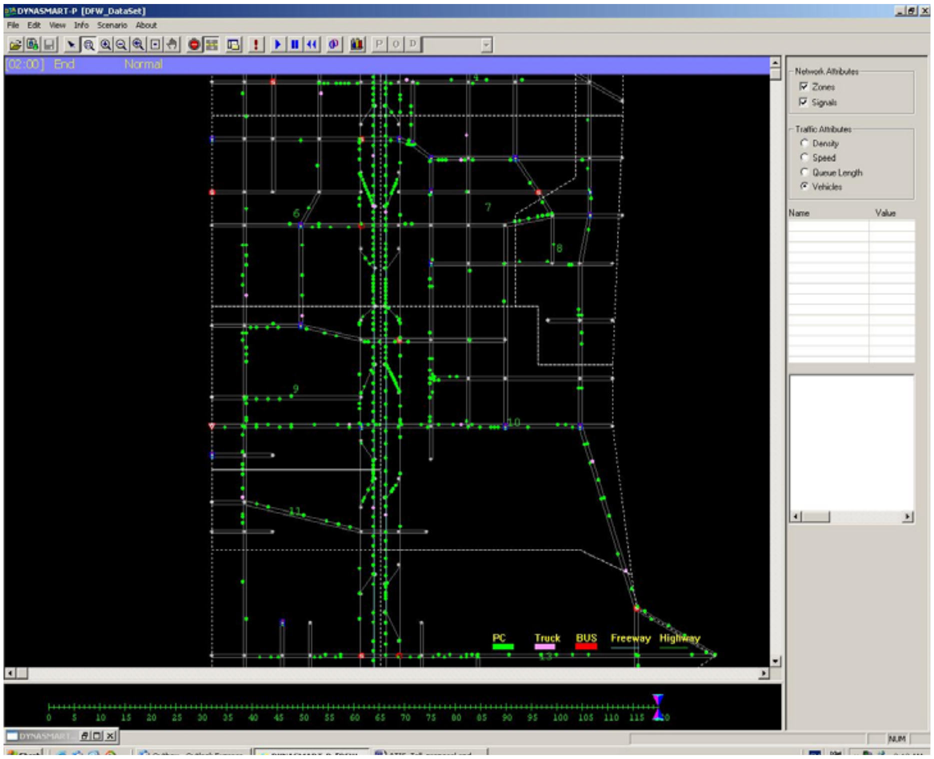

Figure 3.2-1: DYNASMART Simulation Interface

3.3 Input Data

Data sources: The area selected for the case study is the Austin metropolitan area because new toll roads are being built in the area, 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 3.3-1 gives an overview of the entire network. The highlighted links, which represent the IH-35 corridor and SH 130-SH 45 toll road corridor, will be examined in detail.

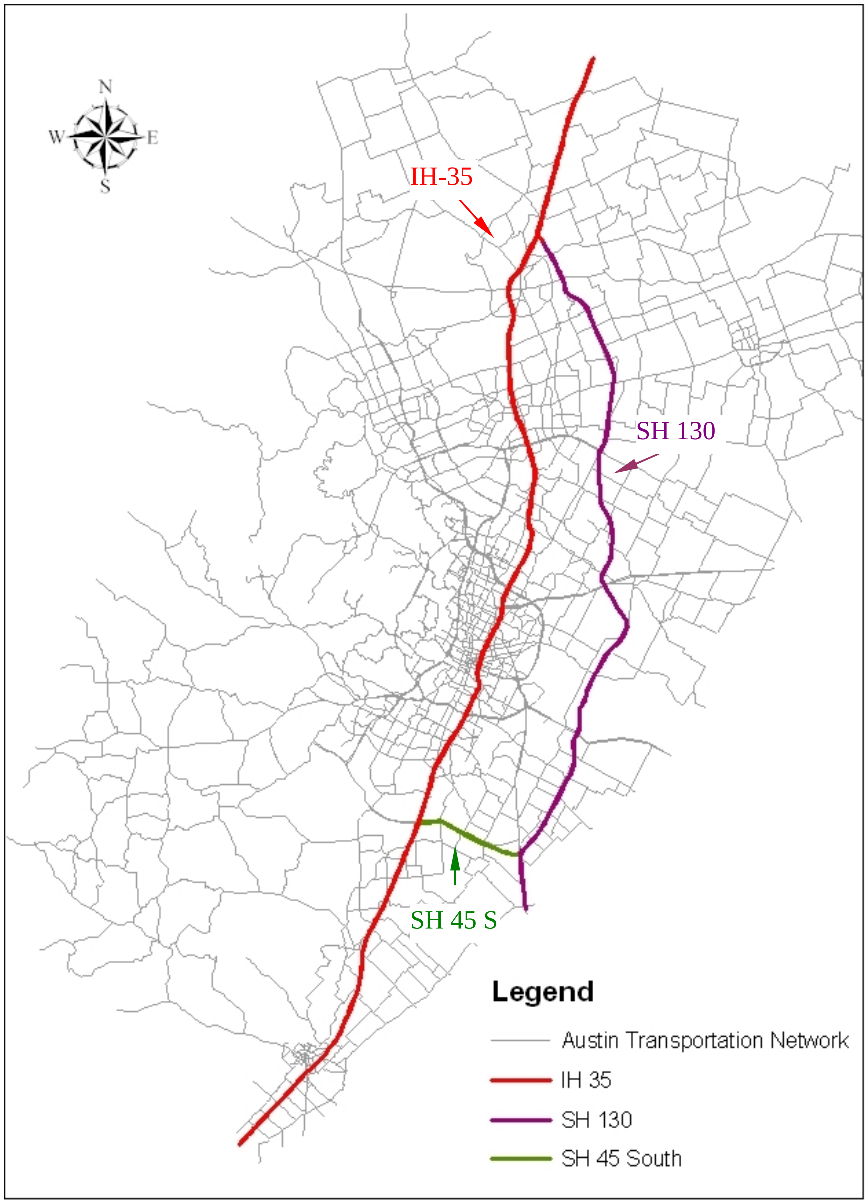

Figure 3.3-1: An Overview of the Austin 2007 Transportation Network

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 3.3-2, in which each color (see color copy) represents one super zone.

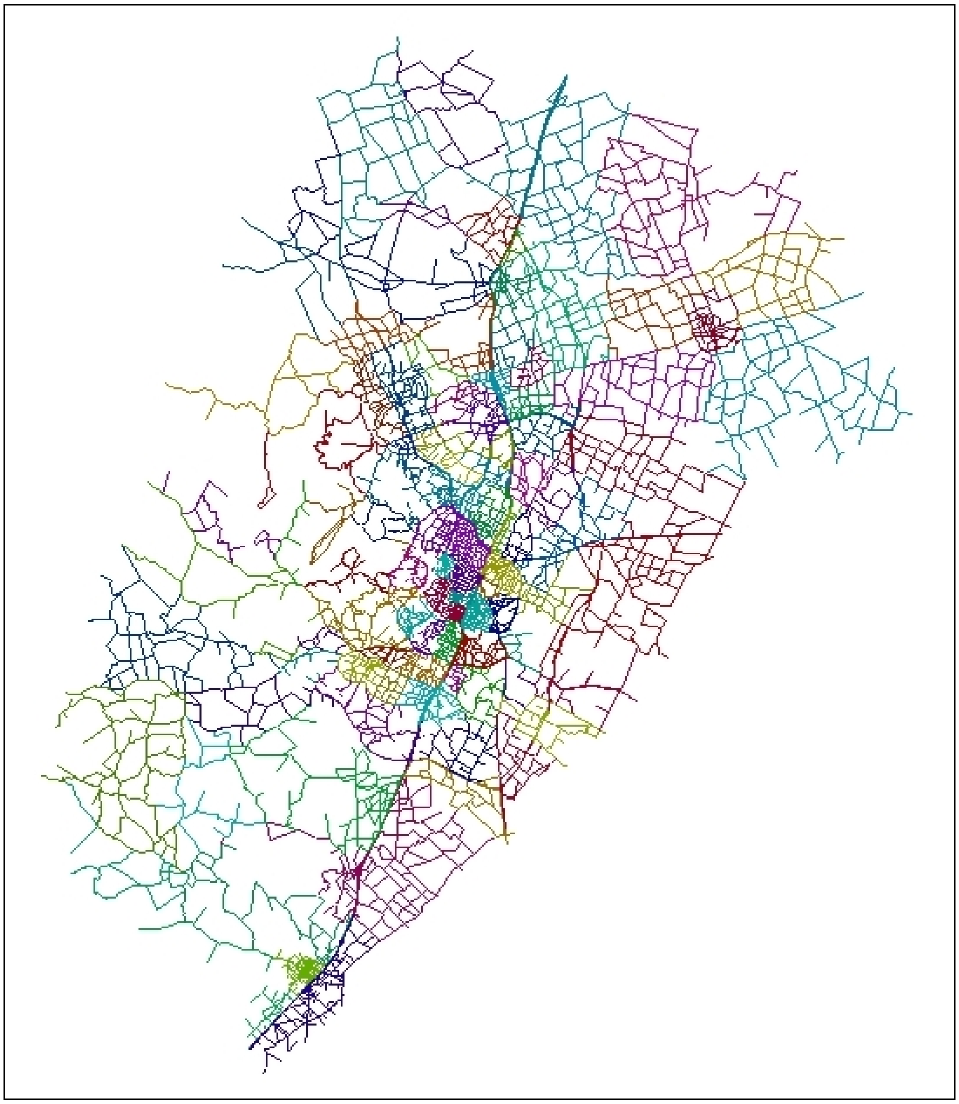

Figure 3.3-2: Aggregation of the Austin Transportation Network (111 Super Zones)

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 3.3-3 gives a screenshot of the Austin transportation network representation in DYNASMART-P when all the necessary data are loaded.

