Effectiveness of Traveler Information Tools

by
Billy M. Williams, Hyejung Hu,
Asad J. Khattak, Nagui M. Rouphail, and Xiaohong Pan

North Carolina State University
Department of Civil, Construction, and Environmental Engineering
Campus Box 7908, Raleigh, NC 27695

Institute for Transportation Research and Education
Campus Box 8601, Raleigh, NC 27695-8601

For the North Carolina Department of Transportation
Research and Development Unit
Raleigh, NC

Final Report
Project HWY-2006-13

January 2008

Technical Report Documentation Page

1. Report No. **FHWA/NC/2006-54**	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **Effectiveness of Traveler Information Tools**		5. Report Date **January 2008**
		6. Performing Organization Code
7. Author(s) **Billy M. Williams, Hyejung Hu,** **Asad J. Khattak, Nagui M. Rouphail, and Xiaohong Pan**		8. Performing Organization Report No.
9. Performing Organization Name and Address **North Carolina State University** **Department of Civil, Construction, and Environmental Engineering** **Campus Box 7908, Raleigh, NC 27695-7908**		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address **North Carolina Department of Transportation** **Research and Development Unit** **1549 Mail Service Center** **Raleigh, 27699-1549**		13. Type of Report and Period Covered **Final Report** **July 2005 – June 2007**
		14. Sponsoring Agency Code **2006-13**
15. Supplementary Notes: **NCDOT Project Engineer: Mr. Ernest Morrison, P.E.**		

16. Abstract

The North Carolina Department of Transportation (NCDOT) sponsored research aimed at enhancing the department's ability to assess the effectiveness of traveler information tools. The NCDOT has and will continue to make investments in Intelligent Transportation Systems (ITS) that fall under the heading of Advanced Traveler Information Systems (ATIS). It is critically important for the NCDOT to be able to assess the impacts, especially the network performance benefits, of candidate ATIS investments in order to make well-informed project decisions and set funding priorities. This final report documents the project's findings, conclusions, and recommendations. The recommendations include the implementation of an ATIS evaluation framework with DYNASMART-P as the primary integration tool and the development of a robust ongoing data collection program to support ATIS research and evaluation.

17. Key Words **Advanced traveler information systems, Evaluation and assessment, Information technology, Traffic simulation, Traffic diversion**	18. Distribution Statement		
19. Security Classif. (of this report) **Unclassified**	20. Security Classif. (of this page) **Unclassified**	21. No. of Pages TBD	22. Price

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

DISCLAIMER

The contents of this report reflect the views of the authors and not necessarily the views of North Carolina State University or the Institute for Transportation Research and Education. The authors are responsible for the accuracy of the data and conclusions herein. The contents do not necessarily reflect the official views or policies of either the North Carolina Department of Transportation or the Federal Highway Administration at the time of publication. This report does not constitute a standard, specification, or regulation.

ACKNOWLEDGEMENT

This work was sponsored by the NCDOT, and the authors are grateful for the support. We would like to thank Ernest Morrison, P.E. who served as the NCDOT Project Monitor and provided invaluable assistance throughout the project. The project steering and implementation committee, chaired by Jo Ann Oerter, provided crucial guidance for which we are thankful and without which this project would not have been successful. The authors would also like to specifically thank Kelly Damron, P.E. of the Intelligent Transportation System Operations Unit and Cheryl Evans and Tom Parker of the Intelligent Transportation Systems Section who provided key information that contributed directly to the completeness and quality of the research and this final report.

EXECUTIVE SUMMARY

The North Carolina Department of Transportation (NCDOT) sponsored research aimed at enhancing the department's ability to assess the effectiveness of traveler information tools. The NCDOT has and will continue to make investments in Intelligent Transportation Systems (ITS) that fall under the heading of Advanced Traveler Information Systems (ATIS). It is critically important for the NCDOT to be able to assess the impacts, especially the network performance benefits, of candidate ATIS investments in order to make well-informed project decisions and set funding priorities. This final report documents the project's findings, conclusions, and recommendations. This executive summary begins with a brief discussion of key highlights and then continues with a high-level summary of the project outcomes.

Executive Highlights

The stated objective of the Effectiveness of Traveler Information Tools research project was the development of usable methods for assessing the benefits of traveler information investments by the NCDOT. The project has been completed, and this objective was achieved. In the course of the project research, a case study of the I-40 pavement reconstruction project was undertaken. The findings of this case study provide a clear picture of the significant value of traveler information.

Traveler information can provide significant time savings. Detailed modeling of the I-40 work zone and the contiguous roadways (including the primary alternate route of I-85 and NC-147) showed that a comprehensive ATIS deployment would be expected to reduce the average travel time for impacted vehicles from about 71 minutes to 36 minutes (a nearly 50% reduction) when compared to a scenario with no ATIS. The "no ATIS" scenario assumes that no drivers would change their route. For reference these travel times should be compared to a 21 minute incident free travel time along I-40. Even though the assumption that no drivers would change their route in the absence of external information is extreme, the 71 minute travel time is a valid measure of worst case conditions, such as a random incident severely reducing the capacity of I-40 or I-85 for a significant length of time. The modeling also showed that the current ATIS deployment (as the sole source of information) would be expected to provide a 15% reduction in travel time (down to 60 minutes). The comprehensive ATIS deployment referred to above includes additional detection and variable message signs placed to maximize the use of multiple alternative routes. These additional devices would be most valuable in the event of a no notice, random incident.

Coordinated public information campaigns are very effective for planned major work zones. By all accounts, the efforts of NCDOT and media outlets coupled with the permanent and temporary ATIS assets were very successful in minimizing delay during the I-40 reconstruction. As a case in point, detailed simulation modeling was conducted and actual archived speed data was gathered for the work zone that was in place overnight from June 6 to June 7. Comparisons showed that the simulations followed the observed initial speed drop reasonably well. However, the observed speeds recovered much more rapidly than did the simulated conditions even with the most extensive ATIS deployment scenario. Even though the simulation models are not field-verified, it is reasonable to conclude that the observed rapid recovery is due largely to the extensive and well-planned public information campaign conducted before and during the reconstruction project. The installed ATIS devices would of course be relied upon more heavily in a no notice situation. Nevertheless, the value of getting the word out for planned incidents is indisputable.

Traveler information users rely on this information to make travel decisions. Through special questions added to the recent Triangle Travel Survey, it was learned that a strong majority of traveler information users consult the information 5 or more times per week. Furthermore, nearly 80% of traveler information users have altered their travel plans based on this information. In general, the survey also indicated that "higher end" information sources, such as the internet, are more strongly correlated with a propensity to change travel plans.

Evaluation Tool Assessment

The first phase of the project included a detailed comparative assessment of available evaluation tools based on a common set of ideal criteria. The mesoscopic network modeling and dynamic traffic assignment tool, DYNASMART-P, and the macroscopic freeway system analysis tool, FREEVAL, were identified as the most promising candidate models and selected for the phase 2 case study evaluations. The FREEVAL tool was considered and evaluation largely because of its successful application in the Incident Management Assistance Patrol (IMAP) planning tool previously developed for the NCDOT.

General ATIS Evaluation

The project team took advantage of an unplanned opportunity to add a series of ATIS-related questions to the Triangle Travel Survey. The responses to these questions provided valuable information on the use of traveler information in the Triangle Region and the types of decisions that Triangle drivers make in response to this information. In addition to directly supporting the modeling of driver response, the survey results point out that most traveler information users are regular users.

Case Study Based Evaluation

In the project's second phase, the DYNASMART-P and FREEVAL tools were applied to the evaluation of case study scenarios involving both planned work zones and incidents occurring during peak commuting traffic conditions. The scenarios were set in a subnetwork of the

Triangle Regional model centered on the I-40/I-85/NC-147 freeway system between the I-40/I-85 split west of the Research Triangle Park the interchange between I-40 and NC-147 (the Durham Freeway). The case studies demonstrated that both the DYNASMART-P and FREEVAL tools were capable of providing reasonable evaluation results while highlighting the comparative advantage of DYNASMART-P's capability to 1) extract network and travel demand data from existing travel demand models, 2) directly model driver response to traveler information, and 3) perform dynamic traffic assignment of vehicles in the context of en-route driver travel decisions. The case studies further illustrated the high value of traveler information through an example benefit cost analysis based on the scenario modeling.

Evaluation Framework

The case study efforts provided the basis for developing an ATIS evaluation framework. The framework provides a systematic procedure for organizing the necessary information, estimating network performance measures, and comparatively evaluating ATIS deployment and/or enhancement alternatives.

Recommendations for the NCDOT

The project team recommends that the NCDOT –

- Implement the recommended ATIS evaluation framework with DYNASMART-P serving as the primary framework integration tool and FREEVAL serving a supporting role for simple analysis of corridor specific deployment options.
- Support continued research into and pursue development of ongoing ATIS data collection policies and procedures. The necessary data include traffic stream data and driver behavior data.

Recommendations for Future Research

The project team recommends that the broader transportation research community conduct targeted research to increase our understanding of driver behavior and decision making coupled with the applied research necessary to accurately represent and model driver behavior within network traffic flow models. Along these lines, the project team recommends specific research aimed at –

- Developing a realistic model of driver response to visual recognition of downstream congestion. (Ideally with testing and implementation within DYNASMART-P.)
- Developing a realistic model of queue propagation that can be implemented in a mesoscopic model such as DYNASMART-P
- Continued research to develop increasingly valid and accurate models of driver behavior.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. INTRODUCTION

Travelers desire static and dynamic information in order to plan their trips and make more informed decisions about whether to make a trip, what destinations to visit, which modes to use, what routes to take, and where to park. In congested urban areas, people use dynamic information to change their regular or selected options in response to unexpected events (e.g., incidents, road construction, and weather) that induce congestion.

Advanced Traveler Information Systems (ATIS) disseminate traveler information by various ways such as Variable Message Signs (VMS), Internet website, TV, Highway Advisory Radio (HAR), phone service (511), and In-Vehicle Information System (IVIS). ATIS can benefit individuals in terms of improved travel planning, knowledge of alternative modes and destinations, avoiding delays, increased certainty in arrival times and lower travel stress and anxiety.

The travelers respond to traveler information in diverse ways. ATIS users' responses resulting changes in travel patterns impacts on the traffic network performance. Lappin and Bottom *(2001)* categorized various travelers' responses into the two types. Responses in the first category effect on the trip making context. For example, adjustments to residential and/or employment location decisions, adjustments to daily activity schedules, changes in habitual trip making behavior, effects on non-travel activities, and trip-related stress or anxiety relief are included in this category. Responses in the second category change trip making itself. The decision to travel or not, the choice of destination, the choice of departure time, mode and route, the re-routing decision in response to an incident, the driving behavior, and the choice of parking location are involved in the second category.

The changes in travel patterns induce difference in travel time and traffic characteristics. In other words, travel information can also benefit the transportation system in terms of lower incident-induced congestion (with accompanying increased safety and decreased travel delay), higher accessibility to destinations and modes, lower fuel consumption and improved air quality.

In response to these known ATIS benefits to individuals and transportation system, the NCDOT has deployed ATIS technologies across the state, and other states have followed a similar pattern of early ATIS implementation. Although transportation agency experience and customer satisfaction with ATIS deployments have generally been positive, methodologies for quantifying the benefits and costs of ATIS are lagging behind. This fact has been brought into keen focus by increasingly constrained transportation budgets.

Therefore, there was a pressing need to develop evaluation methodologies and tools to quantify the costs and benefits of the various ATIS deployable technology options. This work has begun in other states and transportation agencies. Therefore a central element of this research is a comprehensive survey and summary of the disparate ATIS benefit/cost efforts and a synthesis of the results into a framework for North Carolina. The evaluation capabilities covered technologies that have already been deployed in North Carolina as well as other available and appropriate technologies.

The principal research objectives for the proposal project are:

1. Synthesize the US state of the practice in ATIS/ITS deployment evaluation
2. Synthesize the relevant data and preliminary analysis that has been developed by NCDOT ITS units
3. Assess the applicability and accuracy of available ATIS evaluation tools
4. Develop an evaluation methodology based on an existing, enhanced or new tool (or tools)

5. Conduct general and case study based evaluations of ATIS deployment in NC
6. Develop recommendations for the establishment of a robust ATIS/ITS evaluation system

The project tasks were divided into the two phases that correspond to the first and second project years. Primary work of Phase I is synthesis of literature, data and practice. Base on the research results of Phase I, the direction of second year research was determined. During the second project year, project team focused on the ATIS technology evaluation, case study analysis, and evaluation procedure development. Brief descriptions of the project tasks as they were given in the project proposal follow. The proposal task descriptions are followed by a brief discussion of the opportunity that arose for the team to include questions in the Triangle Travel Survey and the project steering and implementation committee's direction for the Phase II tasks.

1.1 Project Tasks

1.1.1 Phase I – Year 1: Synthesis of Literature, Data and Practice

- **Task 1 – Literature review**

  USDOT's ITS Joint Program Office (JPO) provides a coordination and clearing house function for research and assessment activities aimed at evaluating and quantifying ITS benefits and costs. The primary focus of literature review task was the review of *ITS Benefits and Cost Database* provided by ITS JPO. Also, research team reviewed the literature related to ATIS/ITS deployments implementation experience and benefit/cost evaluation case studies which applied simulation tools or used survey data.

  Various ATIS evaluation approaches including traffic flow simulation, field observation, survey, driving simulation experiments, and economic assessment were investigated in this task. In addition, other recent ATIS-related was reviewed, including research regarding traveler response models, driver type differences, user needs, information quality, and the value of ATIS.

- **Task 2 – Evaluation tool assessment**

  The evaluation tools found in Task 1 including DYNASMART-P, INTEGRATION, IMAP, VISSIM and IDAS, were assessed on characteristics such as data requirements, conceptual and methodological validity, analysis outputs (e.g., savings in travel time, emissions, accidents, and increases in travel time reliability), simplicity, robustness, etc. to establish their appropriateness for evaluating ATIS technologies and strategies. Through this functional requirement evaluation, three tools (IDAS, DYNASMART-P, and IMAP tool) were selected as candidates of ATIS evaluation tool for North Carolina. Then, the simple case study was carried to test the functional capabilities and limitations of these three candidates in application.

- **Task 3 – Cost and evaluation data synthesis**

  The ITS Operations Unit has worked on quantifying the operations and maintenance costs of NCDOT's ITS program. We obtained the results and findings of this effort. We identified the contexts in which ATIS are most appropriate and potentially beneficial, e.g., in locations which have higher travel time uncertainty and experience higher levels of traffic congestion levels.

  We determined what additional data are available within NCDOT that can help quantify ATIS costs and benefits. For example, other NCDOT units have developed databases on capital and user costs of ITS deployments. As a secondary focus, we acquired readily available data on ATIS deployments in other states.

- **Task 4 – Obtain information about planned and existing ATIS/ITS devices and systems (e.g., CMS, HAR and 511) throughout North Carolina.**

  The project team cataloged ATIS deployments within the North Carolina. NCDOT has North Carolina statewide ITS strategic plan which consists of 9 regional reports. These reports described ATIS projects that are planned or in consideration. Existing and future deployments found and cataloged from these reports will provide the base information for case studies in Phase II.

- **Task 5 – Define the Phase II project scope detail.**

  Based on the findings from Phase I Tasks 1-4, we coordinated with the NCDOT project leadership to determine the best use of the project resources to satisfy NCDOT's project goals.

- **Task 6 – Phase I Interim Report**

  An interim report will be completed early in project year 2 that documents the Phase I findings.

1.1.2 Phase II – Year 2: ATIS Technology Evaluation, Case Study Analysis, and Evaluation Procedure Development

- **Task 7 – Modify, extend or create a North Carolina appropriate ATIS evaluation tool**

  The findings of Task 2 could range from identification of an evaluation tool that can be applied "off the shelf" at one extreme to the development of a completely new tool at the other extreme. The off the shelf tool considered was IDAS. Other possibilities include identification of an evaluation tool used elsewhere that could be adapted for use in North Carolina, or extension of an existing evaluation tool, such as the IMAP evaluation tool developed for NCDOT under a previous research project. This tool can quantify the effect of providing dynamic traffic information to travelers in incident conditions.