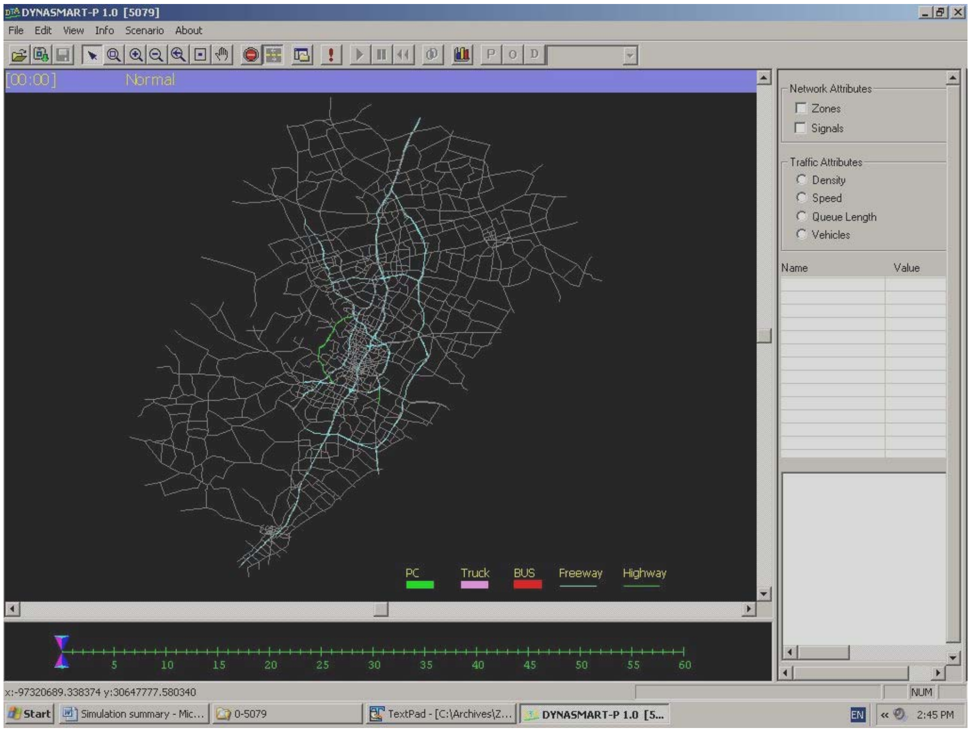

Figure 3.3-3: Screenshot of the Austin Transportation Network in DYNASMART-P

3.4 Experiment Design

Goals of simulation: The overall objective of this study is to analyze the diversion of traffic when provided with traveler information and the resulting impact on the operations of both tolled and non-tolled roads, as well as the entire transportation network for the selected case study area. Keeping this 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:

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

Scenarios: 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 below in Figure 3.4-1.

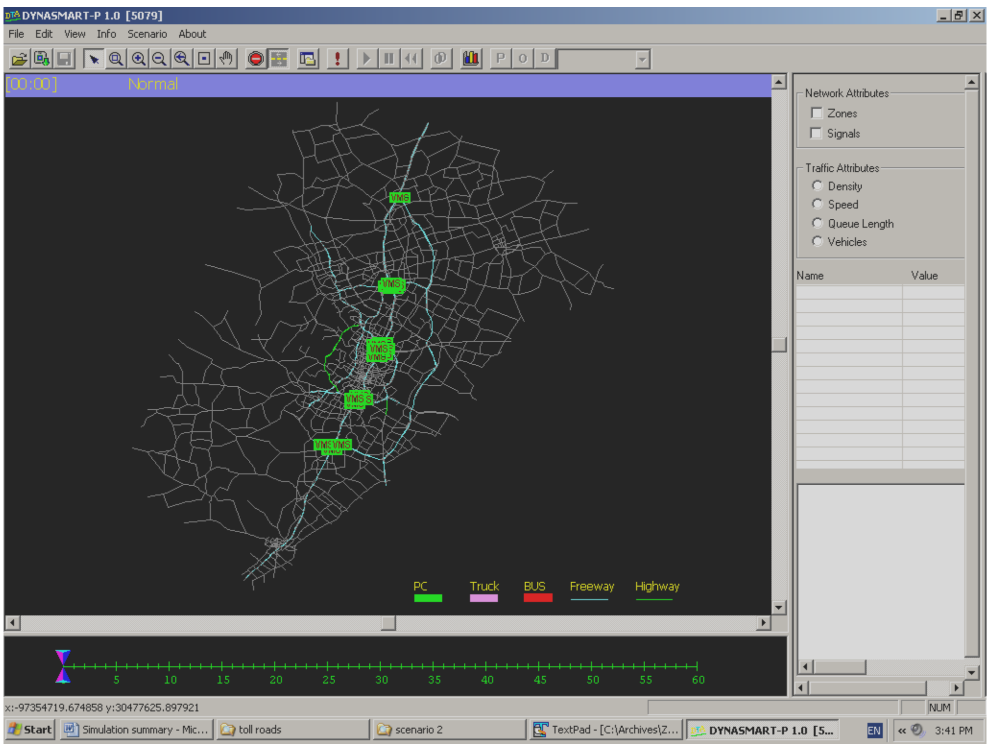

Figure 3.4-1: ATIS Deployments Projected in DYNASMART-P

4 Potential Impact of Traveler Information on Traffic Operations

4.1 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 Origin-Destination (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 percent).
- *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 percent of travelers are assumed to be not responsive to traveler information, 50 percent of the travelers divert at the next opportunity, and 10 percent 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 Graphical User Interface (GUI) that shows the animation of vehicle movements. Figure 4.1-1 and Figure 4.1-2 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.

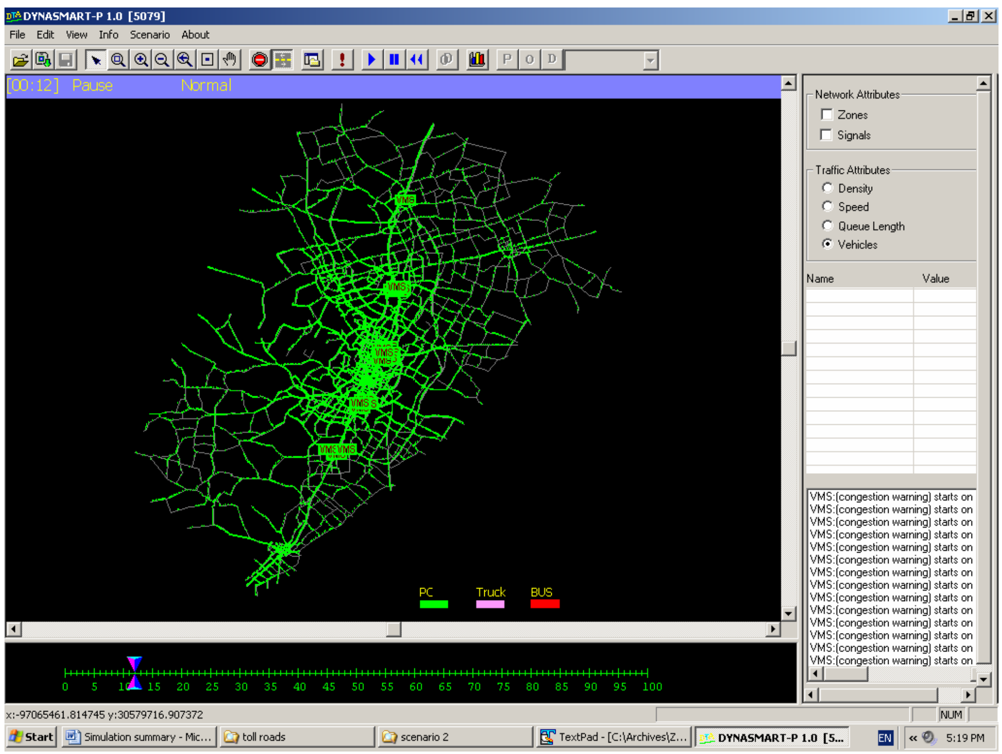

Figure 4.1-1: DYNASMART-P Simulation on the Entire Austin Network

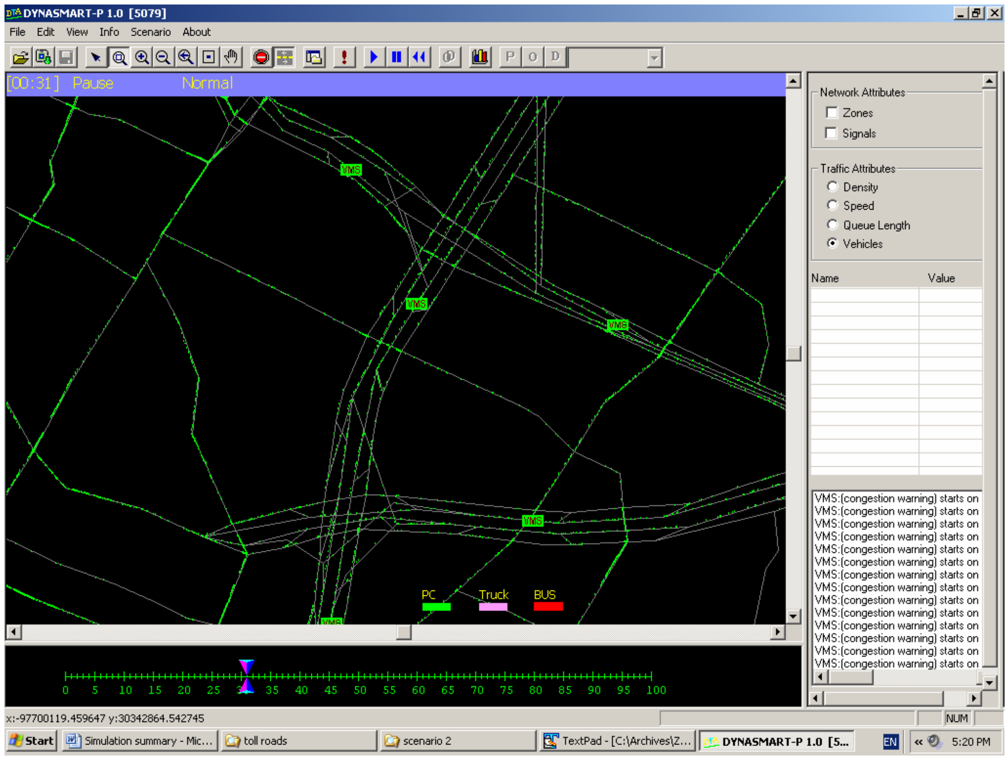

Figure 4.1-2: Vehicle Animation in DYNASMART-P
(IH-35, US 183, and US 290 Triangle Area)

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 output of DYNASMART-P is provided in Appendix 1, and summarized in Table 4.2-1.

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 2 and summarized in Table 4.2-1.

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 4.2-1: 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 4.2-1 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.

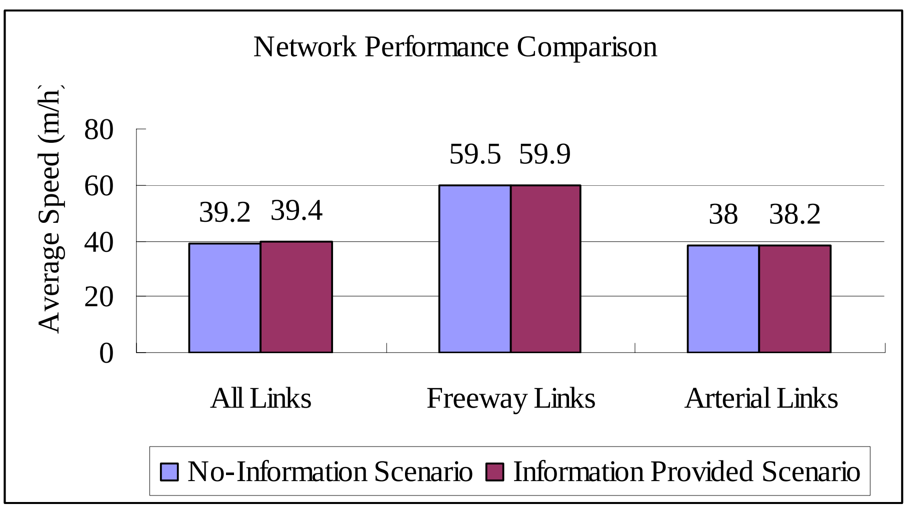

Figure 4.2-1: The Impact of Traveler Information on Network Speeds

4.3 Potential Impact 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 performance of selected IH-35 links were examined. The simulation results are presented in Appendix 3, and the summaries presented here.

Figure 4.3-1 through Figure 4.3-4 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.