- **Task 8 – General Evaluation of Specific ATIS Technologies**

  Using either an "off the shelf" evaluation tool or the tool resulting from Task 7, the project team will evaluate a selected set of ATIS technologies in specific "high-impact" North Carolina locations. ATIS technologies will be evaluated in the context of National Architecture market packages as follows:

  - Pre-trip Information
    - Internet
    - 511
    - Other telephone
    - TV/Radio
    - Kiosks
  - En-route Information
    - 511
    - Other telephone
    - Radio
    - In-vehicle Systems
  - Tourism & Events
    - Travel services
    - Advanced parking
    - Electronic payment

- **Task 9 – Case study based ATIS evaluation**

  Alternatively or in addition to the general technology evaluation, a comparative case study can be used to assess the impact of presence or absence of complementary technologies, such as incident management. Furthermore, the effectiveness of ATIS deployments can be compared between the Triangle and Metrolina. This will require the application of the selected tool to local data. The case study would allow assessment of the effect of real time traffic data on the quality and resulting benefits of traveler information.

- **Task 10 – Development of a recommended framework for ongoing benefits evaluation**

  The findings from Tasks 3 may reveal opportunities for improving the collection of data to support ATIS evaluation and coordination among the responsible NCDOT units. Based on these findings and in consultation with the project steering committee, the project team could develop a recommended framework for collecting the necessary data, identifying appropriate locations for ATIS and conducting ongoing evaluation of ATIS/ITS effectiveness.

- **Task 11 – Prepare final project report and prepare and deliver project presentations.**

  In addition to the benefits-costs evaluation tool that will be developed under Task 4, a final report will be prepared that documents project decisions, task efforts and findings. Formal and informal presentations will also be prepared and delivered as needed to communicate interim and final project results.

1.2 Triangle Travel Survey

During the performance period of this research project the Triangle Travel Survey was conducted as a partnership between ITRE, NCDOT, TTA, CAMPO, and DCHC-MPO. The firm NuStats surveyed over 5,000 households in the Greater Triangle Region from the following counties: Wake, Durham, Orange, Chatham, Lee, Harnett, Johnston, Nash, Franklin, Person, Vance, and Granville.

This survey was conducted to provide behavioral data for estimation of travel forecasting models. Through ITRE's involvement in the survey, the project team was able to add several questions about user response to traveler information. From the survey data, calibration of behavioral models, identification of trends, targeted messaging, insight into population, origin, destination, and route choice, evaluation of program benefit, and insight into the value of collecting more targeted behavioral data will be possible. Furthermore, results from the survey provided the foundation for the team's efforts under task 8 – "General Evaluation of Specific ATIS Technologies."

1.3 Phase II Scope Refinement

Based on review of the phase I results and considering immediate NCDOT concerns and data availability, the project steering implementation committee directed the project team to conduct two basic case study scenarios with both scenarios centered on the Research Triangle Park region of western Wake County. The first basic scenario was designed to evaluate the effectiveness of ATIS under recurring peak hour travel conditions and the occurrence of a lane closing traffic incident. The second basic scenario was designed to evaluate the effectiveness of ATIS during the major I-40 resurfacing project that began during the phase II research work. The project steering and implementation committee further directed the project team to use DYNASMART-P and the traffic model from IMAP as the phase II case student tools. These case studies are presented in Chapter 7.

CHAPTER 2. LITERATURE REVIEW

Travelers desire accurate and up to date information in order to plan their trips and make more informed decisions about whether to make a trip, what destinations to visit, what modes to use, what routes to take, and where to park. ATIS technologies have been deployed to satisfy this desire.

ITS User Services are presented in Appendix A. ATIS-related user services are –

- Pre-trip Travel Information,
- En-route Driver Information,
- Route Guidance,
- Ride Matching and Reservation, and
- Traveler Services Information.

ATIS have been deployed in many cities in U.S. Gordon and Trombley (*2004*) reported on four national ITS surveys. Their data, summarized in Appendix B, show clear growth in deployment of ITS from 1997 through 2005. They found deployment of freeway surveillance and closed circuit television cameras advancing rapidly, along with technology to support transit, public safety, arterial traffic management, and toll collection. However, there was less evident emphasis on creating regionally integrated transportation management systems, which would require real-time data transfer and greater coordination among agencies.

In congested urban areas, people use dynamic information to change their regular or selected travel options in response to unexpected events (e.g., incidents, road construction, and weather) that induce congestion. Better traveler information, disseminated through a variety of sources (such as Changeable Message Signs—CMS, Highway Advisory Radio—HAR, and 511) can benefit individuals in terms of improved travel planning, knowledge of alternative modes and destinations, avoiding delays, increased certainty in arrival times, and lower travel stress and anxiety. Travel information can also benefit the transportation system in terms of lower incident-induced congestion (with accompanying increased safety and decreased travel delay), higher accessibility to destinations and modes, lower fuel consumption, and improved air quality.

However, it is not easy to define and document ATIS benefits, and quantifying ATIS benefits is especially difficult. Nonetheless, there have been many attempts to quantitatively and qualitatively evaluate ATIS benefits. These previous evaluations involved gathering required data from various sources such as surveys, field observations, and simulations. Also, various approaches have been used for analysis and assessment.

The first part of this literature review presents the results of ATIS evaluation from other states. The results were extracted from recent evaluation research reports and the database provided by ITS Joint Program Office website. The second part summarizes evaluation tool research. In the final part, other recent realted research is reviewed. Research projects are classified according to traveler response models, specific driver type characteristics, user needs, information quality, and value of ATIS.

2.1 The state of the practice

Related research and practice literature were thoroughly reviewed to establish the state of the practice in evaluating the relative cost effectiveness of deployed ITS technologies. The information about ATIS evaluation methods and effects of ATIS were gathered from the experiences of other states and the ITS JPO within the USDOT. The ITS JPO updates and provides ITS benefits and costs database through an organizational website. The database provides ITS unit costs and system costs in excel spread sheet files or PDF files. For the benefits data, the web site provides web links to relevant research summaries. The summarized data can be used for developing an ATIS evaluation methodology or adjusting default values in evaluation tools.

Appendix C shows that ATIS have benefits in capacity/throughput, cost/savings, customer satisfaction, delay/time, energy/environment, and safety. The benefits of ATIS in capacity and throughput are trivial in most studies, resulting from reduction in delay and the number of stops. The benefits of ATIS in cost and savings however are measurable and significant. The Appendix C benefits table summarizes the evaluation results from other states and ITS JPO benefit database. Appendix D is the cost database provided from the ITS JPO. Unit costs are adjusted value in 2004 dollars.

A simulation by Shah et al. (*2003*) found 40% of all ATIS users achieved an individual net positive benefit of $60 or more per year. Khattak et al. (*1994*) found that the benefits of incident-induced delay information could range from $124 to $324 per person (1992 dollars), for 40% of the commuters who expressed a willingness to divert to alternative routes in the San Francisco Bay Area. A London Transport survey (*1998*) found that transit information changes behavior and creates revenue up to 14.5 million pounds, including 1.3 million for bus companies, 1.2 million for underground companies, 1 million for railway companies, and 11 million in societal benefits.

Most research on ATIS benefits investigated the level of customer satisfaction and user acceptance. Generally, researchers found that traveler information is useful for making travel decisions and that it reduces stress and travel time. However, research revealed low awareness of ATIS. For example, only 9% of households were aware of TravInfo – a regional traveler information system in California (*Yim and Miller, 2000*). Related studies showed that ATIS significantly reduced the amount of time spent on arrivals in the peak periods, with most studies reporting reductions in number of stops, travel time, and vehicle travel miles. In addition, ATIS has observable benefits in terms of environment, energy, and safety. Better traveler information results in changes in routes and departure time—changes found to reduce vehicle emissions and fuel consumption *(Tech Environmental, Inc., 1993, Jensen et al., 2000, Jeannotte, 2001, and Zimmerman et al., 2000*), as well as fatalities (*Jeannotte, 2001*).

Taken in the aggregate, the major benefits of ATIS lie in reducing uncertainty and delay. The key findings of a series of studies on ATIS include the effectiveness of personalized (route-specific) traveler information compared to general radio advisories and the value of pre-trip information, particularly in high congestion (*Vasudevan et al., 2004*). Individual ATIS users enjoyed benefits year-round, particularly in the afternoon peak period (*Shah et al., 2003*). Most benefit to travelers came not from shortened travel time, but from reduced incidence of early or late arrival (*Shah et al., 2003*). Thus, users need not shorten their trips to feel satisfied with the service, given other benefits, such as more precise travel planning and reduction of stress from congestion and uncertainty. Other relevant studies are presented in Appendix C.

2.2 Evaluation methods

Generally, benefits are measured qualitatively, quantitatively, or both. Also some of these benefits are transformed to monetary values. To evaluate the benefits of ATIS, several methods have been developed and used. Data for the evaluation have also been collected from various sources, such as simulated data, field data, and surveys.

Evaluation methods can be classified into three categories: field studies, simulations, and surveys. Field studies involve the differences in travel times of drivers with and without ATIS on a certain road section. Simulation studies show the potential benefits that could occur if ATIS were used at a certain location(s). Lastly, survey studies poll ATIS users to determine what

ATIS benefits they perceive. In this section, some of the methods and software tools recently used are introduced briefly along with a summary of key research findings.

Simulation methods can be applied to evaluate future ATIS deployment plans while field operational tests and survey studies can be conducted only for the locations that currently have ATIS in operation. Recently, IDAS (ITS Deployment Analysis System), VISTA (Visual Interactive System for Transport Algorithms), DYNASMART-P (DYnamic Network Assignment-Simulation Model for Advanced Road Telematics-Planning), and DynaMIT have been applied to ATIS evaluation with some regularity. HOWLATE (Heuristic On-line Web-Linked Arrival Time Estimation) and OTESP (Orlando Transportation Experimental Simulation Program) are also well known ATIS evaluation methods. These two tools, however, differ fundamentally from the simulation methods mentioned above. These tools require subject drivers to interact with a simulated virtual network and then examine the drivers' responses to the ATIS using post experiment surveys. In contract, the former tools enable evaluation of ATIS effects on large networks.

2.2.1 Field observation

Field observation methods have been used to evaluate the effectiveness of ATIS systems in areas where the system was already in use. System operators gathered data using their own detector systems and surveys for the assessment. Measuring ATIS benefits through field studies is often done with yoked trails, in which two vehicle groups (one equipped with ATIS and one not) travel between the same origin-destination (O-D) pair at the same time. The time it takes these vehicles to travel between each O-D pair is then compared to determine whether the vehicle group with ATIS experienced improved travel times compared to the other driver group.

Schiesel and Demetsky (*2000*) attempted to determine the effect of a Dynamic Message Sign (DMS) system in the Hampton Roads area of Virginia. Data were collected on the DMS system and volume data was obtained using loop detectors, over a period from August 1998 to July 1999. Using this data the difference between the percentage of drivers turning towards the Hampton Roads Bridge Tunnel when the DMS system was and was not in use was calculated. This difference was taken to indicate the diversion percentage. Harder et al. (*2005*) used a field operational test method for their research. They had 117 participants drive along actual routes. Pre-trip travel-time information was provided in the field experiment to half the participants. Various data collection techniques were used including in-vehicle GPS units, pre- and post-experiment surveys, and travel diaries.

In other research, the driver's responses to traveler information have been inferred from the field operational results of a deployed ATIS system. Yim and Ygnace (*1996*) reported drivers' response to real-time traffic information under SIRIUS (Système d'Information Routière Intelligible aux Usagers). SIRIUS is the largest urban field operational test of advanced traveler information and automated traffic management systems in Europe. In this case, the research results have significant potential value compared to one time field test results because long term effects were analyzed.

2.2.2 Simulation Methods

2.2.2.1 Dynamic Assignment Models

Dynamic assignment models attempts to model traveler's behavior including route diversion, mode change, and departure time change depending on market penetration rate and quality of information. Because many of these models are still under development, developers usually test their new algorithms using a small sample network. Gel et al. (*2003*) built the framework consisted of two-level mathematical program. The upper-level program maximizes the reserve capacity multiplier subject to a link capacity constraint, and the lower-level program generates user equilibrium flow patterns under the influence of traveler information. In the lower level, they consider the dispersion parameter theta in the logit model as an indicator of the quality of information provided by ATIS. Yin and Yang (*2003*) classified three classes of drivers on a specific day: drivers without ATIS, drivers with ATIS but without compliance with ATIS advice, drivers with ATIS and in compliance with ATIS advice. All three classes of drivers make route choice in a stochastic manner, but with different degree of uncertainty of travel time on the network. They provided the function of the market penetration of ATIS and the probability of the ATIS compliance rate of equipped drivers. Lo and Szeto (*2004*) applied a stochastic dynamic model based on the cell-transmission model. Two classes of drivers, those with ATIS and those without were considered. Both classes were modeled to follow stochastic, dynamic user optimal conditions, with the equipped drivers having a lower perception of the variation of the network travel time due to the availability of better information. Srinivasan and Guo (*2004*) developed a simulation-based framework to analyze day-to-day dynamics by integrating an empirically calibrated model of route-choice decisions with a dynamic network assignment model. Computational experiments are used to investigate the effect of certain experimental factors—recurrent network congestion level, market penetration, nature of information, and frequency of information updates—on network performance stability and reliability.

2.2.2.2 Numerical simulators

IDAS (ITS Deployment Analysis System) is a sketch planning tool created for the FHWA by Cambridge Systematics (*2000*) to calculate the benefits and costs of implementing an ITS technology within a transportation network. It has a postprocessor and extender to the travel demand model mode choice and assignment steps. Users can view and edit most of the model defaults. The software uses imported data a travel demand model to recreate the model network within the IDAS software. Then the user can build one or several ITS deployment alternatives to evaluate. IDAS calculates the benefits and costs of deploying the specified ITS alternatives, performs internal network assignment and analysis to estimate impacts of ITS, and reports outputs in terms of the incremental change in performance measures and the annual benefit/costs. The software can analyze over 60 types of ITS strategies, eleven of which are related to traveler information. IDAS includes a database of system impacts and costs related to each type of deployment based on national evaluations.

VISTA (Visual Interactive System for Transport Algorithms) was developed by Ziliaskopoulos and Waller (*2000*). VISTA has a simulator, RouteSim, that uses cell transmission rules. The VISTA website provides a program overview and tutorial. VISTA was applied to Chicago's six county-area network. VISTA's innovative network-enabled framework integrates spatio-temporal data and models for a wide range of transport applications: planning, engineering and operational. The software can be accessed via a cross-platform Java client or a web page. The client software provides all basic transportation GIS type operations, such as zooming; displaying multiple layers; adding intersections, street segments, signal controls, ITS devices, etc. The software also provides access the data warehouse and generates network performance reports (mostly graphical, such as 2-D animations). The groundbreaking innovation of VISTA is that it runs over the network on a cluster of UNIX machines. This makes it universally accessible without worrying about available computational power of the client machine to run sophisticated dynamic traffic assignment, control and simulation models.

Mahmassani and Jayakrishnan (*1991*); Mahmassani and Peeta (1993) described the DYNASMART (DYnamic Network Assignment-Simulation Model for Advanced Road Telematics) Dynasmart simulation-assignment model developed at the University of Texas at Austin. DYNASMART-P is a mesoscopic traffic simulator, meaning that it simulates the movement of individual vehicles moving through a network in accordance with macroscopic flow rules (e.g., speed-density relationships.) It simulates several different route choice rules including dynamic system optimality, dynamic user optimality, and a bounded rationality rule in which drivers receiving en-route information about path conditions will only switch paths if the expected improvement exceeds a threshold amount. DYNASMART-P has been widely used for investigations of route guidance.

DynaMIT (Dynamic Network Assignment for the Management of Information to Travelers) is a mesoscopic traffic simulation model developed by Ben-Akiva et al. (*1998*). DynaMIT is explicitly designed for route guidance applications and is a simulation-based real-time system designed to estimate the current state of a transportation network, predict future traffic conditions, and provide consistent and unbiased information to travelers. DynaMIT combines real-time data from a surveillance system with historical travel time data in order to predict future traffic conditions and provide travel information and guidance through an ATIS. Yang et al. (*2000*) develop the microscopic MITSIMLab tool for testing and evaluation of dynamic traffic management systems. Subsequently, Sundaram (*2002*) developed a methodological framework for such applications and implemented this framework in DynaMIT. He modeled traveler behavior and network performance, in response to special events and situations such as incidents, weather emergencies, sport events etc. The resulting new planning tool DynaMIT-P consists of a supply (network performance) simulator, a demand simulator and algorithms that capture their interactions. The supply simulator captures traffic dynamics in terms of evolution and dissipation of queues, spill-backs etc. The demand simulator estimates OD flows that best match current measurements of them in the network, and models travel behavior in terms of route choice, departure time choice and response to information. DynaMIT-P is particularly suited to evaluate Advanced Traffic Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS) at various levels of sophistication. Florian (*2004*) provides an empirical study of the impact of ATIS on transportation network quality of service using an application of DynaMIT in his thesis. An understanding of the relationship between transportation system performance and ATIS market penetration provides important insights into a sustaining market structure for the ATIS industry.

INTEGRATION was conceived during the mid 1980's as an integrated microscopic traffic simulation and traffic assignment model *(Van Aerde, 1985; Van Aerde and Yagar, 1988a and b; Van Aerde and Yagar, 1990)*. It models routing and assignment, thus allowing for the modeling of traffic re-routing in response to real-time traffic information. It allows for the integrated modeling of freeway and arterial systems. This capability allows for modeling of traffic diversion between the freeway/arterial facilities. It has been utilized in the evaluation of the TravTek route guidance system (*Van Aerde and Rakha, 1995)* and the Intelligent Transportation Systems (ITS) architecture study.

Prepared by Khattak and Rouphail (*2005*) recently, IMAP is a decision support tool that allows easy planning and operational assessment of existing and potential service patrol sites in North Carolina. IMAP uses FREEVAL as a traffic simulation tool. FREEVAL replicates the freeway facility methodology in Chapter 22 of the Highway Capacity Manual 2000 (*TRB, 2000*).

It can model the effects of incidents / work zones on traffic operations macroscopically and also model route diversion effects by shifting diverted demand to alternative route.

VISSIM (Traffic In Towns: SIMulation, PTV, http://www.ptvamerica.com/) is a microscopic, behavior-based multi-purpose traffic simulation program. VISUM is another tool provided by PTV. VISUM is for transportation planning, travel demand modeling and network data management. VISSIM networks can be exported from VISUM. Therefore, after editing large networks in VISUM, then users can export the data to VISSIM for simulation. It is able to assess ATIS options such as VMS effects in network by applying dynamic assignment feature in VISSIM.

2.2.2.3 Driving simulation experiments

Driving simulators represent an attractive alternative to field observation in terms of costs, participant safety, and data collection difficulty. Fox and Boehm-Davis (*1998*) evaluated driver compliance with ATIS advice using a high-fidelity driving simulator. Participants drove through a simulated with network the goal of avoiding congestion. A simulated ATIS made route recommendations. They carried the experiments to test user compliance depending on accuracy of information. Their results show that 40 percent accuracy would not support user trust and compliance, but that 60 percent accuracy probably would. Liu and Mahmassani (*1998*) collected data from laboratory experiments using a dynamic interactive traveler simulator that allows actual commuters to simultaneously interact with each other within a simulated traffic corridor. Given real-time information provided by the system, commuters determine their departure time and route at the origin and select paths en-route at various decision nodes along the trip. Also, Bogers et al. (*2005*) used interactive travel simulator to collect data for their model estimation.

HOWLATE (Heuristic On-line Web-Linked Arrival Time Estimation, Jung at al, *2002*) was developed by Mitretek Systems. HOWLATE uses simulated yoked pairs traveling between specified origin and destination (O-D) pairs, one of which has ATIS and one that does not. The simulation extracts traffic data every 5 minutes from an Internet service provider that records link travel times on various roadways. The first step of the simulation is to establish the routes and departure times for the ATIS traveler and the non-ATIS traveler. Once the routes and departure times have been chosen, the second step consists of using the archived data to construct actual travel and arrival times in traffic conditions during the date and time used for simulation. While many yoked-pair studies have drivers depart at the same place and time, HOWLATE focuses on the destination and target arrival time of the yoked pairs. HOWLATE allows conducting controlled experiments based on travel times for different driving trips at different times on different days in the archive. In this simulated environment, one could determine the effectiveness of ATIS for freeway trips across the region by comparing the outcome of an ATIS user who may leave earlier or later or change route in response to real-time traffic information and a "habitual" commuter who maintained the same time of departure and route from day to day. Jung at al (*2002*), Toppen and Wunderlich (*2003*), Jung et al. (*2003*), and Toppen et al. (*2004*) employed this simulation technique for estimating ATIS effects. Due to high data collection costs, analysts are commonly faced with the problem of limited data in the evaluation of ITS systems. Vasudevan et al. (*2004*) suggested and applied an analog of statistical resampling ("experimental resampling") to generate a larger sample based on actual data.

OTESP (Orlando Transportation Experimental Simulation Program, *Abdel-aty, 2003*) is a powerful interactive computer simulation tool. It creates a simulated roadway environment and presents a human subject with several travel scenarios between trip origin and destination. Abdel-aty (*2003*), and Abdel-aty and Abdalla (*2004*) used OTESP as data collection tools for route choice modeling purposes under ATIS. A subject has the ability to move the vehicle on different segments of network using the computer's mouse. Different levels of information are provided to the subjects, including transit and route information, pre-trip and en-route information, and information with and without advice. Different travel congestion levels are also provided. All the travel decisions are captured and coded to a database for analyses.

2.2.3 Survey Methods

Surveys are the most common methods for ATIS evaluation. Surveys conducted after installing and operating an ATIS are designed to estimate user satisfaction and the effects of ATIS operation. Appendix C shows benefit evaluation results from other states. Many of the benefit evaluations used survey methods. Various kinds of collection methods such as telephone, mailing, e-mail, and on-line surveys were used. Question selection depends on the research objectives and the level of compliance desired. Pierce and Lappin (*2002*) investigated the usage of Internet, radio, and television in Seattle, Washington along with the users' response. They found 3.2% of respondents consulted traveler information: in-vehicle radio 56%, pre-trip radio 22%, TV news 13%, traffic websites 6%, and transit websites 6%. Also, the survey results showed 37% of information users reported a change in travel plan (1.1% of total trips) divided among the following: changed departure time 13%, made a minor route change 11%, took a whole different route 9%, delayed or cancelled trip 2%, and changed mode 1%. Appendix C provides information on other survey research and results.

2.2.4 Economic ATIS benefit cost assessment

Research reported in Levinson et al. *(1999)* and Levinson *(2003)* found that the effect of traveler information is to shift both the supply and demand curves for travel. The researchers attempted to estimate the monetary value of ATIS benefit and cost effects based on the supply and demand curves for travel.

2.3 Other Recent Research

ATIS provide both static and dynamic information before and during a trip to support pre-trip and en-route decisions. By dynamically adjusting schedules, modes and routes, travelers can respond to travel information. In this chapter, various areas of research related to traveler response to ATIS information are presented. This research is classified into the following categories: traveler response models, driver type differences, user needs, information quality, and the value of ATIS.

2.3.1 Traveler Response Models

An understanding of how information affects travelers' decisions can help in evaluating benefits. Traveler's responses data on ATIS usually gathered using survey and simulation, and then various statistical methods were applied for analyzing the survey result and modeling traveler's behavior.

Khattak et al. (*1996*), Khattak and Khattak (*1998*), and Khattak et al. (*1999*) modeled traveler responses to ATIS using the multinomial logit formulation, a maximum likelihood nested logit model, and a probit model. Viswanathan et al. (*2000*) used a multivariate probit model for traveler's decision making when they have traveler information.

Recently, Abdel-Aty and Abdalla (*2004*) modeled correlated multinomial route choice data under ATIS. The Multinomial Generalized Estimating Equations (MGEEs) methodology was applied with generalized polytomous function and exchangeable correlation structure. The researchers' goal was to gain a better understanding of which factors influence driver's decisions.

In order to estimate traveler response behaviors realistically, Ettema and Timmermans (*1996)* introduced a model of activity scheduling, SMASH (Simulation Model of Activity Scheduling Heuristics). SMASH has aspects of discrete-choice modeling and CPMs (computational process models). CPMs enable realistic traveler responsive modeling due to their ability to perform heuristic search through suboptimal reasoning processes.

Similar research was conducted in Taiwan. Jou et al. (*1997*) conducted an extensive home interview survey in the Taichung metropolitan area. A binary logit model was applied to estimate whether or not a traveler switches departure time, route, mode, or any combinations of the three after receiving traffic information.

2.3.2 Focused Research by Driver Type

Traveler responses and their needs are likely to vary across different driver types. The following research efforts focused on a specific driver groups and usually use survey data. Ng and Mannering (*1998*) analyzed private and commercial drivers' information requirements for an ATIS. Their results show that significant differences in trip behavior and socioeconomic characteristics exist among the observed two groups. Khattak et al. (*1999*) studied the behavioral responses of automobile and transit commuters as well as non-commuters. They found non-commuters have a high receptivity to cancel their trips in response to travel information. Henk and Kuhn (*2000*) examined departure time choice for non-work trips. Kraan et al. (*2000*) studied travel decisions of trip makers for non-commuting, recreational, and shopping trips. Peeta et al. (*2000*) found differences in the response attitudes of motor carrier drivers compared to other travelers.

2.3.3 User Needs Assessment

Knowing user's needs and relative satisfaction is helpful when planning a new ATIS or planning improvements to a current ATIS. Various survey methods were used to assess the ATIS needs and user's satisfaction.

Hobeika et al. (*1996*) assessed the ATIS needs of I-95 corridor users. Users ranked roadway safety, personal security, and traffic information high in importance. Wells and Horan (*1999*) developed a survey to assess public attitudes toward ITS. Mehndiratta et al. (*2000*) found user interest in traveler information systems to be a function of complex travel behavior, demographics, and factors related to attitudinal and technology interest based on research in the Seattle metropolitan region.

The following research efforts were designed to assess user needs for a specific system, driver group, or area types. Mehndiratta et al. (*1999*) researched user preferences for dynamic in-vehicle navigation (IVN) units. Kim and Vandebona, (*1999*) conducted a survey to derive the commuter's needs and preferences in Sydney, Australia. Pagan et al. (*2000)* conducted research to define user desires and preferences for information when traveling in unfamiliar areas.

2.3.4 Information Quality

Previous research has investigated different traveler compliance depending on the quality of ATIS. Fox and Boehm-Davis (*1998*) use a driving simulator to simulate driver compliance as a function of ATIS accuracy. Participants drove through four trials of ten intersections each. Each trial has different level of information accuracy. Chen et al. (*1999*) also investigated the compliance behavior of commuters under different ATIS information strategies. They conducted their simulation using an interactive, dynamic, multiuser, computer-based simulator. Toppen et al. (*2004*) evaluated the effects of ATIS accuracy and the extent of ATIS roadway instrumentation using HOWLATE.

2.3.5 Value of ATIS

The monetary value of ATIS benefits is hard to estimate. Investigating user willingness to pay is a promising method for estimating the value of ATIS. Recent research efforts that have investigated willingness to pay include Polydoropoulou et al. (*1997*), Kim and Vandebona (*1999*), Wolinetz et al. (*2001*), and Harder et al. (*2005*). Each of these investigations attempted to quantify travelers' willingness to pay for ATIS information. Results from this body of research reveal varying values levels for traveler information. The values imputed to traveler information depend on travel purpose, general user attitude toward traveler information, and prevailing traffic conditions.

CHAPTER 3. EVALUATION TOOL ASSESSMENT

3.1 Functional Requirement Evaluation for ATIS evaluation Tools

3.1.1 ATIS Tools evaluated

Recent ATIS evaluation tools were reviewed in the literature review task. IDAS is a popular evaluation tool for ATIS sketch planning and has been used in several states. DYNASMART-P and DynaMIT both have capabilities to simulate various situations including recurring and non-recurring congestion and to evaluate the network effects of various ATIS options under the simulated traffic condition by virtue of their embedded dynamic assignment and traffic simulation models. However, DYNASMART-P is more readily deployable than DynaMIT because DYNASMART-P is implemented in the Microsoft Windows environment while DynaMIT is implemented in the UNIX operating system. The INTEGRATION mesoscopic simulation program has also been used as an ATIS evaluation tool. Recently driving simulation tools including HOWLATE and OTESP have been introduced as a substitute method of field operation tests. However these implementations were site specific and not adaptable to the current research.

Accordingly, IDAS, DYNASMART-P, and INTEGRATION were selected as the candidate ATIS evaluation tools for the current research. In addition, the IMAP evaluation tool (more specifically, the FREEVAL freeway facility modeling tool) previously developed for NCDOT and the VISSIM microsimulation program were also included in the candidates list of ATIS evaluation tools. The IMAP evaluation tool was developed as an incident management planning tool for North Carolina using the FREEVAL tool to provide network flow modeling. FREEVAL has potential capabilities as an ATIS evaluation tool. VISSIM is a popular microsimulation program that can be used to assess ATIS options in network models by applying its dynamic assignment feature in conjunction with a scripting tool to define the functionality of simple ATIS implementations.

3.1.2 Evaluation Criteria

Evaluation criteria were defined in terms of ATIS functional requirements. Sixteen primary criteria plus sub criteria are shown in Table 3-1. Criteria 1 through 8 assess the tools' functional capabilities. Criteria 9 to 11 relate to data acquisition and use. Criteria 12 to 15 evaluate the tools' ease of use. Finally Criteria 16 evaluates each tools' robustness.

The evaluation grading scale is zero (0) to four (4) as follows:

0: tool does not meet criterion

4: tool fully meets the criterion

1, 2 or 3: degree to which tool meets criterion

The total score for each tool is shown in the last row of Table 3-1. The scores for each criterion and sub-criterion were simply added together. Specific weighting factors were not assigned. Therefore, each sub-criterion carried equal weight.

3.1.3 Evaluation Results (ratings by team members)

As shown in Table 3-1., DYNASMART-P received the highest grade (77), and Integration (58), IDAS (53) were second and third, respectively. IMAP (FREEVAL) and VISSIM received two grades, one for current or off-the-shelf capabilities and one for extended capabilities. IMAP received a total score of 43 for current capabilities and 80 for extended capabilities after anticipated program extensions. VISSIM received a score of 36 for its off-the-shelf capabilities and 61 for extended capabilities through API programming.

According to functional requirement evaluation, DYNASMART-P, IDAS, and extended IMAP were judged to be the appropriate ATIS candidate evaluation tools for further consideration. As mentioned above, DYNASMART-P was the highest scoring alternative as an ATIS evaluation tool. It has robust ATIS evaluation capabilities and is also relatively easy to use by virtue of the ability to transfer network model input data from other programs, such as TransCAD. IDAS provides sketch planning evaluation for various ATIS options but it does not have capability to model ATIS-induced traveler responses, such as route diversion, mode shift, departure time shift, and destination choice shift. Although the current version of IMAP does not include ATIS evaluation capabilities, the project team recognized the ability to provide this functionality through program modification and extension via the FREEVAL freeway facilities model.

Table 3-1 Functional Requirements for ATIS tools

CRITERIA (0 to 4 reflecting relative value)		DISCUSSION	IDAS	DYNASMART-P	INTEGRATION	IMAP		VISSIM	
						Existing	Extension	Existing	API
1	Ability to cover broad geographical area	What tool covers: point, facility, corridor or network	4	4	4	2	3	4	4
2	Ability to incorporate multiple travel modes	Minimum car pool and transit options	4	3	3	0	1	4	4
3	Ability to incorporate the effects of various ATIS components such as:								
	-pre-trip information	Pre-trip affects departure time and mode, in-vehicle affects route choice so does en-route (CMS)	4	4	4	1	2	0	2
	-in vehicle information		4	3	0	0	3	0	2
	-en-route information		4	3	0	2	3	0	3
4	Ability to EXPLICITLY model ATIS technologies								
	-Internet, 511, TV/Radio, PDA, Kiosks (pre-trip)	Some tools just 'emulate' the effect of technologies, others may be more explicit	2	2	2	1	3	0	1
	-In Vehicle, 511, Radio, PDA, CMS		2	3	3	0	3	0	1
	-Other: Parking Management; ETC; Tourist Information System.)		2	0	0	0	2	0	1
5	Ability to model the effect of ATIS under BOTH recurring and non-recurring congestion	ATIS provide max value during incidents work zones, evacuations, etc.	2	4	3	3	3	0	2
6	Ability to model various traveler responses to ATIS, including:								
	-pre-trip route diversion	This criterion looks at the diversity in the travelers' response that the tool can accommodate.	0	4	3	2	3	0	0
	-pre-trip mode shift		0	0	0	0	1	0	0
	-en-route route diversion		0	3	2	0	3	0	4
	-en-route modal shift		0	1	0	0	1	0	0
	-departure time shift		0	2	0	0	2	0	2
	-destination choice shift		0	1	0	0	2	0	2
	-induced demand		0	0	0	0	2	0	2
	-foregone trip		0	0	0	0	3	0	2

CRITERIA (0 to 4 reflecting relative value)		DISCUSSION	IDAS	DYNASMART-P	INTEGRATION	IMAP		VISSIM	
						Existing	Extension	Existing	API
7	Ability to generate benefit-related statistics from ATIS deployment, such as:								
	-reduction in network travel time or delays	These are critical since the benefit would be calculated as the difference in system performance with and without ATIS presence	4	4	4	3	4	4	4
	-reduction in network VMT		0	3	4	0	4	4	4
	-reduction in queue lengths		0	4	4	1	3	4	4
	-revision to modal split, including car-pool		0	0	0	0	1	0	0
	-reduction in crashes		0	0	0	0	2	0	0
8	Ability to model the impact of market penetration of the technologies to be assessed	e.g., is the tool sensitive if CMS are deployed every 10 versus 50 miles?	3	4	3	4	3	1	2
9	Tool is autonomous or requires interface with other tools?	e.g., IDAS requires interface with TDM output	0	4	2	4	4	4	4
10	Amount and availability of local data to execute the ATIS assessment tool, including the availability of defaults	How 'data-hungry' is the tool, are defaults readily available, how much it will cost to provide local data?	3	3	4	3	3	2	2
11	Ability to transfer input data from other tools and data post-processing requirements	Data management issue	4	4	2	2	2	3	3
12	Availability of tech support, adequate documentation.	Long-term usability of the tool	4	3	2	3	3	2	2
13	Ease of use and training	Data preparation, run time	3	3	2	3	3	2	2
14	Track record on the use of the tool, including	Have there been similar applications	4	3	3	4	3	0	0
15	Previous successful applications to NC for that specific tool?		0	3	2	4	4	0	0
16	Robustness	Traffic flow model, Theoretical base	0	2	2	1	1	2	2
	TOTAL SCORE BY EACH TOOL (MAX= 124 POINTS)		**53**	**77**	**58**	**43**	**80**	**36**	**61**

3.2 Preliminary Case Study for Assessment of ATIS Evaluation Tool

The purpose of the simple case study was to investigate the functional capabilities and limitations of candidate ATIS evaluation tools under a realistic evaluation for an actual network. As detailed above IDAS, DYNASMART-P, and NCDOT's IMAP tool were selected as candidate evaluation tools based on the literature review (Chapter 2) and functional requirements evaluation (section 3.1).