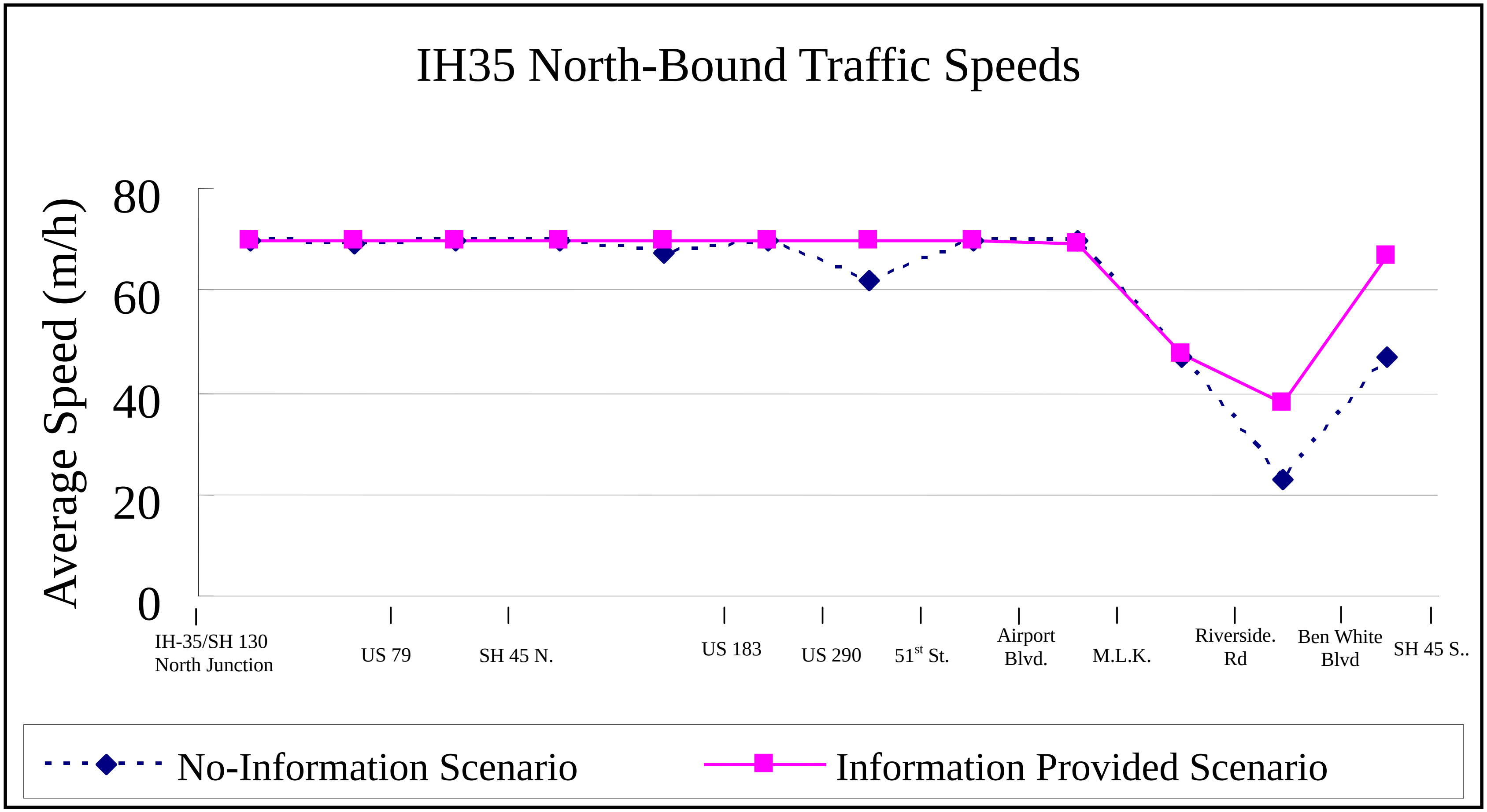

Figure 4.3-1: IH-35 North-Bound Traffic Speeds

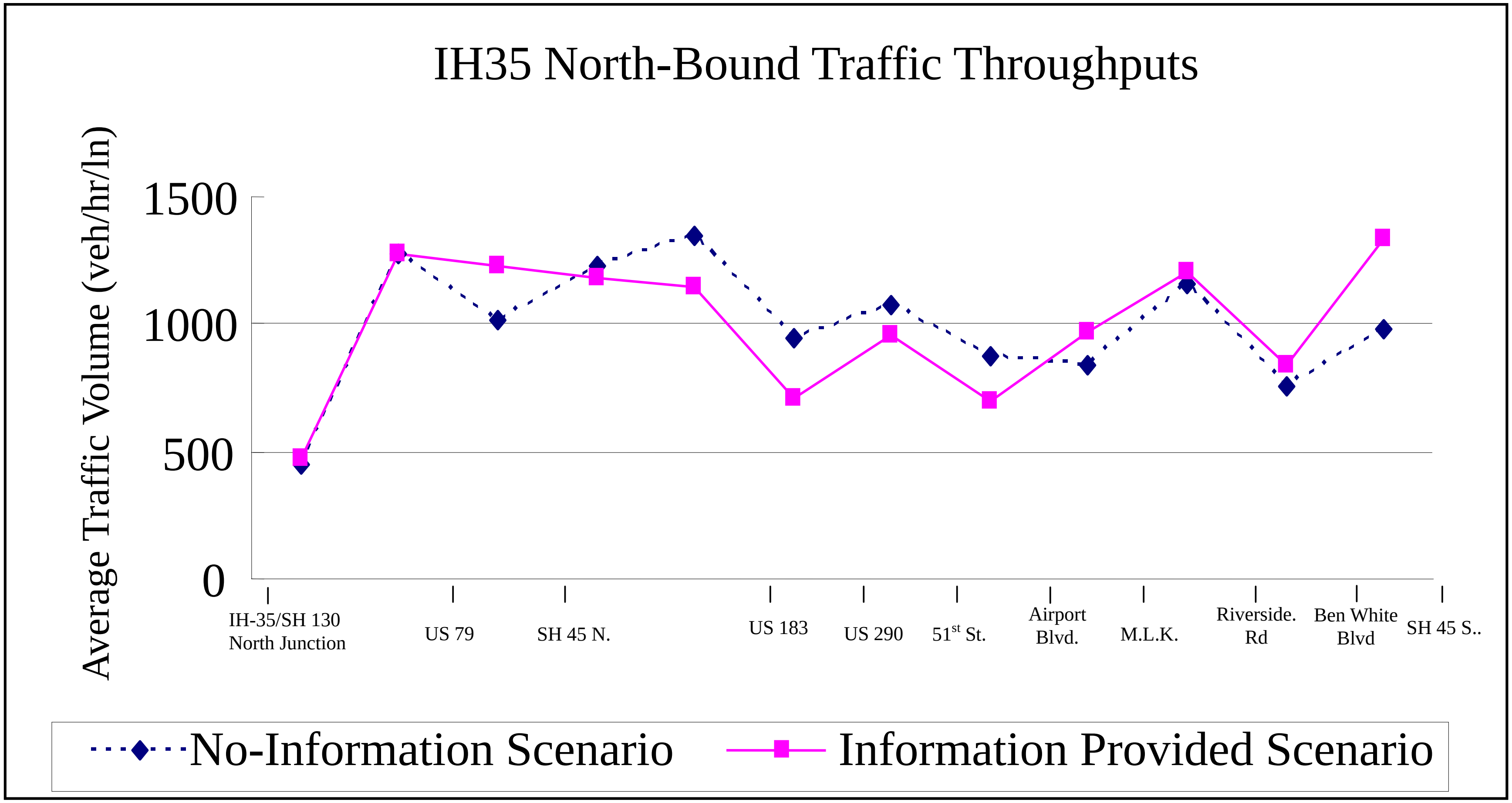

Figure 4.3-2: IH-35 North-Bound Traffic Throughputs

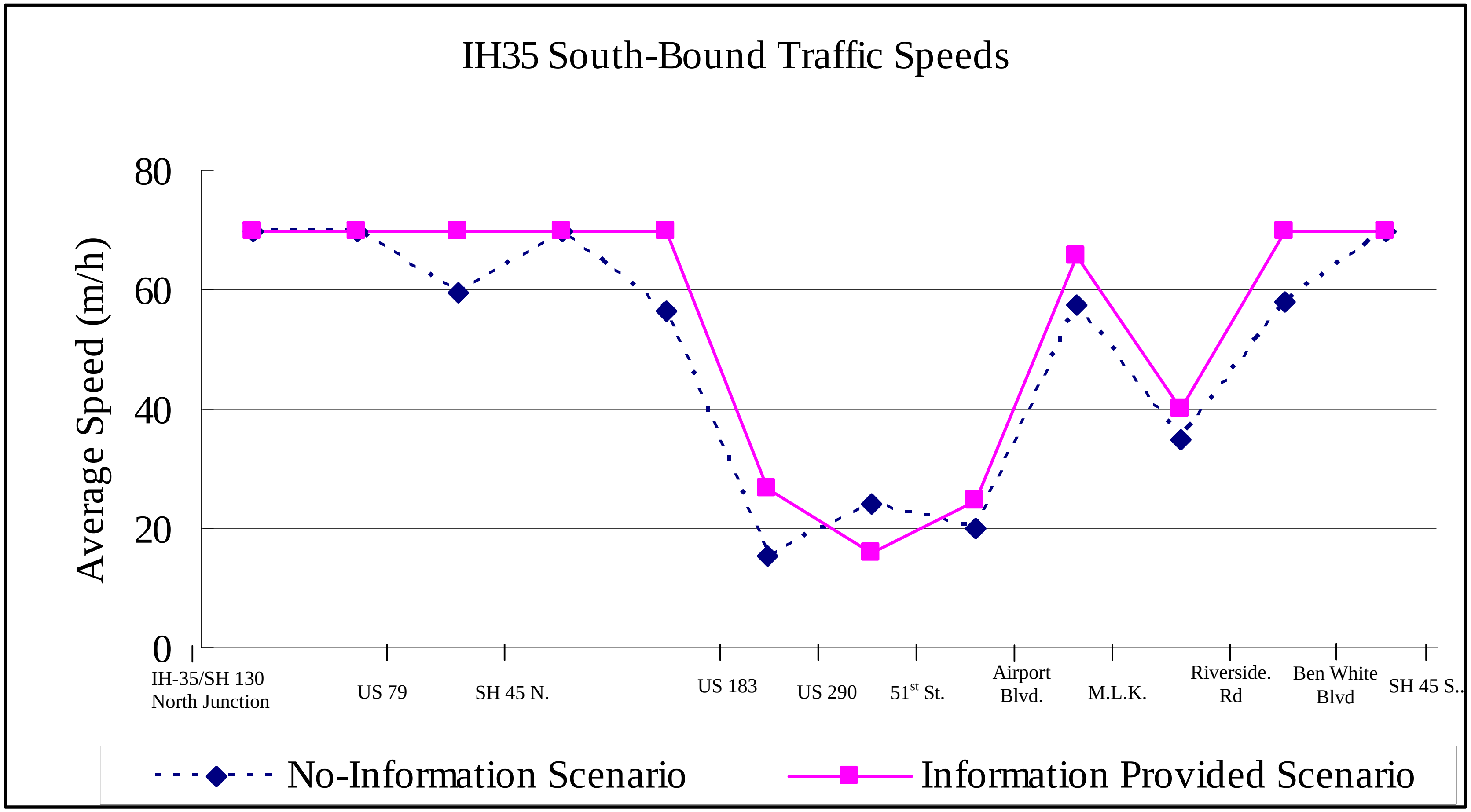

Figure 4.3-3: IH-35 South-Bound Traffic Speeds

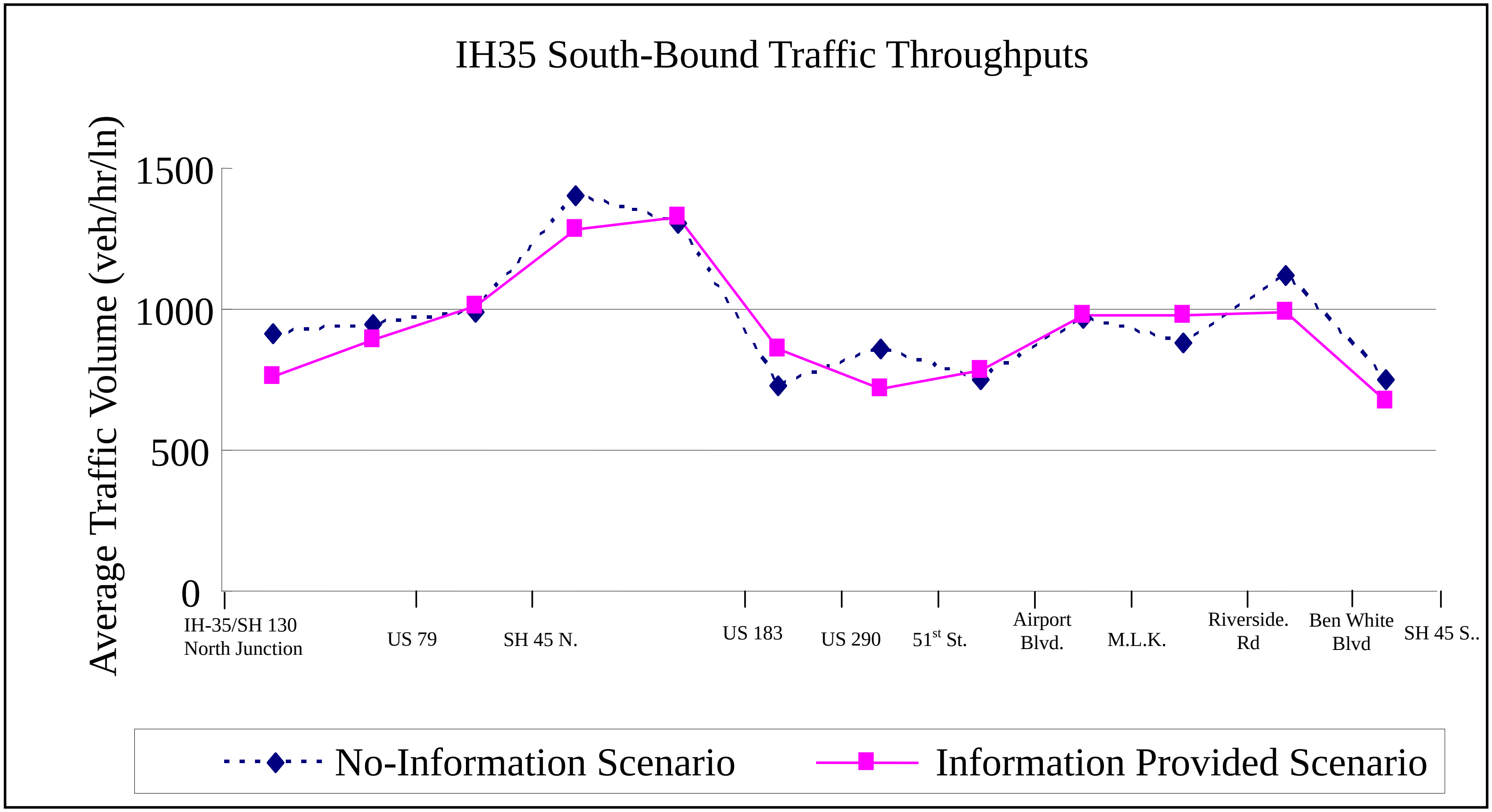

Figure 4.3-4: IH-35 South-Bound Traffic Throughputs

4.4 Potential Impact on Toll Roads

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 4. 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 4.4-1 illustrates traffic volumes on southbound SH 130 with and without traveler information provided and Figure 4.4-2 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 percent in some segments, and by about 50 percent 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 4 of this document and in Product 1 of this research project (submitted December 2005).