Identical traffic network data were assembled for the three tools. DYNASMART-P and IDAS have the capability to import network data; IMAP does not. The extracted dual route network (main road and diversion route) were used for building the IMAP network.

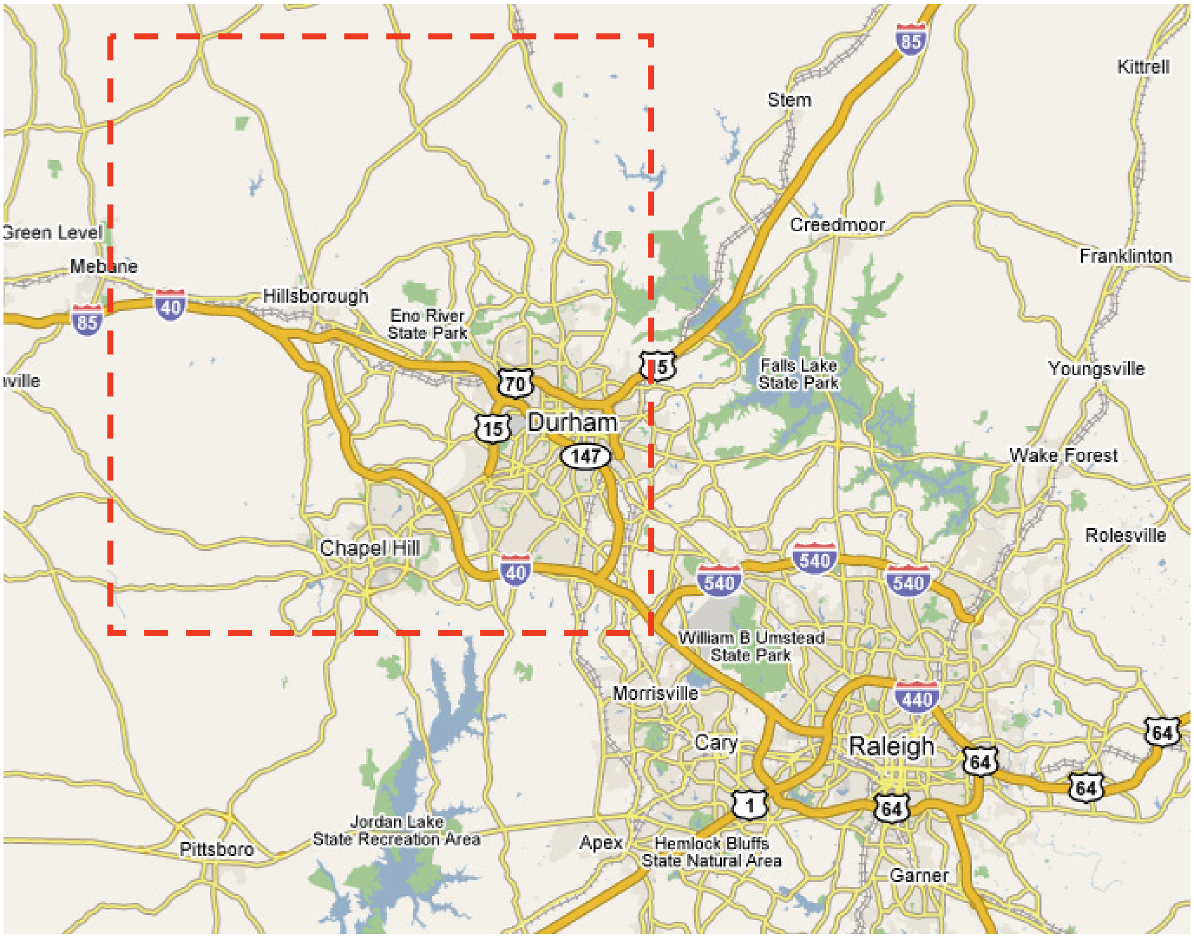
It was difficult to evaluate the same ATIS options in the same situation because the three tools have very different ATIS evaluation capabilities. For example, DYNASMART-P and IMAP can estimate ATIS impacts under specific incident situations while IDAS cannot. Therefore, the case study analysis is focused on the functional capabilities and limitations of each tool.

3.2.1 Study Area

Through ITRE, the project team has access to the Triangle Area travel demand model. The model is developed in TransCAD. The model includes a large network with approximately 3,000 zones. DYNASMART-P is not recommended for application to a network this large because of memory and computational time requirements. Therefore, a sub-network area was defined. The sub-network area data were extracted directly from the overall network data. The sub-network for the preliminary case study consists of 758 zones, 3460 nodes, and 8562 links. Four-hour AM peak origin-destination demands were used for the analysis.

The dotted rectangle in Figure 3.1 illustrates the sub-network area extracted from the Triangle Area model. This sub-network was selected because I-40 and I-85 represent viable, complementary alternative routes for each other. If one of the routes has a serious incident or congestion, drivers may choose the other route to traverse the study area. Therefore, a goal of ATIS in the study area would be to facilitate near optimal diversion behavior under incident conditions.

The work to extract the sub-network encountered challenges in data transfer from TransCAD. Specifically, the IDAS program requires a continuous zonal centroid numbering system, and DYNASMART-P requires manually changing external node generated by the extraction procedure into an appropriate zone number for properly modeling the origin-destination flows.



Map Source: Google map (http://maps.google.com)

Figure 3.1 Study Area

3.2.2 IDAS Case study

3.2.2.1 IDAS

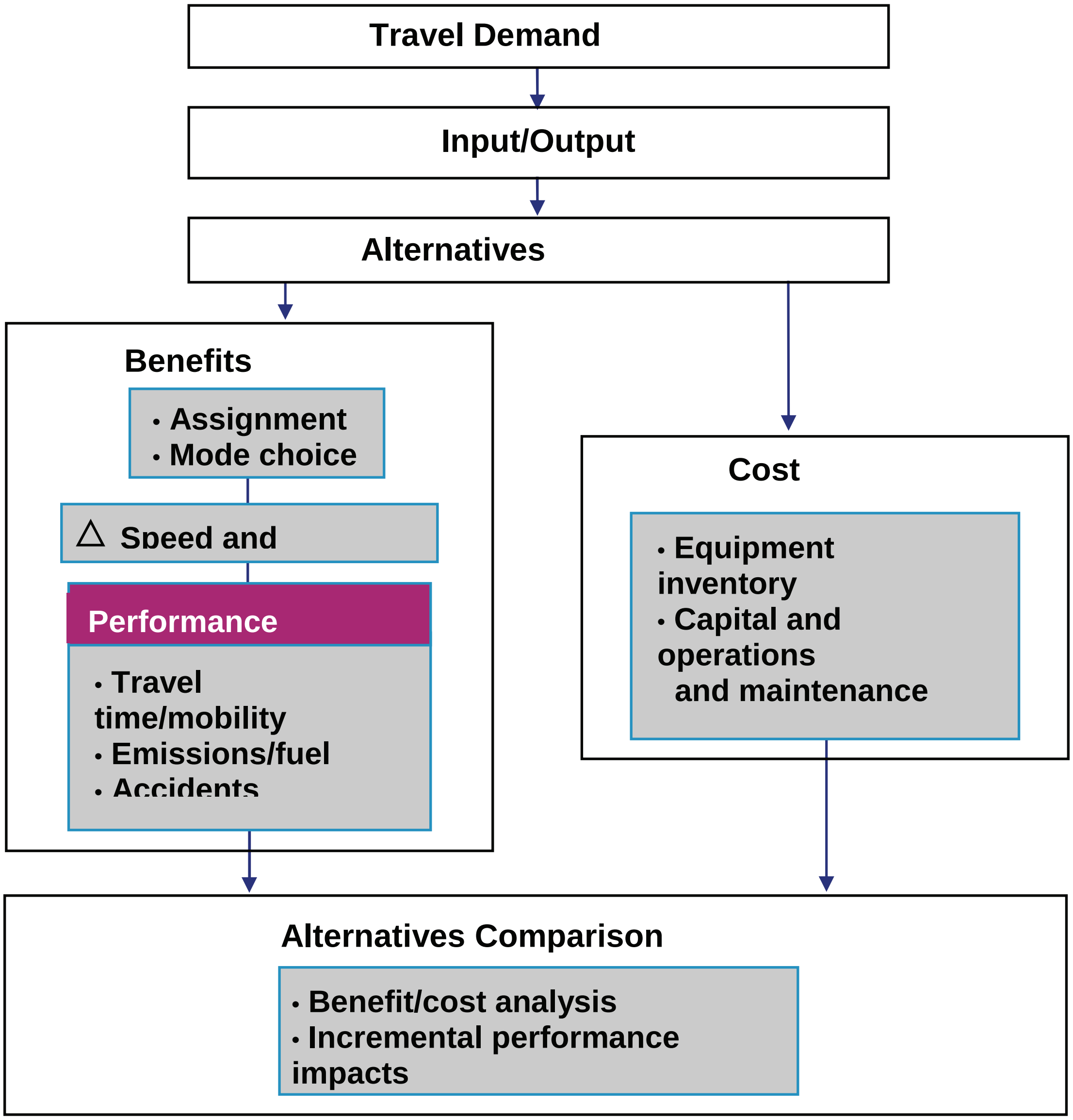
IDAS is an assessment tool for ITS benefit and cost impacts. It provides an evaluation method for most of the ITS deployment options defined in the National ITS Architecture. IDAS includes a cost database for ITS deployments provided by the ITS JPO. The ITS JPO provides ongoing updates to the cost database, and the IDAS program can easily upload the database updates. However, the IDAS analysis methods are at a sketch planning level and are based on an extensive list of assumptions, especially for the ATIS deployment options. IDAS does not measure actual ATIS effects on the real network. Rather, it uses simple multiplicative relationships to estimate ATIS benefits. For that reason, although IDAS may be quite appropriate for sketch planning, it is not appropriate for project level analysis where detailed modeling of network operations are desired or required.

Figure 3.2 shows the overall structure of IDAS. Node, zone, network, and demand data are mandatory input data for IDAS. User can make input data by manually in certain spread sheet program but usually, traditional travel demand model output become major source for preparing IDAS input data. After building a baseline network through the input data, alternatives which have different ITS deployment plans are defined at ITS option panel in IDAS.

IDAS has internal mode choice and traffic assignment steps. IDAS runs these two steps for all alternatives, including a control alternative (baseline network) and then generates comparisons between the alternatives. The differences in network performance such as link speed and volume are used for benefit calculation in terms of travel time/mobility, emissions/fuel, accidents, or travel time reliability.

Costs for the alternatives are calculated based on required equipment costs, capital and operations and maintenance (O & M) costs, and life-cycle costs. As mentioned above, the cost database is stored in IDAS and is easily updated. Furthermore, users can make specific modifications to the database according to local project needs and conditions.

The final step in an IDAS analysis (alternatives comparison) gives the annual benefit, B/C ratio, and net benefit for each alternative. Additionally, this step provides estimates of incremental performance impacts, risk analysis, and performance summary reports. User can use these reports for decision support including sensitivity analysis.



Source: IDAS user's mannual

Figure 3.2 Overall structure of IDAS

IDAS can evaluate eleven ATIS types:

1. Highway Advisory Radio;
2. Freeway Dynamic Message Sign;
3. Transit Dynamic Message Sign;
4. Telephone-Based Multimodal Traveler Information System;
5. Web/Internet-Based Multimodal Traveler Information System;

6. Kiosk with Transit-only Traveler Information;
7. Kiosk with Multimodal Traveler Information;
8. Handheld Personal Device – Traveler Information Only;
9. Handheld Personal Device – Traveler Information with Centralized Route Guidance;
10. In-Vehicle – Traveler Information Only; and
11. In-Vehicle – Traveler Information with Centralized Route Guidance.

The benefit calculation step for ATIS options is different than it is for the other ITS options. According to the IDAS overall framework, benefits are estimated from the differences in network performance after running the mode choice and traffic assignment steps (IDAS Postprocessor). However, deployment of ATIS options does not result in differences in network performance because travelers do not change their original travel plans even in the presence of traveler information. Therefore, IDAS estimates general ATIS benefits on network by using simple factors without modeling the network impacts.

IDAS includes a database of system impacts and costs related to each type of deployment. The database provides default values collected from other research. Users can view and edit most of the default values if better local information is available. Important default parameters for ATIS options are –

- Penetration rate (usage rate)
- Percent vehicle getting information that save time
- Percent time that extreme traffic conditions are occurring
- Average time savings of the vehicle has information

Advantages and disadvantages of IDAS are discussed in several published assessments. Kristof and et al. (2005) suggested IDAS as the best alternative of ATIS evaluation tool for Washington State, specifically citing the following advantages –

- **Sponsored by USDOT –**Consequently, research and development is assured to continue. The definitions and concepts found in IDAS conform to the National ITS Architecture, and the output meets the requirements of the U.S. DOT's ITS Evaluation Guidelines and other federal requirements, such as those of the Environmental Protection Agency.
- **Progressive software –** The IDAS program will continue to advance through the release of updated versions, and the methodologies are sure to be improved according to the latest research. The development of IDAS is supported by the ITS Benefits and Costs Database, which is maintained by the ITS Joint Program Office.
- **Inexpensive software –** The latest version of IDAS can be purchased from McTrans Software Center at the University of Florida for $795.
- **User friendly –** IDAS runs in a Windows environment with click and drag capabilities. The various application modules are straightforward and easily managed.
- **Uses data that are readily available –** The input for IDAS are travel demand data (including a link-node network), ITS deployment data, and a set of assumptions for the evaluation. (Default values are given for all the assumptions, but the software developers recommend the use of values based on local conditions.)
- **Compatible with the leading travel demand forecasting models –** IDAS operates as a post-processor to a travel demand forecasting model. It is readily compatible with TRANPLAN, EMME/2, MINUTP, TransCAD and other packages.
- **Evaluates other ITS components –** IDAS can analyze the benefits of 69 ITS treatments, 11 of which are information-based components. It can also analyze a user-defined "generic" component.

Cheng and Demetsky (2001) also mentioned similar advantages to those mentioned above and concluded IDAS is an inexpensive but efficient tool to help planners get a general idea of the performance of each alternative as a sketch planning tool.

However, the research of Yun and Park (2003) discovered the disadvantage of IDAS. They pointed out following needs of IDAS –

- Elaborating ITS impact methodologies,
- Upgrading default values in the cost and benefit modules, and
- Incorporating emission factors based on MOBILE 6.

Furthermore, relying on case studies of Hampton Roads area and a simple network with six popular ITS options, they identified the following three issues –

- Overestimation of ITS option benefits when the benefits are estimated from travel time savings,
- Incorrect interpolation on travel time reliability rates for non-integer V/C ratios, and
- Insensitive cost savings for combined ITS options

3.2.2.2 Network Data Preparation

IDAS uses the data imported from other traffic demand models. IDAS requires specific formats for the input data. After generating the original data file using data export feature in TransCAD, additional editing work is required and can be carried out using Microsoft Excel. The input data are –

- Analysis network – extracted from a travel demand model if possible
    - Node coordinates
    - Link characteristics
    - Turn prohibitor (optional)
    - Origin-destination (O-D) number of trips
    - Zone-to-zone travel times (optional for in-vehicle auto trips)
- User modifications to default parameters, impacts, and costs – No changes were made for the preliminary case study.
    - Speed-flow curves
    - Rates (related to emissions, fuel, and safety)
    - Impacts of ITS options
    - Dollar values of benefits
    - Unit costs of equipments

3.2.2.3 ITS Option Deployment

IDAS can evaluate 11 ATIS options. The user's guide explains in detail how IDAS estimates the benefits of these options. The ATIS options have a similar methodology for calculating benefits. ATIS options do not change the traffic network performance. ATIS benefits are estimated based on simple multiplicative factors. In this case study, all default parameters in IDAS were left unchanged.

Two ATIS options were selected for testing:

- Case 1: One VMS is deployed in I-40 (shown in Figure 3.3), the link from node 2869 to node 2945 in IDAS.
- Case 2: One HAR is deployed in same location with VMS

The link chosen for installing VMS or HAR is the same as was chosen for the DYNASMART-P case study.

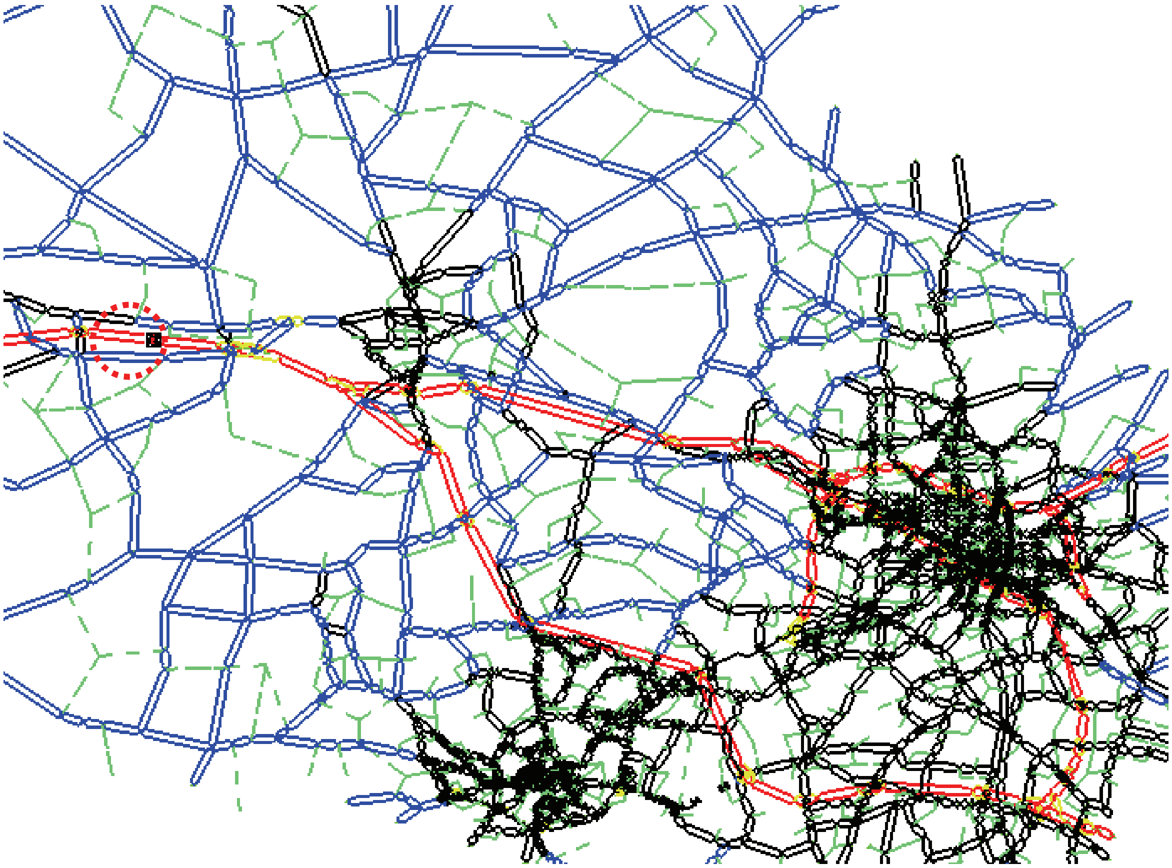


Figure Source: ITS option panel in IDAS

Figure 3.3 The location for ATIS options

3.2.2.4 Validation

IDAS has own postprocessor (mode choice and traffic assignment module). IDAS assignment results should be similar to the assignment results for the corresponding travel demand model. The IDAS developers suggest that users validate the network assignment results before using the benefit estimation results.

Performance summaries and link flow data are useful information for validating the IDAS assignment results. As Table 3-2 shows, IDAS did provide similar assignment results when compared to the TransCAD assignment for this case study.

Table 3-2 Comparison of performance summary

	Input data (TransCAD)	IDAS
Total Vehicle Miles of Travel (VMT)	3,495,140	3,667,654
Total Vehicle Hours of Travel (VHT)	102,646	111,004
Average Speed (mph)	29.85	33

3.2.2.5 Benefit/Cost analysis results

Case 1. VMS installation in 2869 to 2945 link

The VMS Benefit estimation method presented in IDAS user guide is:

Travel time savings (person–hours) = [Traffic volume in DMS-equipped link] × [percent time sign is turned on] × [percent vehicles passing sign that save time] × [average amount of time savings in hours]

Benefits = Travel time savings × 3 × the standard value of time in IDAS × Number of periods per year

(The reason given for multiplying by 3 is that DMSs are most effective under non-recurring congestion conditions and any delay incurred under such conditions is unexpected and, thus, more “expensive” than normal traffic delay.)

The assigned traffic volume on the link from node 2869 to 2945 was 12,248. IDAS default values were applied for the other variables. Therefore, the benefit of VMS in this link can be calculated as shown in below, and the manually calculated result is very close to the IDAS results shown in Figure 3.4.

Travel time savings (per unit time)=12,248 × 0.1 × 0.28 × 11/60=62.87 person–hours

Annual benefits = 62.87 × 3 ×$ 9.63 × **247**= $ 448,651

cf. **247**: number of periods per year

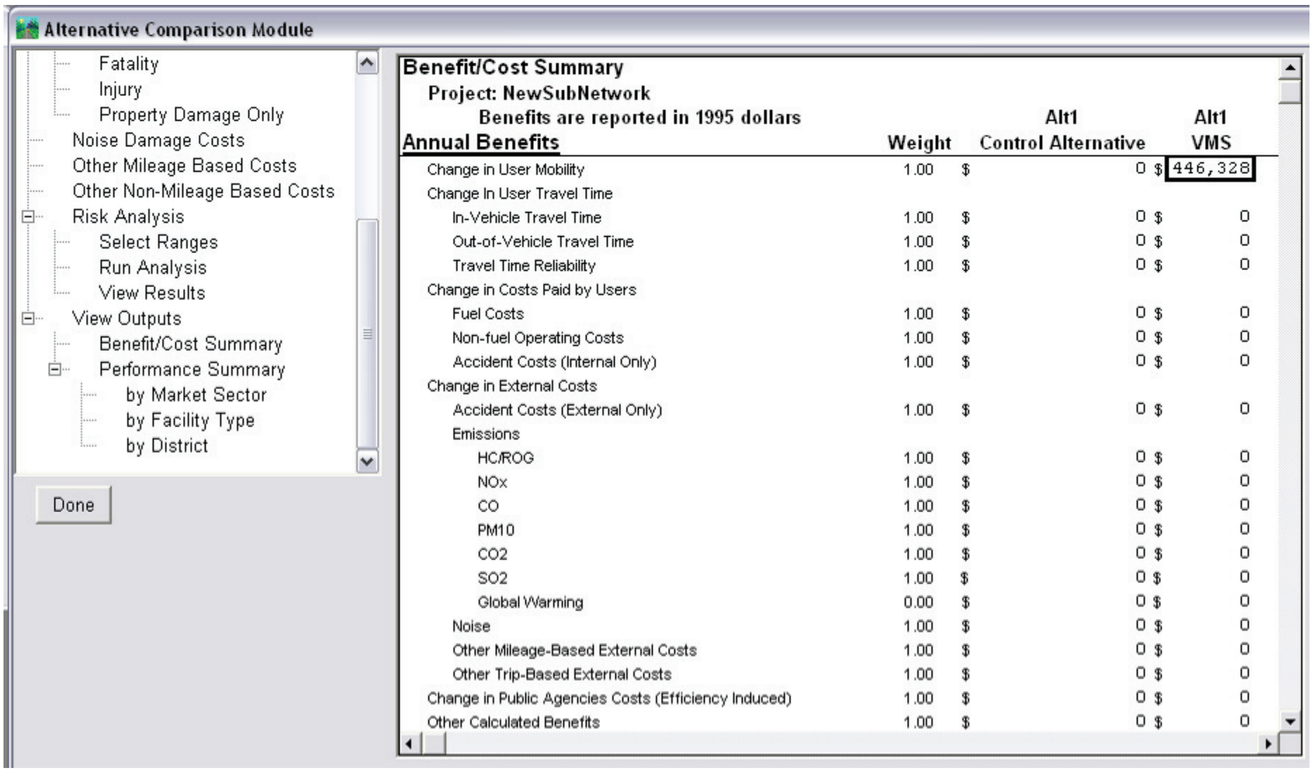


Figure 3.4 Benefit/cost summary of VMS

Case 2. HAR in 2869 to 2945 link

The HAR benefit estimation method is also presented in IDAS user guide, and it is very similar to the DMS method.

Travel time savings (person–hours) = [Traffic volume in HAR-equipped link] × [HAR usage percentage] × [percent time that extreme conditions are occurring] × [HAR usefulness percent] × [average amount of time savings in hours]

Benefits = Travel time savings × 3 × the standard value of time in IDAS× Number of periods per year

If traffic volume in the link and the IDAS default values are substituted into the formula above, the benefit of HAR in this link can be calculated as shown below, and once again, the manually calculated result is very close to the IDAS results shown in Figure 3.5.

Travel time savings=12248 × 0.05 × 0.1 × 0.25 × 4/60=1.0206 person–hours

Annual benefits = 1.0206 × 3 × $ 9.63 × 247= $ 7283.30

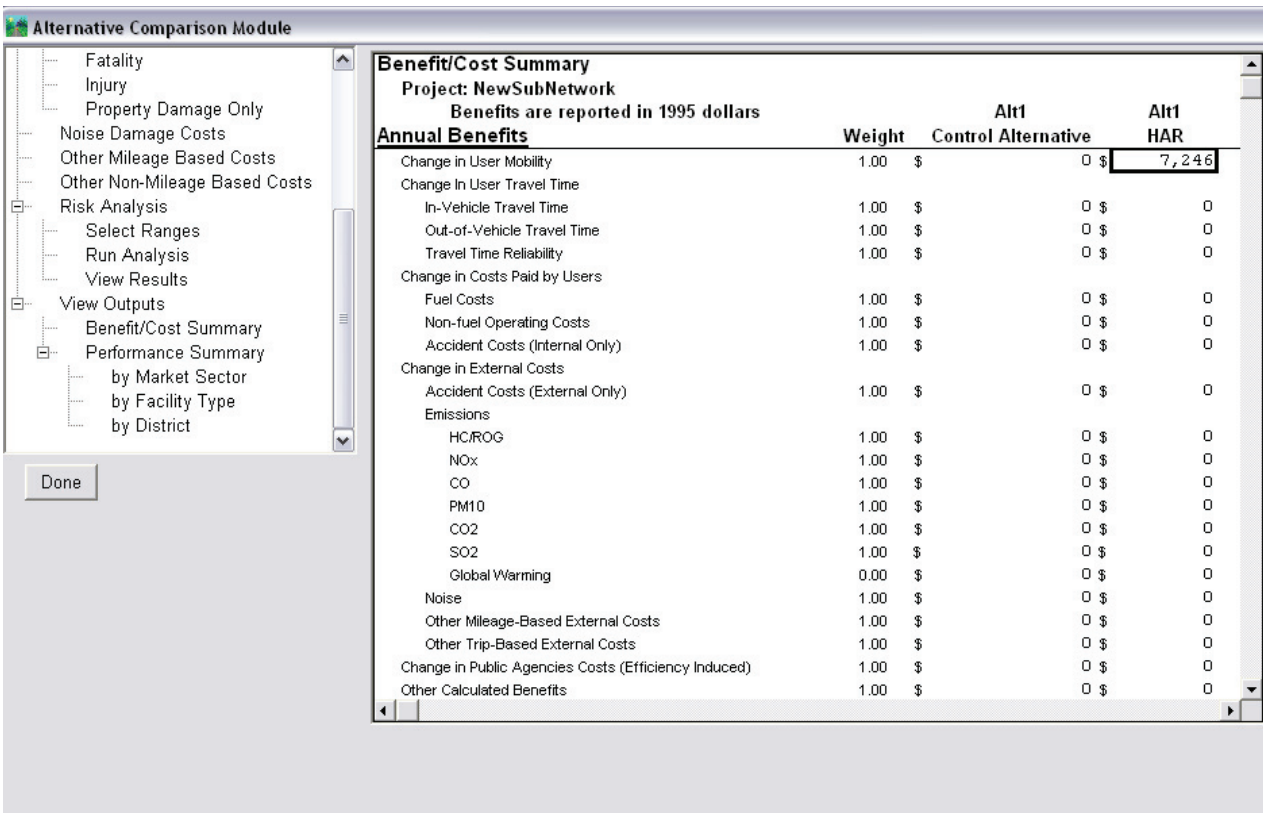


Figure 3.5 Benefit/cost summary of HAR

3.2.2.6 Results

IDAS can evaluate most of ITS options described in National ITS Architecture. The benefits of 11 ATIS options are included in the IDAS evaluation option. Additionally, the required network preparation and assignment validation are not especially difficult.

Furthermore, IDAS produces B/C ratios and net benefits in a benefit/cost summary report. However, previous research has indicated that the benefit can be overestimated. However, the primary limitation of ATIS benefit estimation is that the method does not model the traveler's response to ATIS (e.g., route diversion, or departure time shift). IDAS estimates ATIS benefits based on simple formulas. In fact, the ATIS benefit estimation function in IDAS is essentially identical to the estimation carried out by the SCRITS spreadsheet evaluation tool.

3.2.3 DYNASMART-P Case Study

3.2.3.1 DYNASMART-P

DYNASMART-P (Dynamic Network Assignment Simulation Model for Advanced Road Telematics for Planning Applications) integrates two classes of tools: network assignment models and traffic simulation models. Through these two models, DYNASMART-P can be used to model and evaluate problems which have traffic operation and transportation planning characteristics. Therefore, DYNASMART-P is the right tool for an area if:

- Planning decisions require realistic traffic representation
- Planning decisions encompass measures that have an operational element, e.g. work zone management, or ITS deployment, such as VMS locations, evaluation of information strategies, HOV/HOT deployment
- Need closer interaction between traffic engineers and planners, and more efficient sharing of both planning and traffic data
- Need to consider corridor and network effects in evaluating traffic improvements

Therefore, DYNASMART-P can be widely applied to various network operations and planning decisions, including:

- Assessing infrastructure investments (signals, HOV/HOT lanes, etc…)

- Determining network congestion pricing schemes
- Evaluating ITS deployment alternatives and their geographic coverage (VMS locations, information strategies, etc…)
- Verifying incentive strategies (increase night and weekend work shift) for work zone management
- Planning transit/bus routes or services
- Air quality conformity analysis

Figure 3.6 shows the framework of DYNASMART-P. The required input data are time-dependent OD matrices and network data. DYNASMART-P consists of traffic simulator, path processing, and user decisions components.