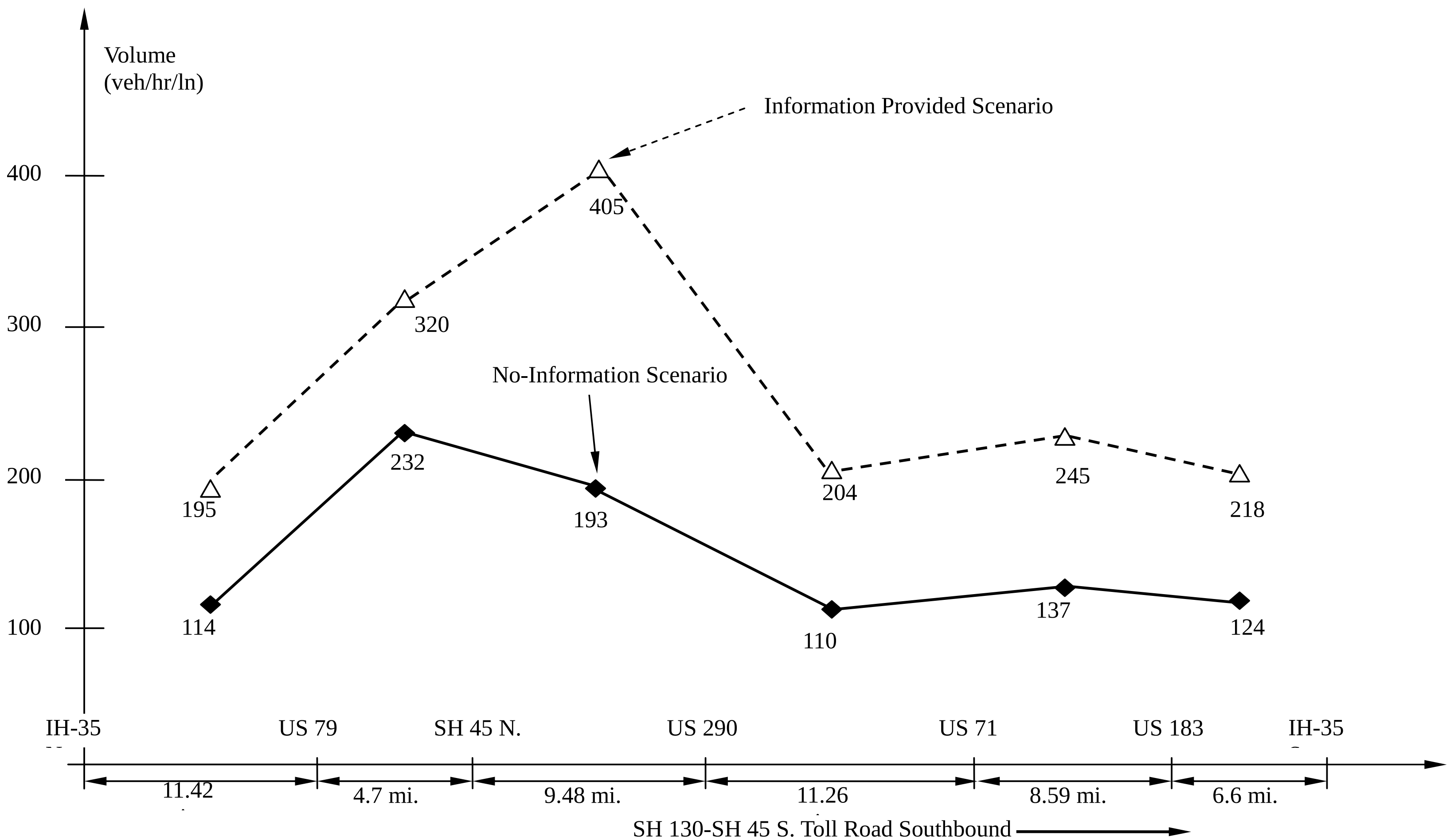

Figure 4.4-1: Traffic Volumes on SH 130 Toll Road Southbound Links

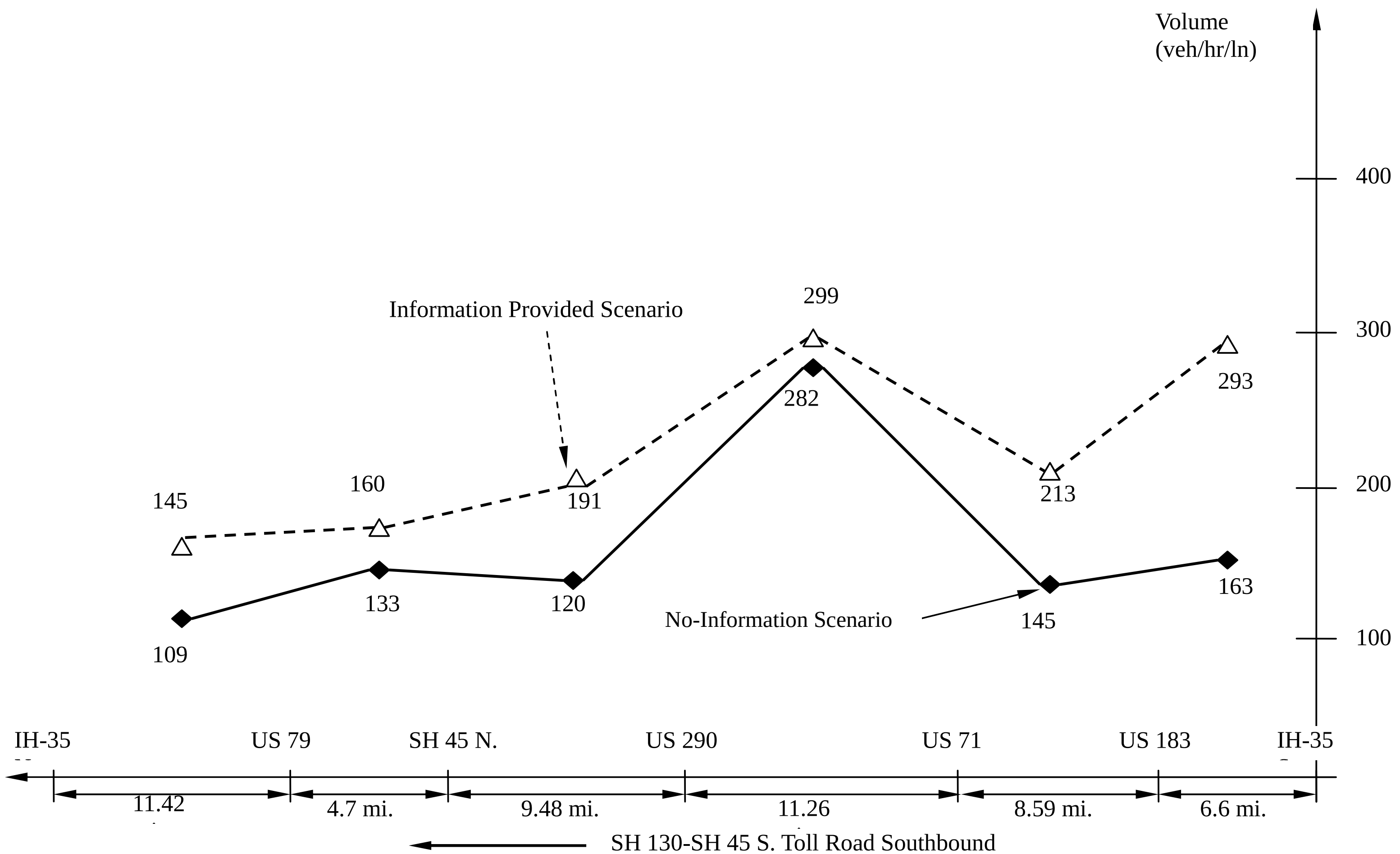

Figure 4.4-2: Traffic Volumes on SH 130 Toll Road Northbound Links

4.5 Case Study Summary

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 non-toll 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.

5 An Overview of Traveler Information Technology

The foregoing results have demonstrated the potential of automated traveler information systems (ATIS) to improve both the operations of non-toll routes and the revenue potential of toll roads. In this section, technologies and a framework for implementing ATIS in the toll road context are presented.

5.1 Traveler Information Content

From the Austin commuter survey conducted for this research project, the types of traveler information sought and the percentage of the 706 respondents likely to seek that information is shown in Table 5.1-1. The table also shows the desirable frequency of updates to the content.

Table 5.1-1: Traveler Information Content and Update Frequency

Type of Information	**% Likely to Seek**	**Desirable**
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

Priorities: Accidents, congestion, lane closures, trip time, and alternate routes make up 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 is therefore 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.

5.2 Information Collection and Processing

As part of this research, the capabilities of the 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 now exists some software for scanning images and detecting unusual flow conditions. Most TMCs have agreements with local television stations to share video feeds, and in some cases, even control the cameras.

There are some other sources for incident data. Many radio and television 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 (DPS) 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/website, which is now being made available to news outlets and even 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 indicating 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 the time of day, day of the week, and time of year (e.g., when schools are 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 global positioning system (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 Geographical Information Systems (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 color-coded indicators advising where traffic volumes are light (green), medium (yellow), or heavy (red). In Japan, commuters see overhead visual displays, similar to maps, well in advance of congestion 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 for lanes to be 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 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, e.g., 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 website now has a “Dynamic Route Builder”, which allows you to chain segments into a trip and find out the estimated travel time. The website 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 the 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, as well as alerts, watches, and warnings of dangerous conditions. Television 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 this information, in addition to music and news. The station continually urges drivers to call a toll-free number to report useful information.

5.3 Information Dissemination Systems

Technology preferences: 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 5.3-1 shows the responses of 706 commuters in the Austin area regarding technology preferences for traffic information (they were allowed to 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 5.3-1: Commuters' Technology Preferences for Traveler Information

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

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

- Highway advisory radio (HAR)
- Commercial radio
- Satellite radio traffic channel
- Commercial and cable television
- 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, HAR is a low power signal available in a limited area and the messages are refreshed once a day. Because of 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/website, from police, fire, and EMS radio transmissions, from flyover services, and/or from commuter phone calls. Typically, traffic updates are provided every 10 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 has yet to design a traffic information service specific to the user's location.

Commercial and cable television: Commercial and cable television play to different markets than radio: pre-trip users who are interested in unusual conditions on their usual routes. Most TMC provide video feeds from their cameras to local television stations. For example, the Austin CTECC provides local cable channel 8 with feeds from twenty-two of its cameras. The stations can choose which feed to show. Many stations also display map graphics of the locations of incidents. Most television traffic reports are delivered in the morning, at about 10-minute intervals, to commuters about to depart into 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 television 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 send 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 $300,000) 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 systems
- On-board GPS navigation devices

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. The 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's 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 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 kiosks
- Internet-based systems accessible by personal computers
- 511 systems
- Personal Digital Assistants

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

Kiosks: Traffic information kiosks typically provide a limited menu of options and generate a fixed set of outputs. They are of use especially to tourists and low-income citizens who do not have ready access to more sophisticated systems. One shortcoming is that sometimes the information provided 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.

Websites: Internet-based systems are gaining popularity. Many of the TMCs now have their own websites, with displays of traffic conditions and interactive query-response options. Private providers are also entering the arena. One example is Traffic.com, a service now available in several large metropolitan areas. As their website 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 percent of the U.S. population has access, though not in Texas, which is in the planning process. 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 percent 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 for driving than cell phones and similar interactive devices. With a text-to-voice converter, they perform 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 (USDOT) will deploy advanced vehicle-vehicle and vehicle-infrastructure communications (USDOT, 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 to establish an implementation strategy. The consortium consists of the vehicle manufacturers already involved in the VII, the American Association of State Highway Transportation Officials (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 Radio Frequency Identification (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 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 Local Area Network (LAN). As soon as two or more vehicles are in radio communication range, they connect automatically and establish an ad hoc network (Figure 5.3-1).

Figure 5.3-1: Car-to-car Ad hoc Networks

As the range of a single Wireless LAN link is limited to a few hundred meters, every vehicle acts a router, sending messages over multi-hop to farther vehicles. 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.

Cell phone tracking: Cell phones periodically send signals to their networks in order to track their locations and quickly route calls. The accuracy of location can be within a 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 determine 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.

5.4 Message Design Requirements

Route switching propensity: In the commuter survey for this project, the information content likely to affect route switching was found to be as shown in Table 5.4-1:

Table 5.4-1: 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

Content priorities: These findings indicate a priority for information content and relevance. Accident locations are by far the most likely information that would 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. Information on recommended alternate routes is also highly valuable, followed by road hazards. Surprisingly, estimated travel time ranks somewhat low as an incentive to switch routes. It is possible that drivers are now accustomed to getting this information (as with weather information) and are deliberately ranking the less-accessible information more highly.

What drivers need: 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 doing so 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 occur 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.

The desirable features of message design are therefore:

- Accuracy/ reliability
- Timeliness
- Cost (capital and operating)

- Degree of decision guidance and personalization
- Convenience (ease and speed of access)
- Safety (of operation)

5.5 The Market for Traveler Information

Thresholds for switching: 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 the value of those time savings. Figure 5.5-1 shows the threshold time savings likely to stimulate route switching.