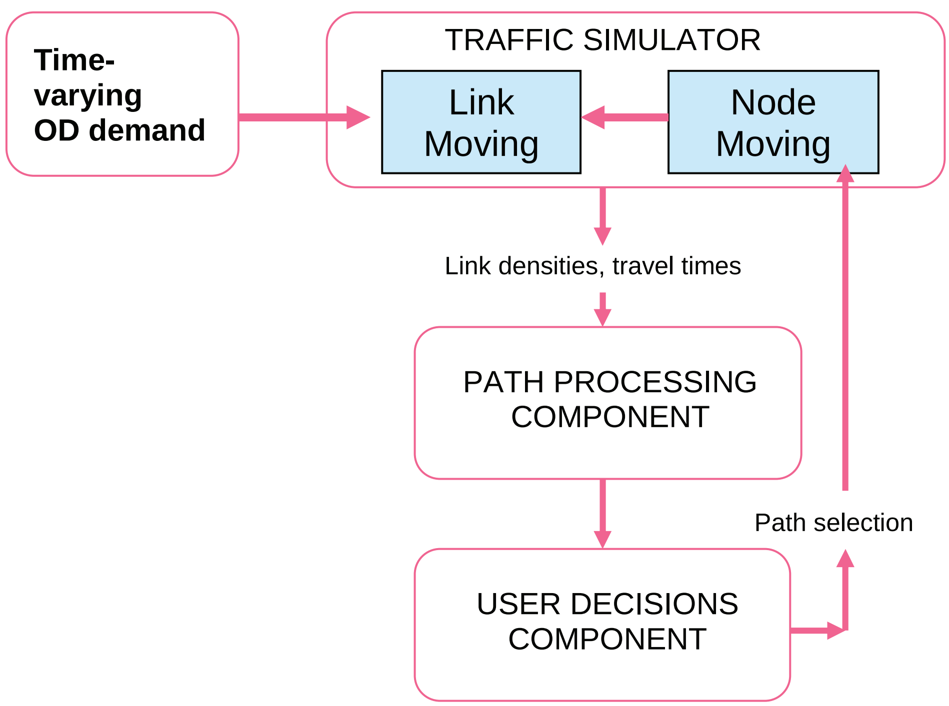


Figure 3.6 Basic Framework of DYNASMART-P Model

DYNASMART-P applies an efficient hybrid traffic simulation approach, which models individual vehicles according to robust macroscopic traffic flow relations (mesoscopic). Through the traffic simulation models, DYNASMART-P can capture traffic flow phenomena such as congestion build-up and dissipation. The traffic simulation component has two major modules: link movement and node transfer. Network's links are subdivided into smaller sections for simulation purposes. The link movement module calculates inflow, outflow, the vehicle concentration from the solution of the finite difference form of the continuum model, and estimate speed according to a speed-density relationship. The node transfer module performs the link to link transfer of vehicles at each node. It determines the number of vehicles that are traversing each intersection in the network at each simulation time step as well as the number of vehicles entering and exiting the network according to the control strategy at the node. It represents traffic processes at signalized junctions, under a variety of operational controls (critical for urban congestion and ITS).

The path processing component determines the route-level attributes (e.g. travel time) for use in the user behavior component from the given the link-level attributes obtained from the simulator. A multiple user class K-shortest path algorithm model is used for calculated K different paths for every origin-destination pair.

The user behavior component models traveler's route-choice decision. It applies micro-simulation of individual trip-maker decisions, particularly route, departure time and mode, including user responses to varying types of information. Iterative algorithms are used for the computation of mutually consistent flow patterns and user decisions, e.g. time varying user equilibrium where applicable.

DYNASMART-P represents multiple user classes in terms of (1) operational performance (e.g. trucks, buses, and passenger cars), (2) information availability and type, and (3) user behavior rules and response to information. The capability selection panel in Figure 3.7 allows users to define a combination of user classes.

Multiple user information classes in DYNASMART-P are defined broadly into three groups for ATIS application. The unresponsive user class can be further divided into two groups, distinguishing between who has pre-trip information or not traveler information. This characteristic determines whether the users use the path file or not when they select their travel route. Vehicles that receive real-time en-route information via in-vehicle equipment are allowed to re-route at any intersection. Re-routing is based on the boundedly rational behavior mechanism, namely the fraction of travel time improvement and the time improvement (in minutes) are criteria for route switching decisions. When either of these two criteria exceeds the threshold, the user will switch routes at the next intersection. There are three types of VMS: congestion warning VMS, optional detour VMS, and mandatory detour VMS. The traveler's response rule to VMS is defined based on the selected VMS types. The user classes modeled in DYNASMART-P can be summarized as the following.

- Unresponsive
    - Historical travel info
    - Pre-trip Info
- In-Vehicle Info
    - Update path at each intersection based on prevailing shortest paths
    - No prediction
- VMS Responsive (Could be applied to all users)

- Congestion Warning VMS (multiple routes): alerts travelers of potential downstream congestion, allows the user to switch to better (faster) paths, and provides multiple route switching possibilities
- Optional Detour VMS (two routes): advises travelers of lane closures, and allows all travelers to either keep their original path (through detoured link) or follow pre-specified detour
- Mandatory Detour VMS (single route): advises travelers of lane closures, and mandates all travelers to follow a (user-specified) detour

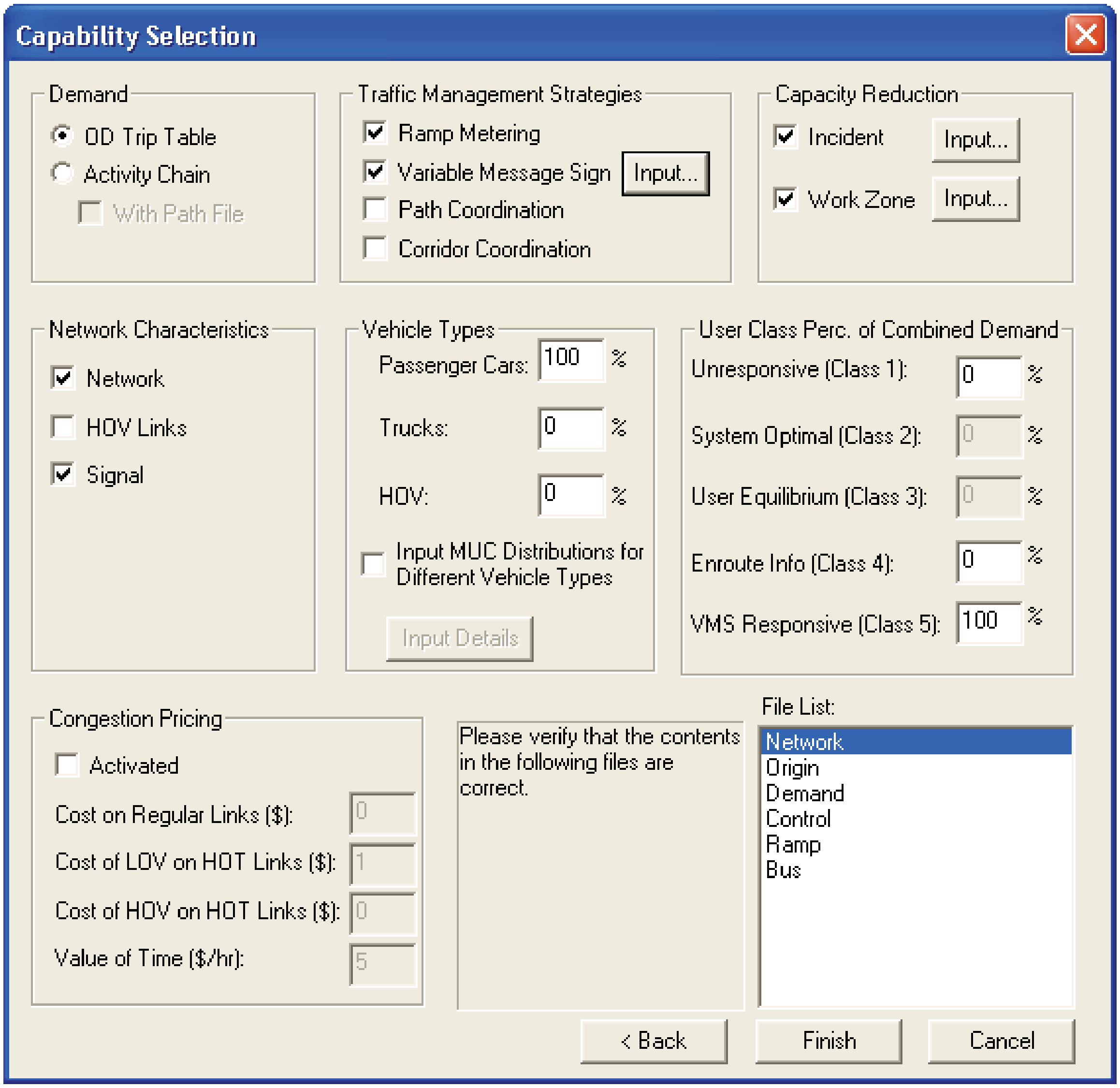


Figure 3.7 Capability selection panel in DYNASMART-P

Network data for DYNASMART-P can be prepared by converting an existing network from TransCAD or CORSIM formats, or by building a new network using the DYNASMART-PED program. Additional network information includes time-dependent O-D demand, signal timing plans, and supplemental link/intersection geometric data. Final inputs include defined ATIS strategy scenarios to be evaluated, user segmentation of different information types, VMS activation times and locations, and non-recurring congestion scenarios (e.g. incident, work zone).

The following output information is generated from a fully specified DYNASMART-P simulation run.

- Facility-level performance measures: Speeds, densities, volumes, occupancies, in/out flows, etc….
- Network-level performance measures (average/total): Trip hours, delay hours, vehicle miles, etc.
- Economic benefit measures: Estimated user operating cost, safety, the environment, energy consumption and noise, etc…
- Alternative evaluation suggestions: Priorities, trade-offs

3.2.3.2 Case Study Set Up

The network used in the DYNASMART-P case study was the same as the one used in the IDAS case study, including the same network zone, node, link, and demand data. 192,000 vehicles were generated during demand horizon of 90 minutes, and total simulation duration was set 4 hours to discharge all vehicles entering the network.

DYNASMART-P offers a wide range of distinct functions compared to IDAS. A key feature is that DYNASMART-P can emulate incidents and evaluate the effect of ATIS under the incident condition. This case study considers an incident that occurs on eastbound I-40. Figure 3.8 illustrates the incident location. A variable message sign (VMS) was located at the split point I-40 with I-85 in order to provide congestion information to travelers before they choose one of two routes. Figure 3.9 shows the incident location and the VMS location defined in DYNASMART-P. The capacity reduction was set at 90% resulting from an incident lasting 45 minutes and beginning 20 minutes after the simulation start time.

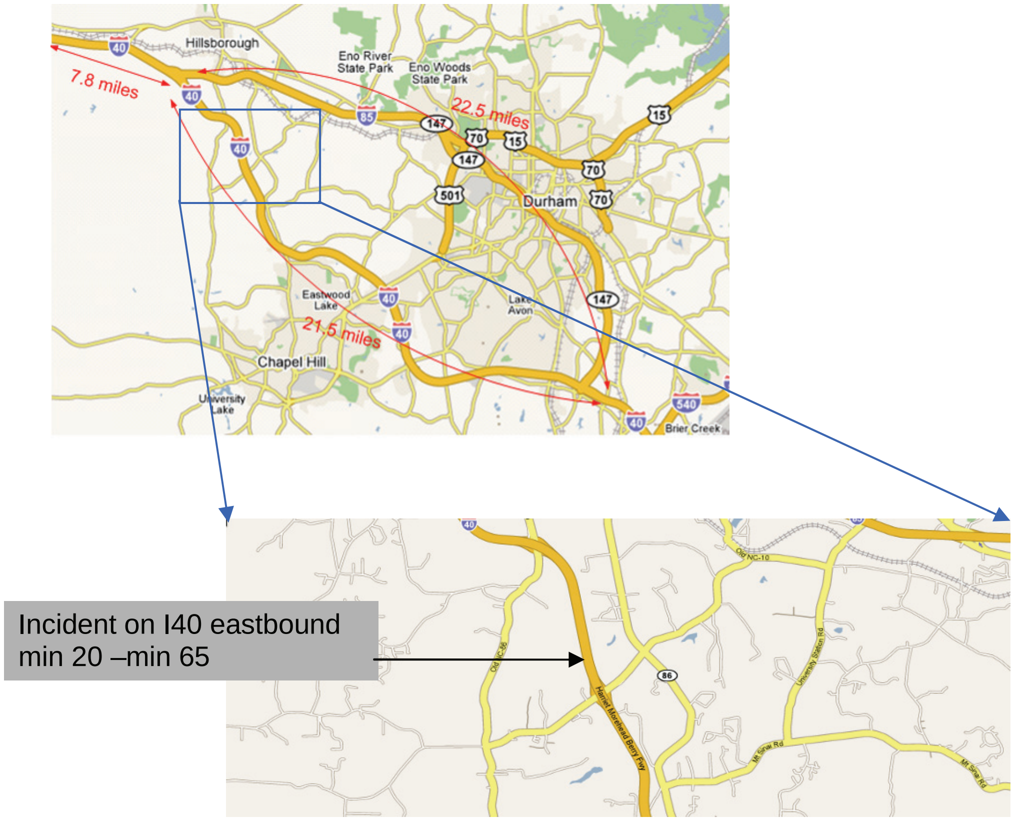


Figure 3.8 Incident location in DYNASMART-P case study

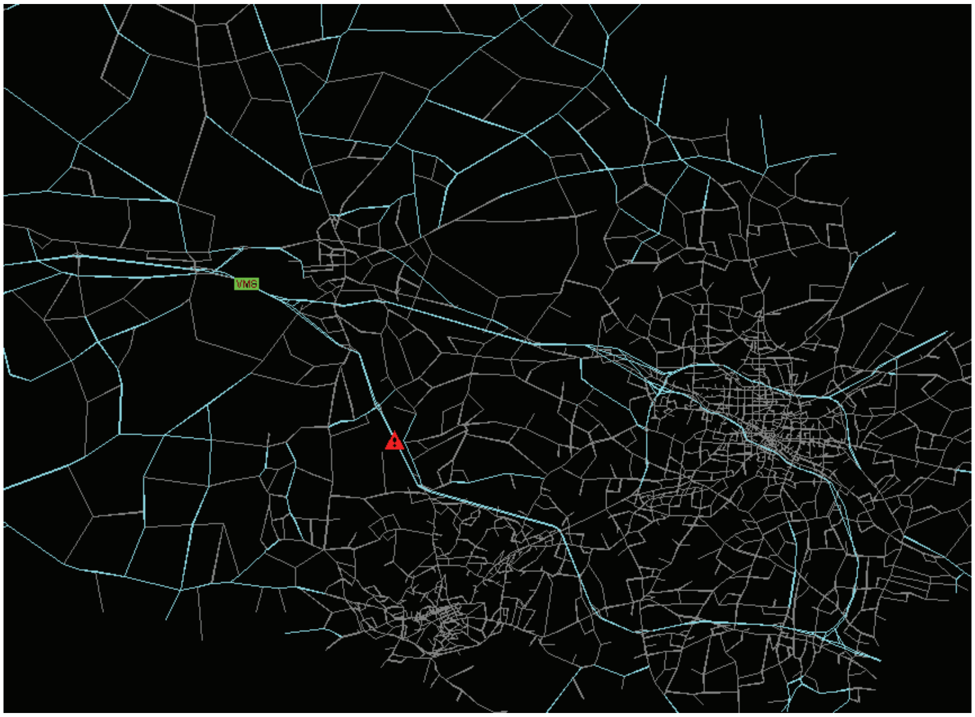


Figure 3.9 VMS location and incident location in DYNASMART-P case study

3.2.3.3 Network Data Preparation

DYNASMART-P requires a large set of input files. However, several tools are provided to help with the preparation of these input files. Because the preliminary cast study network data is available in TransCAD format, DYNABUILDER, a software package for converting networks from GIS network or CORSIM network into DYNASMART-P, offers the best option for preparing the input files.

It should be noted that DYNABUILDER does not import GIS format data directly. For the case study, TransCAD network data was exported to Microsoft Excel format (alternately, users could choose Microsoft Access format). Three tables of TransCAD network data are exported for DYNASMART-P input: the node table, link table, and OD matrix. Figure 3.10 depicted the steps of generating DYNASMART-P input files. After the exporting work is complete, the fields in excel files need to be edited according to the defined order and formats of

DYNABUILDER. After preparing node, link, and zone information, DYNABUILDER generates the input files for DYNASMART-P.

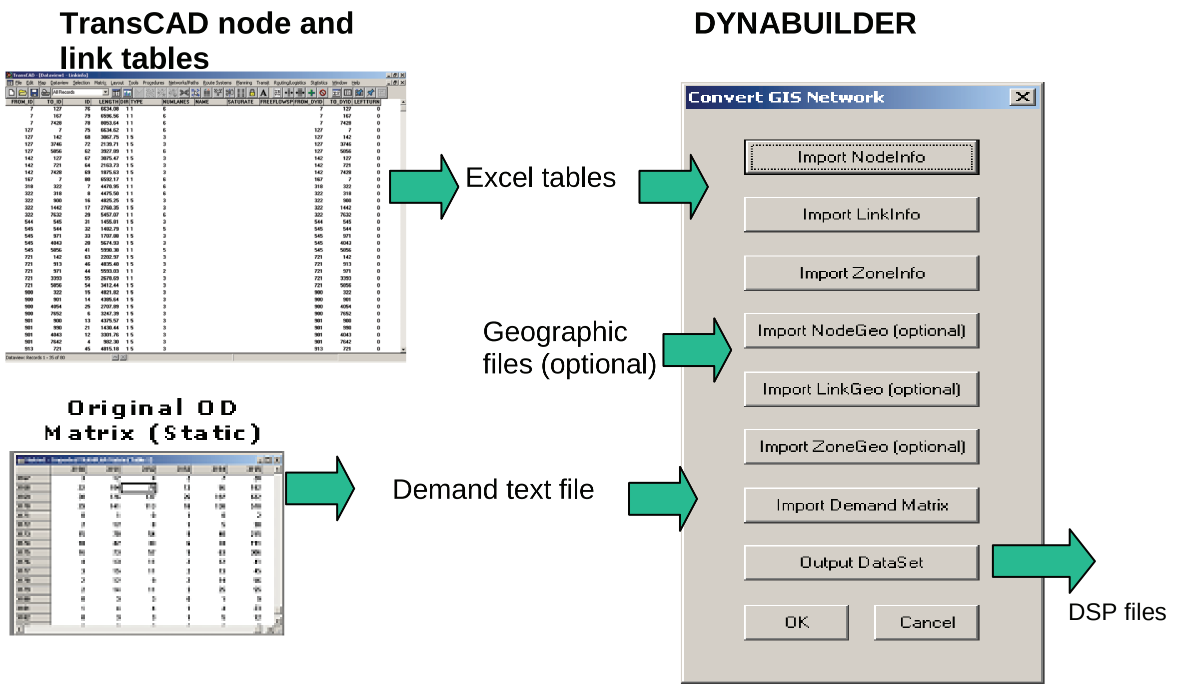


Figure 3.10 Generate DYNASMART-P Input Files

3.2.3.4 ATIS option deployment and effects

The locations of the incident and the VMS were described in section 3.2.3.3. The incident link has 2 lanes and a 90% capacity reduction rate is selected. The 90% capacity reduction means that only 10% link capacity can be used during the incident period. The effect of VMS and in-vehicle information system (IVIS) were examined through the simulation runs.

Experiments of VMS effect

To investigate the impact of VMS on the network performance, six different VMS response rates (0, 10, 15, 25, 30, and 40%) were set and tested. DYNASMART-P provides MOEs (measures of effectiveness) for network-wide and impacted vehicles which pass through incident link (this case study has 3791 impacted vehicles over 90 min). Average travel time in minute is selected as the network-wide MOE. Table 3-3, Figure 3.11, and Figure 3.12 show the summary results as a function of various VMS response rates. Average travel time in terms of overall network is not dramatically changed depending on the underlying VMS response rates. Average travel time of impacted vehicles, on the other hand, is significantly decreased when the VMS response rate is greater than 15%, but remains quite stable for further increased VMS response rates. The results illustrate that the VMS effects are growing until the VMS usage reaches a certain market penetration rate, however, and from that point, increasing market penetration only generates marginal benefits.

Table 3-3 Average Travel Time (min) in various VMS response rate

VMS response rate	Network wide	Impacted vehicle		
		subtotal	Non-diverted	Diverted
0%	11.7975	37.534	37.534	-
10%	12.5559	37.081	37.404	29.225
15%	11.6043	29.316	29.316	27.164
25%	11.596	29.324	29.347	28.117
30%	11.596	29.347	29.347	28.117
40%	11.4442	28.311	28.346	25.755

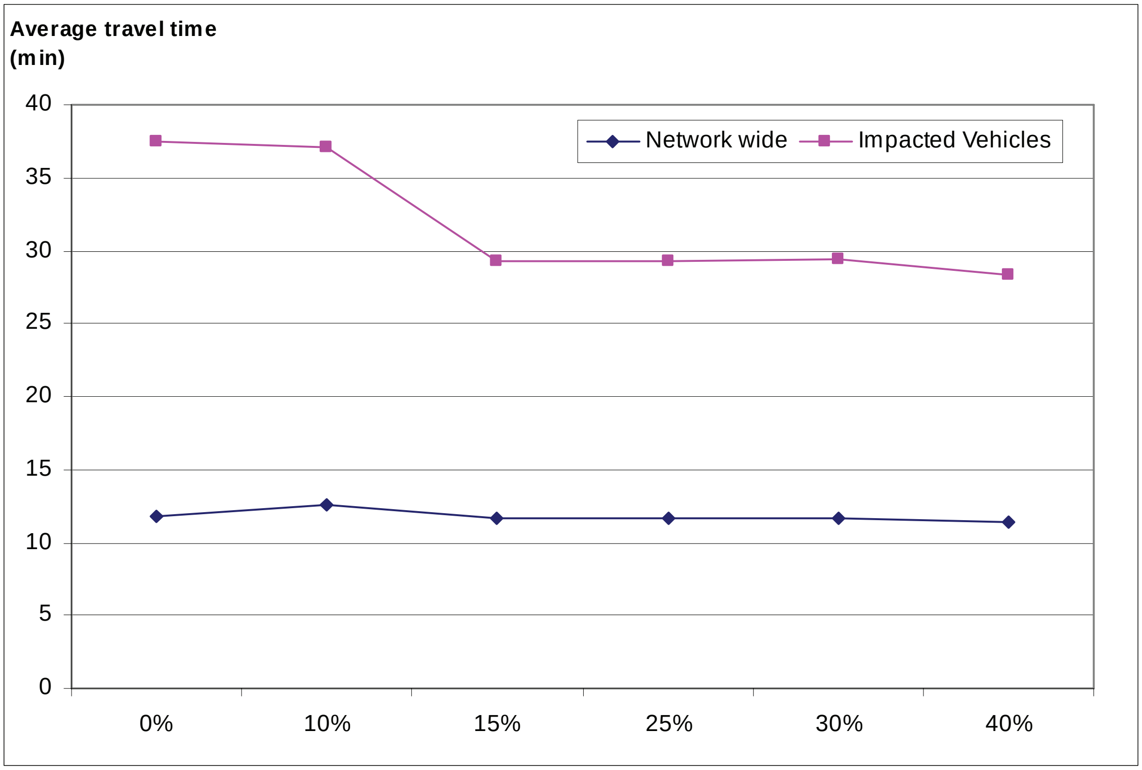


Figure 3.11 The average travel time on various VMS responsive rate

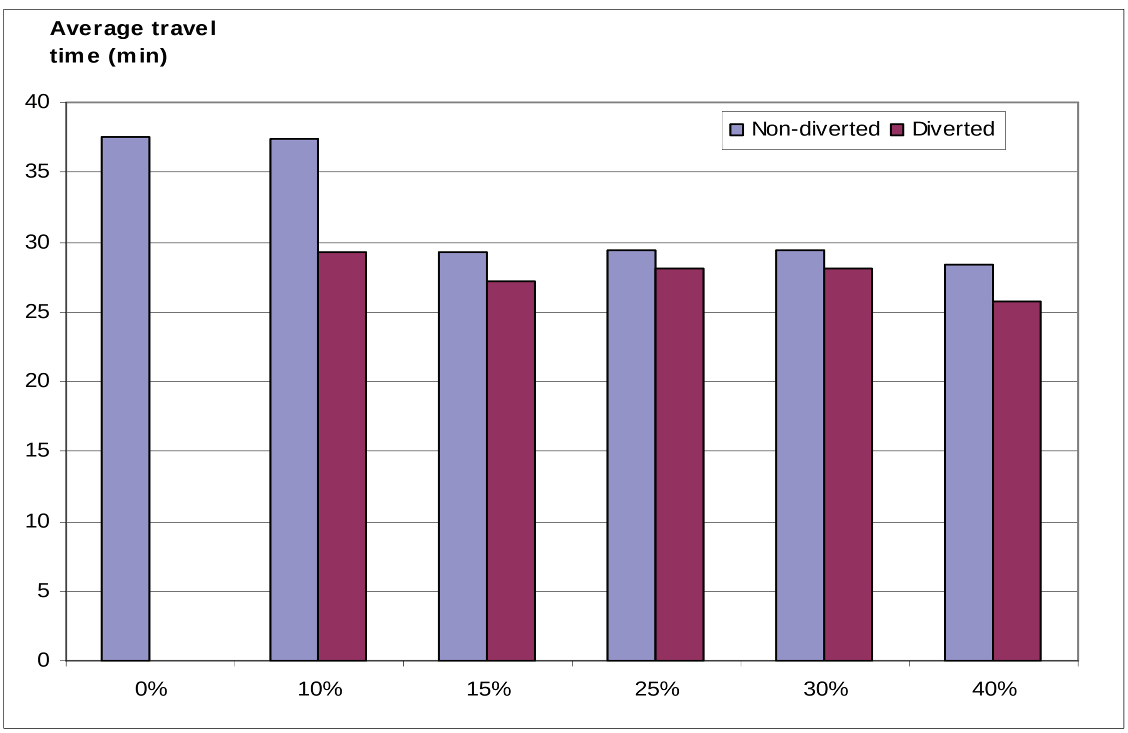


Figure 3.12 Comparison average travel time of Non-diverted and diverted vehicle in various VMS responsive rate

Effect of combined information (VMS and In-Vehicle Information)

The traveler information is usually provided by several channels at the same time. In this case, information is disseminated through VMS and IVIS to network traveler. To test how DYNASMART-P estimates the effect of combined information, two groups of travelers are considered. The first experiment group has various VMS response rates (0, 10, and 20%) and fixed IVIS (5%). The second experiment group has various IVIS service rate (0, 5, 10, and 15%) and fixed VMS response rate (10%). The first group represents network effects by increasing VMS penetration under a same IVIS service rate. The second group shows the difference in network by various IVIS service rate under a certain VMS response rate. The result for the first set of experiments is summarized in Table 3-4 and Figure 3.13. Table 3-5 and Figure 3.14 present the result of second group. Average travel time of overall network, with IVIS, and without IVIS are shown in summary tables. The results from do not reveal the VMS effects clearly because the effect of a VMS depends heavily on the location of the VMS and on the underlying vehicular route flow structure. Nonetheless, the experimental results demonstrate that the travelers with IVIS have a lower average travel time than those without IVIS.

In addition, as shown in Figure 3.15, the vehicular paths used by different user classes from different OD pairs at different departure time intervals can be displayed in DYNASMART-P, in conjunction with the corresponding average travel time and travel time variability.

Table 3-4 Average Travel Time in various VMS response rate with 5% IVIS.

Information	Overall	with IVIS	without IVIS
No information	11.7975	-	11.7975
No VMS with 5% IVIS	11.0463	9.5266	11.1263
10% VMS with 5% IVIS	10.9676	9.4866	11.0456
20% VMS with 5% IVIS	10.4735	9.5287	10.5232

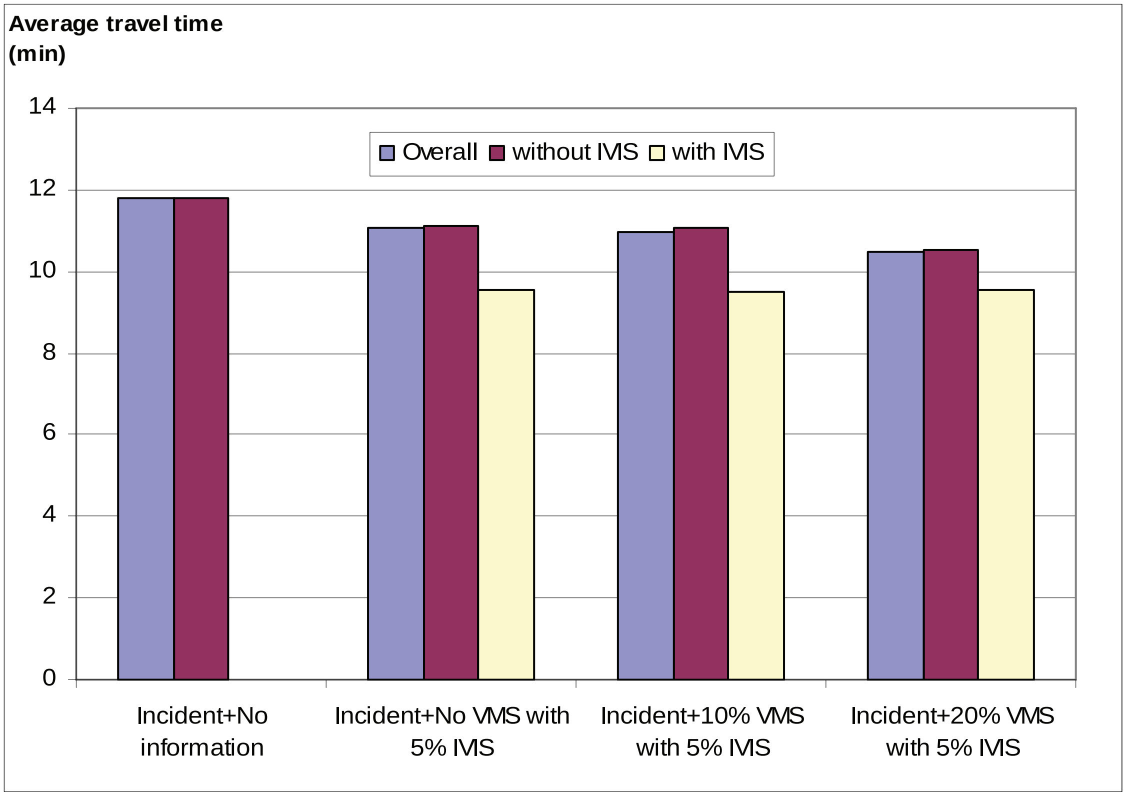


Figure 3.13 Average travel time of in various VMS response rate with 5%

Table 3-5 Average travel time in various IVIS with 10% VMS response rate.

Information	Overall	with IVIS	without IVIS
Incident+No information	11.7975	11.7975	-
Incident+0% IVIS with 10% VMS	11.6263	-	-
Incident+5% IVIS with 10% VMS	10.8723	9.6344	10.9375
Incident+10% IVIS with 10% VMS	14.0388	10.2231	14.4645
Incident+15% IVIS with 10% VMS	11.3837	9.0596	11.7954

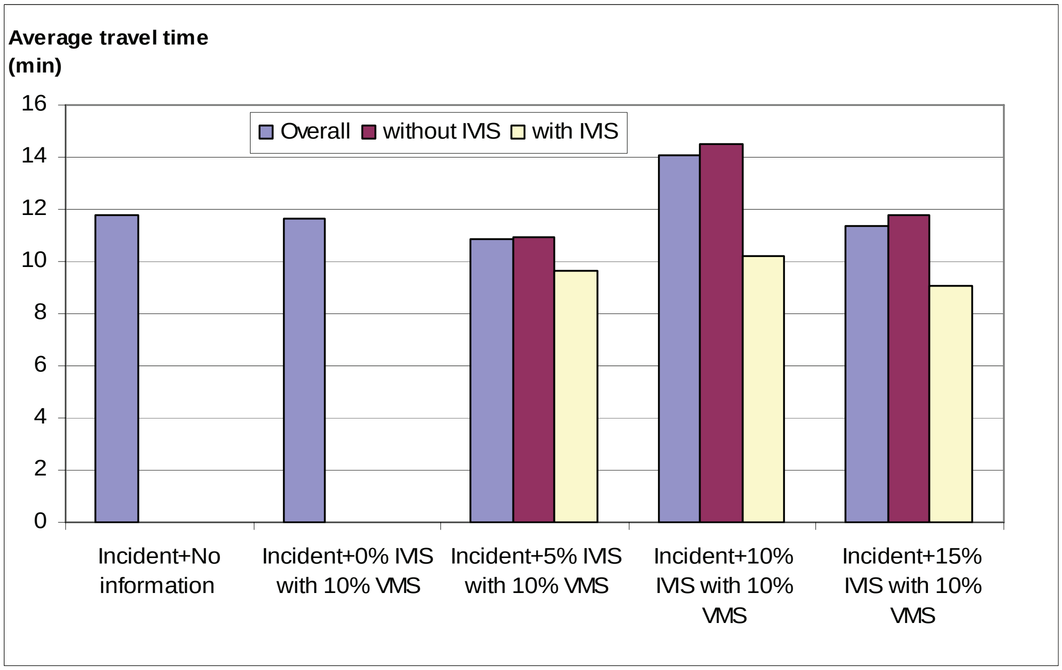


Figure 3.14 Average travel time of in various IVIS with 10% VMS response rate.