The average desired time savings is 12.5 minutes, but the median is only about 8 minutes, i.e., 50 percent of commuters would switch routes for an 8-minute time savings. About 40 percent of respondents indicated they were 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.

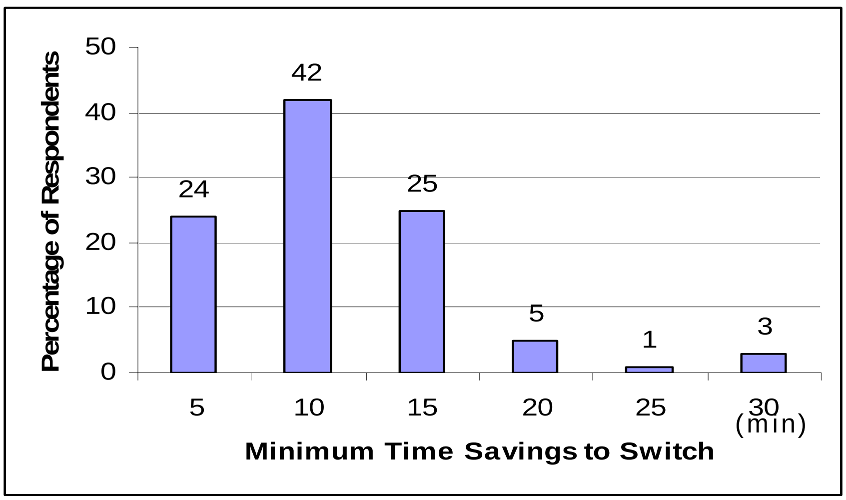

Figure 5.5-1: Threshold Time Savings to Stimulate Route Switching

Technology evolution: However, the travel information market is expected to evolve incrementally. 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 that is collected and transmitted from other segments to optimize individual travel. The evolution of ATIS systems can be traced through three stages:

- 1990 to 2000: This stage focused on improving information access and timeliness. Most of these systems relied on existing technologies and drivers' knowledge of the networks.
- 2000 to 2010: This stage focuses on en-route information systems, with increasing interactive content. Drivers are becoming part of the feedback loop.
- 2010 to 2020: 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 5.5-2 presents an overview of the evolution of ATIS technologies and trends.

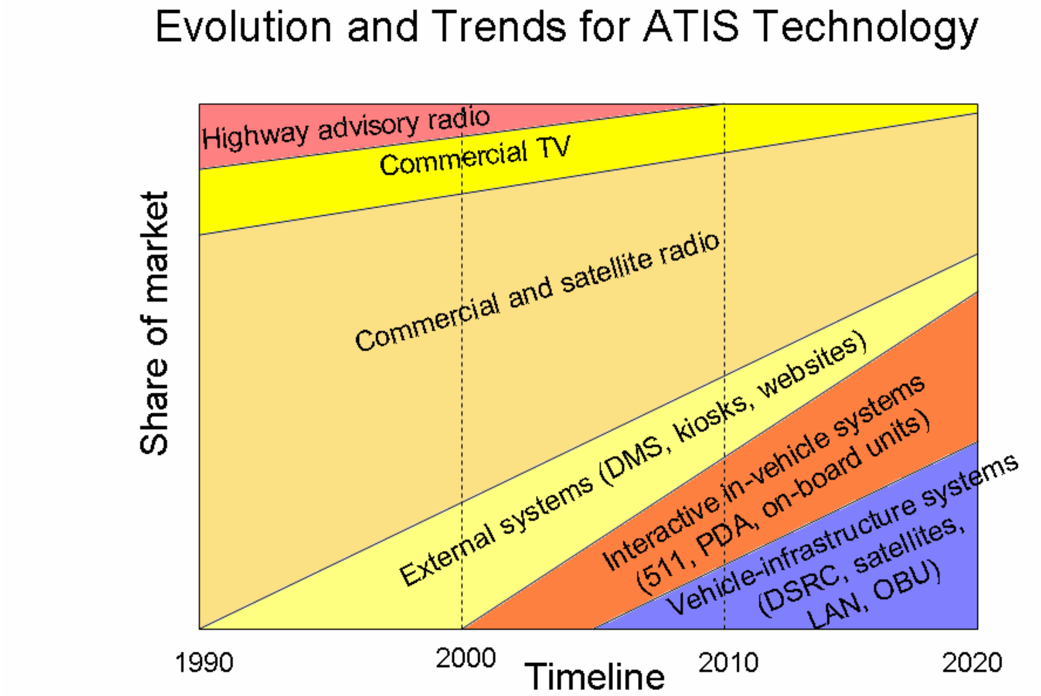

Figure 5.5-2: The Evolution of ATIS Technology and Trends

ATIS scoping: Rapid development of ATIS technology provides transportation agencies with many options for implementation. It is therefore critical that the scope be carefully considered. It is worthwhile for DOTs to consider a formal planning and scoping process, working with an experienced technology integrator. Factors that should be considered include:

- *Focus*. The primary intent should be to help the agency better manage the elements of the overall transportation system. A secondary goal should be to provide the public with new sources of information to increase their options when traveling. The primary emphasis will determine the overall design and operation of the system.
- *Tangible system or user benefits.* It is generally accepted that ATIS will provide the traveling public, businesses, and commercial carriers with the right information at the right time to improve the convenience of their trips and the overall performance of the transportation system. A successful ATIS implementation will result in a tangible system and significant user benefits.
- *Risk*. From a technical standpoint, there are three fundamental risk elements: collecting data, consolidating that information, and then disseminating the "processed" information to various users and/or the public. Managing the risks in these three elements will significantly affect the outcome.
- *Public or private market.* ATIS implementation could be very costly in data collecting, data consolidating, and information disseminating. Since the ATIS

market is still maturing, it is unknown what its ultimate size or worth will be. The data and information can be used by both public and private sectors. In the initial stage, government funding may be necessary to deploy and operate ATIS. However, in the long term, the industry is optimistic that private resources will be able to support these services.

- *Technology*. There are many ATIS technologies and alternatives available for providing traveler information, each with its own advantages and market. A mix of these alternatives will meet the needs of different user groups. In terms of technological trends, the on-board audio/video systems using satellite/GPS technology is recommended because it has the following advantages:

    - Lower cost and requirement on infrastructure improvement than roadside systems.
    - User-friendly. The features of on-board unit can be customized to meet users' preferences. An audio system is preferred by a driver who is familiar with the local network, but a video system can be used by a co-pilot to assist in navigation.
    - Large coverage. Satellite/GPS technology provides users large coverage for traveler information. This feature is especially useful in rural areas.
    - Marketability. The functions of the on-board unit are not necessarily limited to receiving traveler information. With added features, such as entertainment, the on-board unit has more potential to be marketed.

Combined tolling/ATIS units: In the toll road context, there is an opportunity to combine tolling technology with on-board units (OBU). 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 OBU that reports its location as well as road conditions to the vehicle-infrastructure network, and, in return, receives guidance, entertainment, etc . 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.

6 Conclusions

Summary: 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. In the literature review conducted for this research, no studies were found on how commuters' toll road choice decisions will change when provided with information and the resulting benefits. This research product provided in-depth analysis of the impact of traveler information on commuters' route choices in the toll road context, as well as recommendations for ATIS technologies.

Case study results: The case study conducted in Austin, Texas using the DYNASMART-P program indicated that providing congestion information on non-tolled alternate routes would:

- Improve the entire network performance in travel time, delay, and number of stops.
- Significantly increase the number of toll-road users.
- Reduce traffic on the non-tolled alternative route and improve its performance.

ATIS technology: ATIS technology has evolved very rapidly since the 1990s. ATIS has been recognized as one of the most promising ITS strategies in meeting travelers' needs and enhancing transportation system operations. 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.

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Appendices

Appendix 1: Simulation Results 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
NO INFO : 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
NO INFO : 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
NO INFO : 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
NO INFO : 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
NO INFO : 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
NO INFO : 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
NO INFO : 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
NO INFO : 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
NO INFO : 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
NO INFO : 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

Appendix 2: Simulation Results 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
NO INFO : 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
NO INFO : 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
NO INFO	:	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
NO INFO	:	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
NO INFO	:	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
NO INFO	:	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
NO INFO	:	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
NO INFO	:	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
NO INFO	:	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
NO INFO	:	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 3: Traffic Operations on IH-35 with and without Traveler Information

Traffic operations on IH-35 links with and without provision of traveler information are presented as following:

1) Link 10242: the 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 A3-1 presents a comparison of the link volumes in two scenarios.

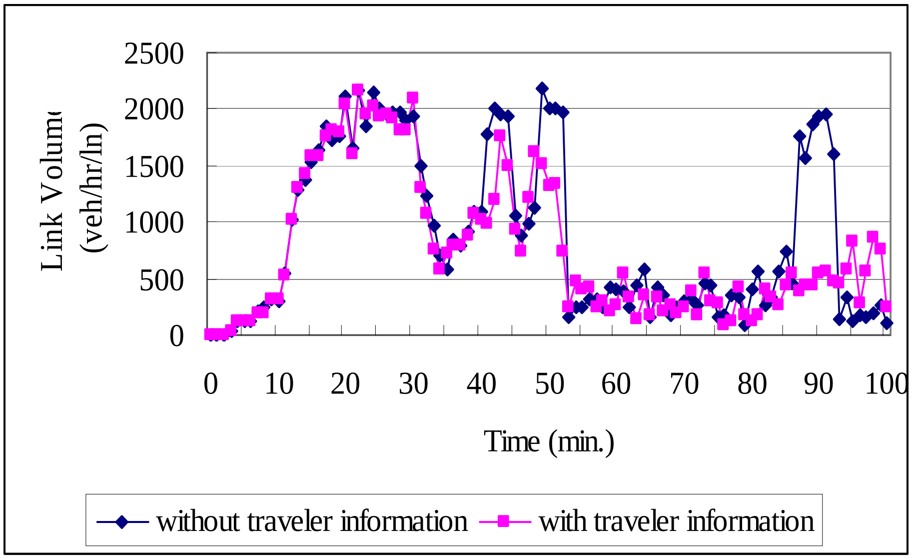

Figure A3-1: Traffic Volumes on IH-35 South Main Lanes
(Lanes Starting at the IH-35/SH 130 Junction in Northern Austin)

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/hr/lane. When ATIS is deployed, the average volume on this link decreases to 770 vehicles/hr/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 A3-2 presents a comparison of the link volumes in two scenarios.

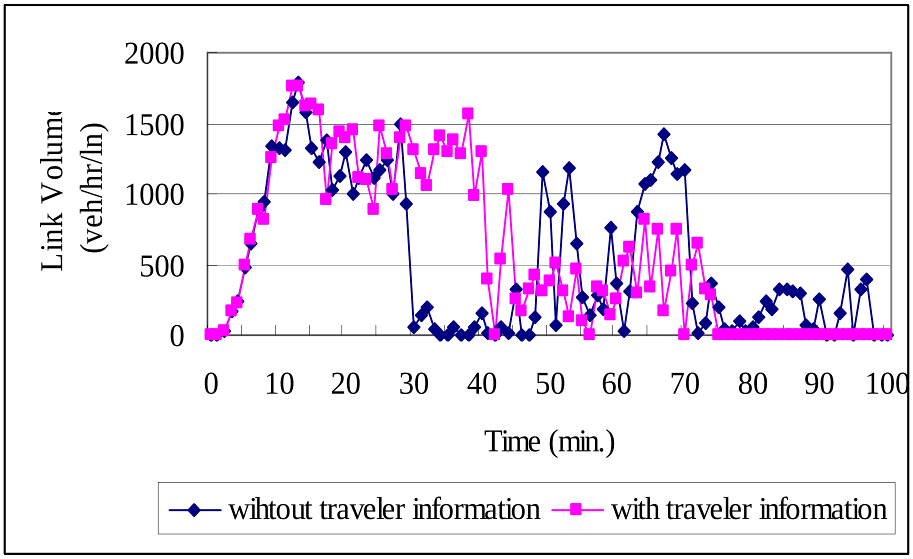

Figure A3-2: Traffic Volumes on IH-35 South Main Lanes at 51st St.

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/hr/lane in no-ATIS scenario. It increases to 585 vehicles/hr/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 St.

This link is a heavily congested link in both scenarios. Figure A3-3 presents a comparison of the link volumes in two scenarios.

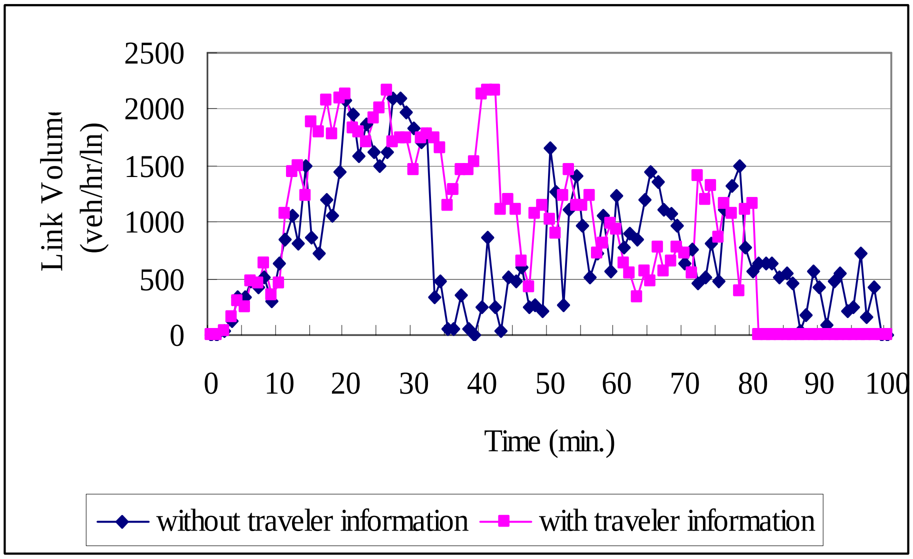

Figure A3-3: Traffic Volumes on IH-35 South Main Lanes at 26th St. (Upper Level)

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/hr/lane. It increased to 930 vehicles/hr/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.

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 A3-4 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/hr/lane. It decreased to 498 vehicles/hr/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.

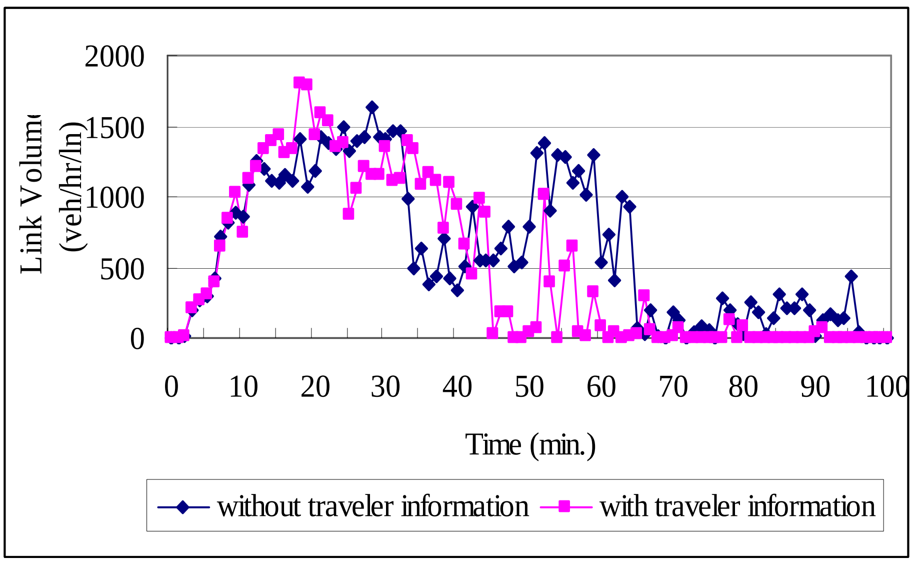

Figure A3-4: Traffic Volumes on IH-35 South Main Lanes at M.L.K.

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 A3-5 presents a comparison of the link volumes in two scenarios.

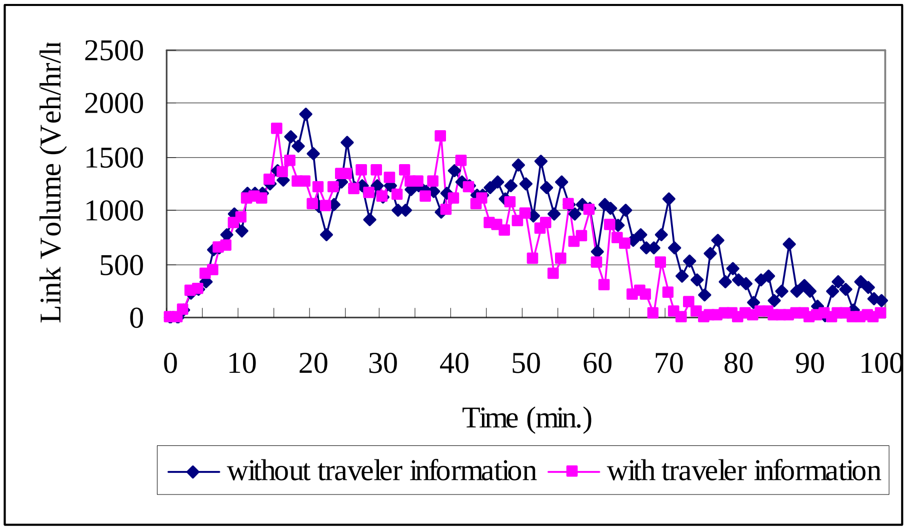

Figure A3-5: Traffic Volumes on IH-35 North Main Lanes at M.L.K.

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/hr/lane. It decreased to 646 vehicles/hr/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 St.

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 A3-6 presents a comparison of the link volumes in two scenarios.

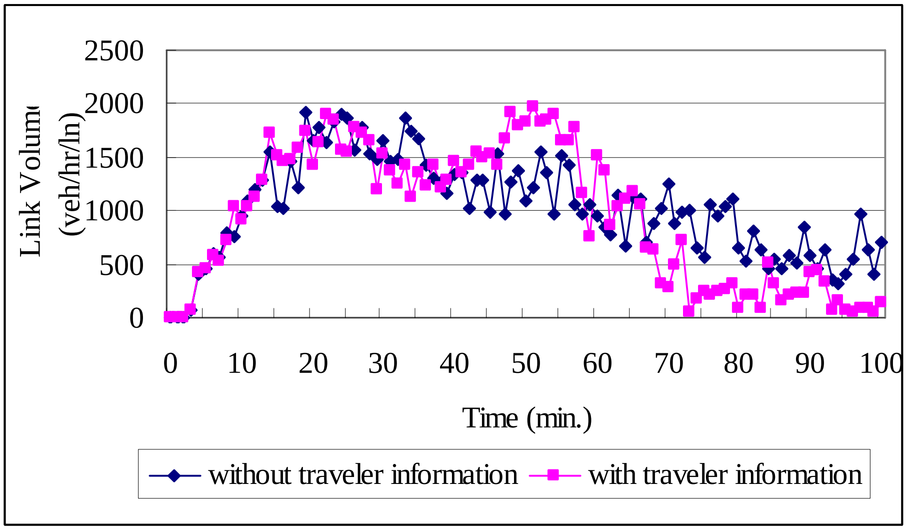

Figure A3-6: Traffic Volumes on IH-35 North Main Lanes at 51st St.

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. Because 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 1,037 vehicles/hr/lane. When ATIS is deployed, the average volume on this link decreases to 961 vehicles/hr/lane.

Appendix 4: Traffic Operations on the SH 130 Toll Road with and without Traveler Information

Traffic operations on the SH 130 toll road links with and without provision of traveler information are presented as the 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 A4-1 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/hr/lane. When ATIS is deployed, the average volume on this link increases to 195 vehicles/hr/lane.

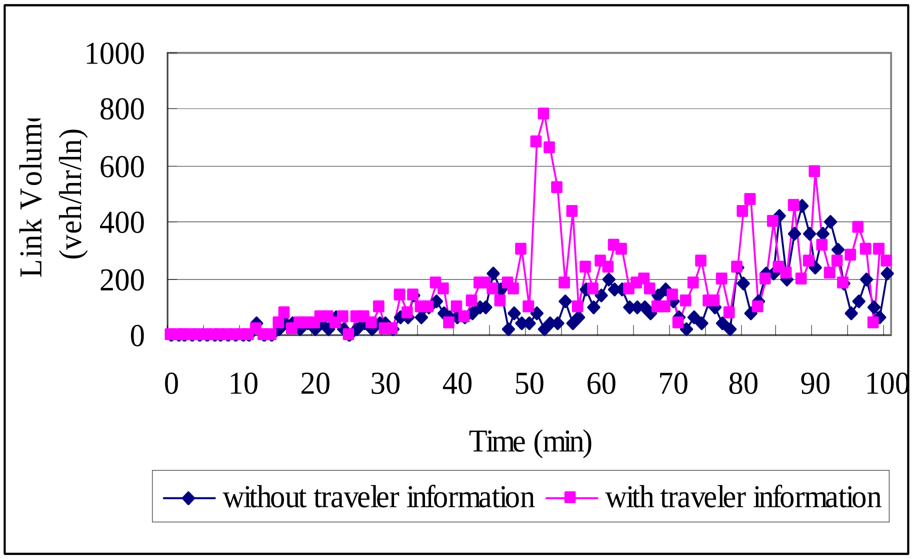

Figure A4-1: Traffic Volumes on SH 130 South Main Lanes (Lanes Starting at the IH-35/SH 130 Junction in the north)

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 A4-2 presents a comparison of the link volumes in two scenarios.

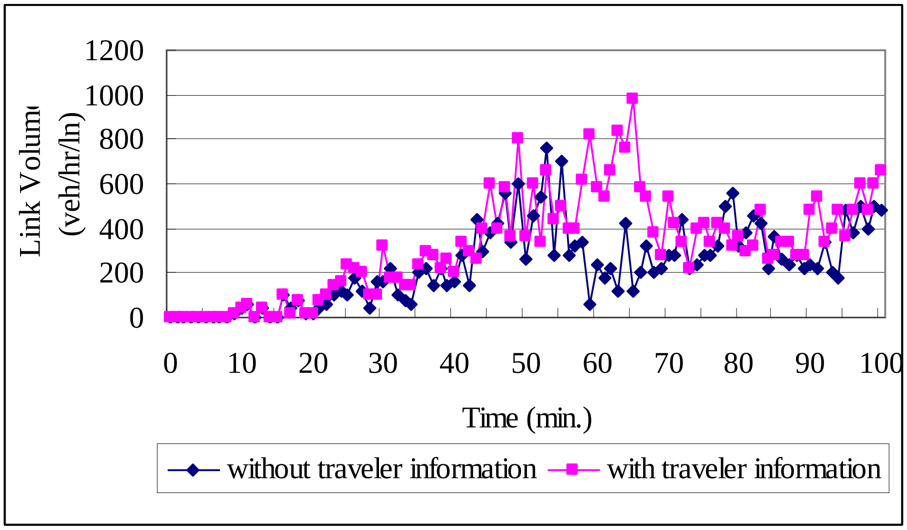

Figure A4-2: Traffic Volumes on SH 130 South Main Lanes (Lanes Starting at the IH-35/US 79 Junction)

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/hr/lane. When ATIS is deployed, the average volume on this link increases to 320 vehicles/hr/lane.

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

Figure A4-3 presents a comparison of the link volumes in the two scenarios.

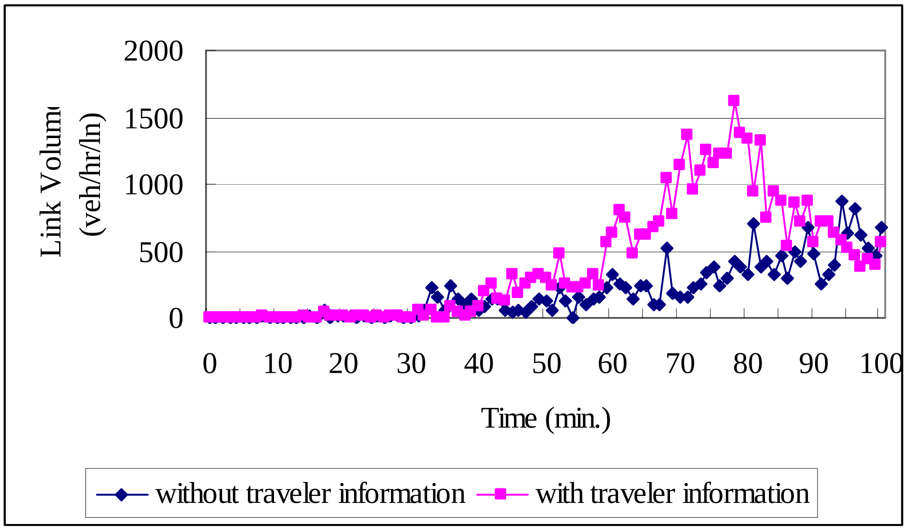

Figure A4-3: Traffic Volumes on SH 130 South Main Lanes (between SH 45 North and US 290)

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 the no-ATIS scenario is 193 vehicles/hr/lane. When ATIS is deployed, the average volume on this link increases to 405 vehicles/hr/lane. The number of vehicles using toll roads almost doubles on this link in this scenario.

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

This link has free flow speed in both scenarios. Figure A4-4 presents a comparison of the link volumes in two scenarios.

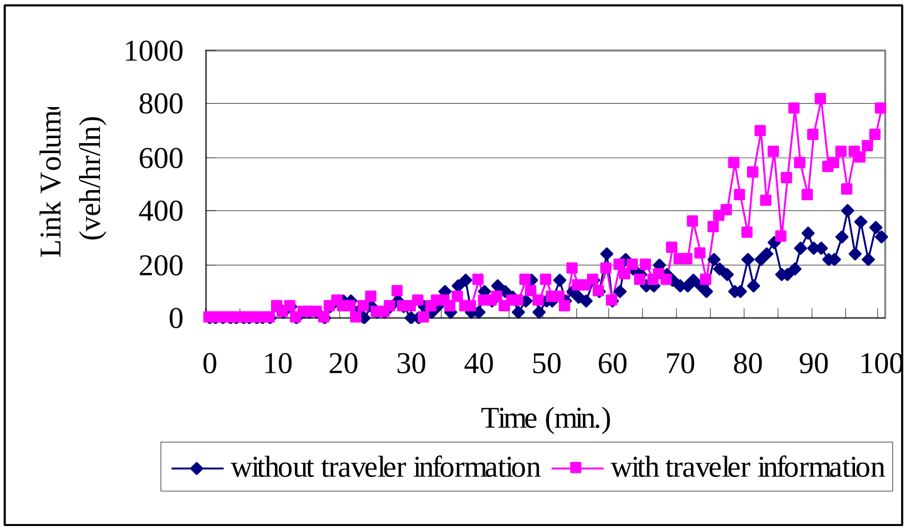

Figure A4-4: Traffic Volumes on SH 130 South Main Lanes (between US 290 and US 71)

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/hr/lane. When ATIS is deployed, the average volume on this link increases to 204 vehicles/hr/lane. The number of vehicles choosing toll roads almost doubles on this link.

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 A4-5 presents a comparison of the link volumes in two scenarios.

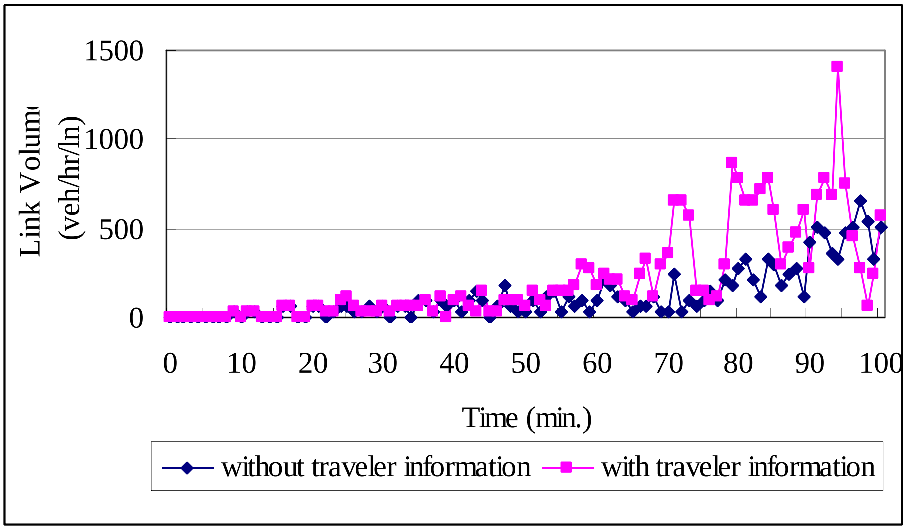

Figure A4-5: Traffic Volumes on SH 45 S. Main Lanes
(Lanes Starting at the IH-35/SH 45 S. Junction)

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/hr/lane. When ATIS is deployed, the average volume on this link increases to 218 vehicles/hr/lane.

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

Figure A4-6 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/hr/lane. When ATIS is deployed, the average volume on this link increases to 82 vehicles/hr/lane.

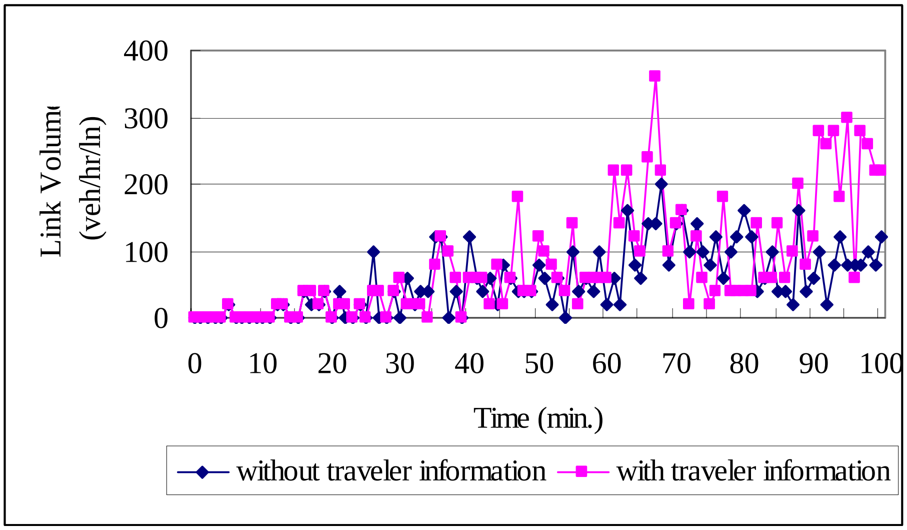

Figure A4-6: Traffic Volumes on SH 130 N. Main Lanes between US 71 and US 290