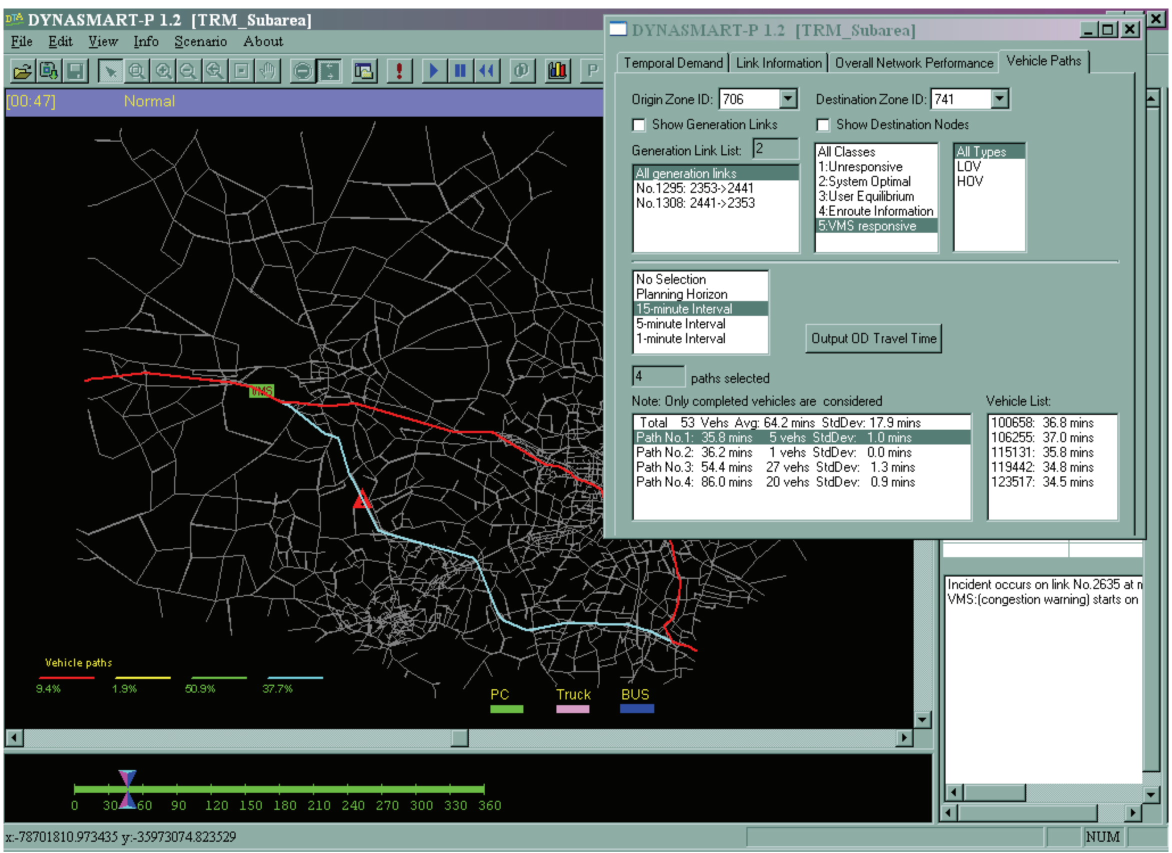


Figure 3.15 Displaying vehicle paths in DYNASMART-P.

3.2.3.5 Summary

DYNASMART-P network data sets can be constructed from TransCAD or CORSIM files. In this case study, a TransCAD network data set was used for network building. DYNASMART-P simulation is computationally burdensome for large networks. In a large network it is hard to isolate the network impact of traveler information clearly because effects of all information sources are absorbed into the network. However, DYNASMART-P offers rich capabilities for emulating ATIS effects. For example, DYNASMART-P can simulate impacts of several types of ATIS (including VMS, Internet, 511, HAR, and IVIS systems) individually or in combination deployment under detailed scenarios defined by service location, service duration, incident severity, incident duration, and incident location.

DYNASMART-P provides summary statistics for the overall network, impacted vehicles, and in-vehicle information types (with or without). Also, traffic characteristics such as density, flow rate, speed, and queue length can be extracted for specific links at specific times. However, DYNASMART-P does not provide benefit in monetary value and cannot estimate safety and environmental effects. Follow on estimation steps based on the simulation results are required for assessing these benefits.

3.2.4 IMAP Case Study

3.2.4.1 Summary of Incident Management Assistance Patrol (IMAP) Tool

Prepared by Khattak and Rouphail (*2005*) recently, IMAP is a decision support tool that allows easy planning and operational assessment of existing and potential service patrol sites in North Carolina. Analysis of three incident/crash indices was combined in the tool with spatial analysis, incident type distributions, average hourly freeway traffic volumes, and incident delay estimations to identify, evaluate, and compare IMAP expansion candidate facilities. By comparing performance values between sites, modeling the effect of IMAPs, and estimating their key potential benefits and costs, decision-makers can quickly assess the needs of different facilities to make an informed, cost-effective decision to determine the most beneficial locations for implementing the next service patrol.

Figure 3.16 shows the conceptual model of the proposed IMAP tool. Two levels of analysis are performed in the IMAP tool to determine the suitability of different facilities for IMAP deployment. The planning level consists of comparing the candidate sites in terms of crashes per 100 million vehicle miles, crashes per mile per year, and average annual daily traffic per lane to statewide statistics. The operational level consists of calculating delay savings at the selected facilities with and without IMAPs, where the FREEVAL model is used to estimate the effects of queuing and vehicle delay for traffic flow, including under incident conditions. FREEVAL replicates the freeway facility methodology in Chapter 22 of the Highway Capacity Manual 2000 (*TRB, 2000*), which enables modeling of the effect of incidents on traffic operations macroscopically.

The tool showed that present IMAPs in NC are located in the areas of greatest need. And the analysis identified sites near Asheville and the Raleigh beltway as having good IMAP deployment potential. The decision support tool is flexible and supports more informed IMAP implementation decisions while maximizing their impacts. Ultimately, by expanding IMAPs properly, it can offer benefits in terms of ameliorating traffic congestion, improving network performance, and enhancing travel safety, thus providing economic and environmental advantages.

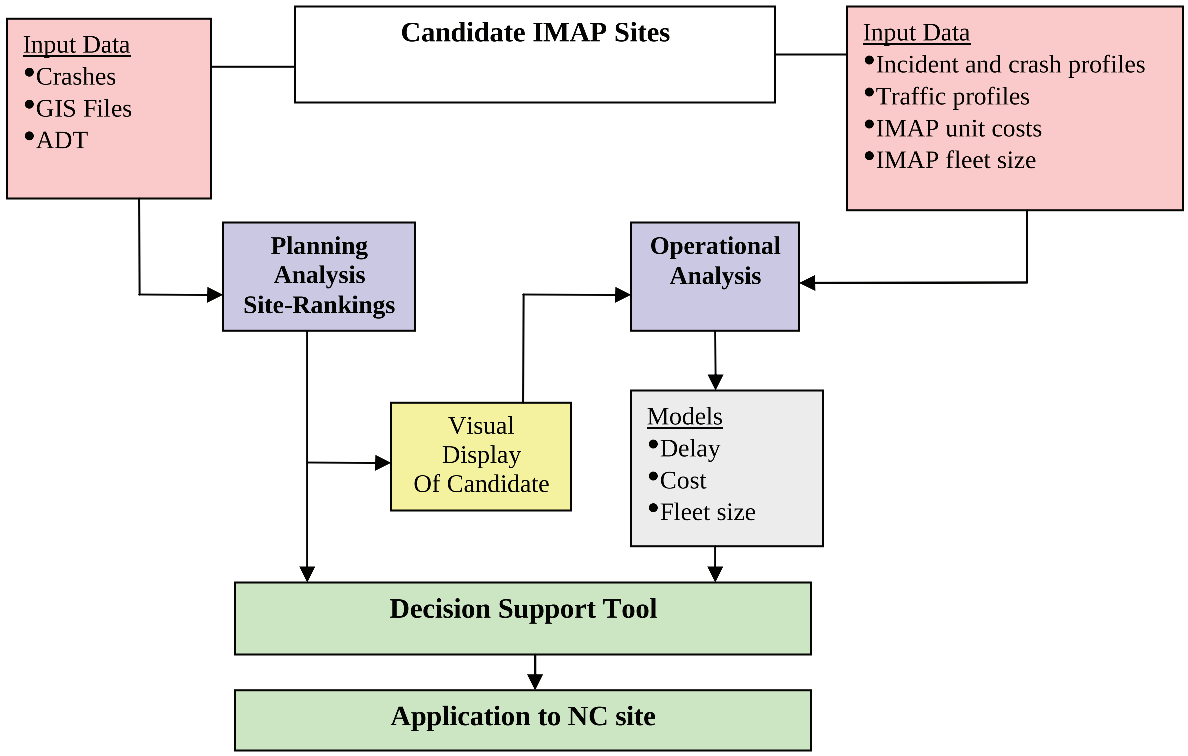


Figure 3.16 Conceptual Model of IMAP

3.2.4.2 Modifications for Advanced Traveler Information System (ATIS) Evaluation

While IMAPs can reduce incident duration and the associated delay costs, disseminating real-time information about incidents can reduce the network demand through behavioral changes (diversions in routes and departure times) and in this way reduce the associated delay costs. Therefore, applying the tool in the context of advanced traveler information systems is beneficial. With regard to the application for ATIS evaluation purpose the IMAP decision support tool needs modifications. Specifically, instead of only considering one freeway to estimate the effects of queuing and vehicle delay for traffic flow, IMAP should add at least one alternate route to calculate the network performance as a result of providing dynamic information.

3.2.4.3 Road Network

A simple road network was defined with two routes but a single origin (point A) and a single destination (point B) for the case study, as shown in Figure 3.17. Route 1 is a freeway (I-40) with capacity μ_1 and free-flow travel time T_1, and Route 2 is an alternative route (I-85) with capacity μ_2 and free-flow travel time T_2, where $\mu_1 \geq \mu_2$ and $T_1 \leq T_2$. Incidents are modeled to occur on route 1 at a time when the traffic conditions are unsaturated.

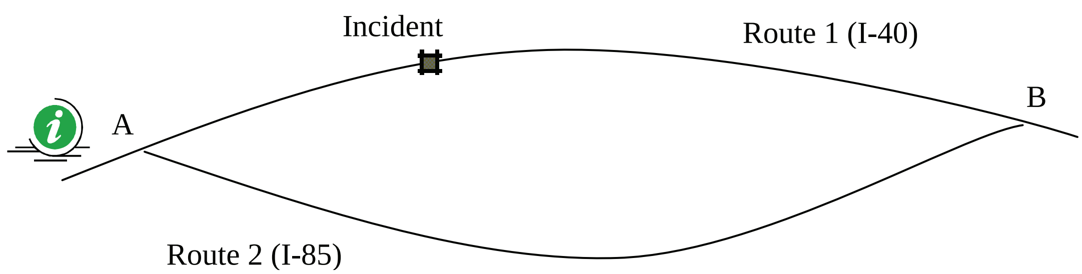


Figure 3.17 Simple Network for Case Study

The road network and incident parameters used in the tool are:

- Free flow travel times in Route 1 and 2 are 18.4 and 19.4 minutes, respectively;
- Route length of Route 1 and 2 are 18.4 and 19.4 miles, respectively;
- Free flow speed for each route is set to 70 miles per hour;
- Initial traffic flows in each route in fixed to 2600 vehicles per hour;
- Incident duration is 60 minutes;
- There are several kinds of scenario with different incident severities are modeled, i.e., case 1 – no incident, case 2 – with incident (80% of capacity remains), case 3 – with incident (60% of capacity remains), case 4 – with incident (60% of capacity remains and 10% drivers divert), case 5 – with incident (60% of capacity remains and 25% drivers divert), case 6 – with incident (60% of capacity remains and 40% drivers divert).

These settings are for demonstration purposes, and are realistic for an urban area, with alternate routes and ATIS availability. These values can be changed in the tool in order to also evaluate the benefits of ATIS expansions, e.g., requiring a distribution of annual incidents in the network.

3.2.4.4 Performance Measures

Three performance measures are used for the proposed ATIS evaluation process, i.e., Total Travel Time (in hours), Average Travel Time (in minutes), and Total Delay (in hours). These measures directly represent the benefit of ATIS (but do not capture additional benefits e.g., lowering fuel and pollution costs).

3.2.4.5 Results

As shown in Figure 3.18, the overall trend of changes in network total travel time is that it will be increased when incident happens and when incident becomes more severe, which is as expected. However, there is a decrease in network total travel time with the increased percentage of diversion. The effect of diversion, as opposed to the situation where nobody diverts to alternate route, shows the benefits of providing ATIS to travelers. For example, having 40% travelers diverting to alternate route (assuming that the alternate route has the additional capacity to accommodate the traffic) could improve the network performance by 15.2% in terms of total travel time.

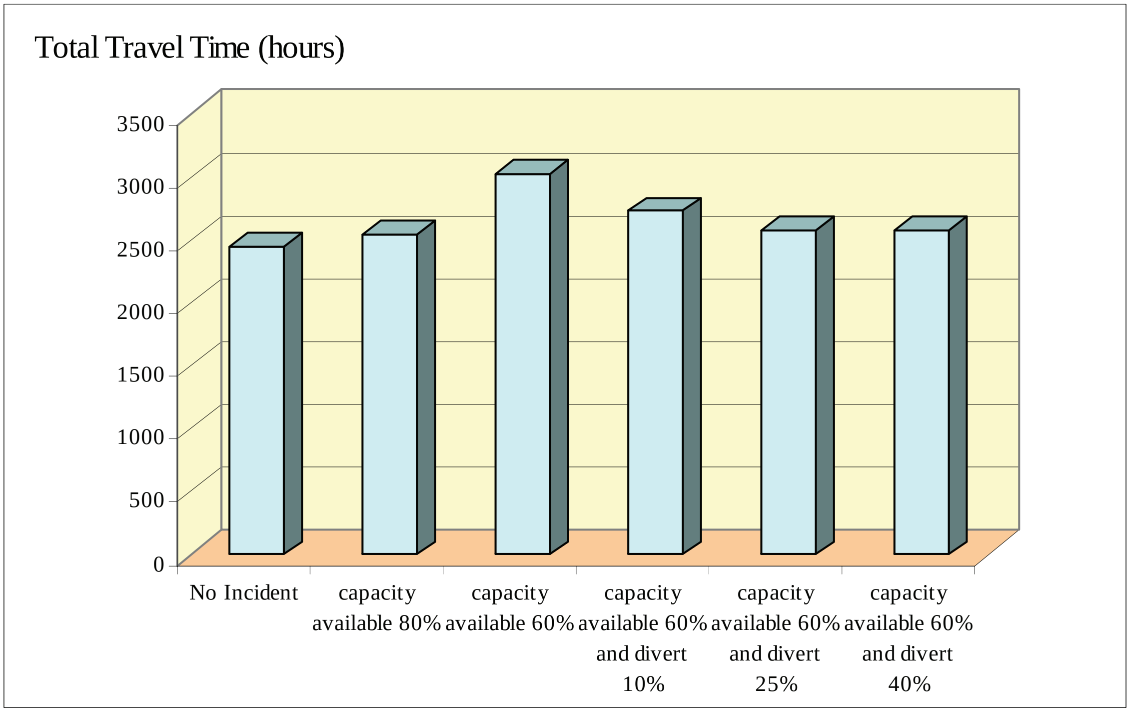


Figure 3.18 Comparison of Total Travel Time

In terms of network average travel time, the increased incident severity still is associated with an increase in network average travel time, as shown in Figure 3.19. The trend of declining network average travel time with an increasing percentage of diversion also remains as expected. These results indicate that, under incident situation (for severe incidents), guiding travelers to divert to alternate route with ATIS brings noticeable benefits in network performance.

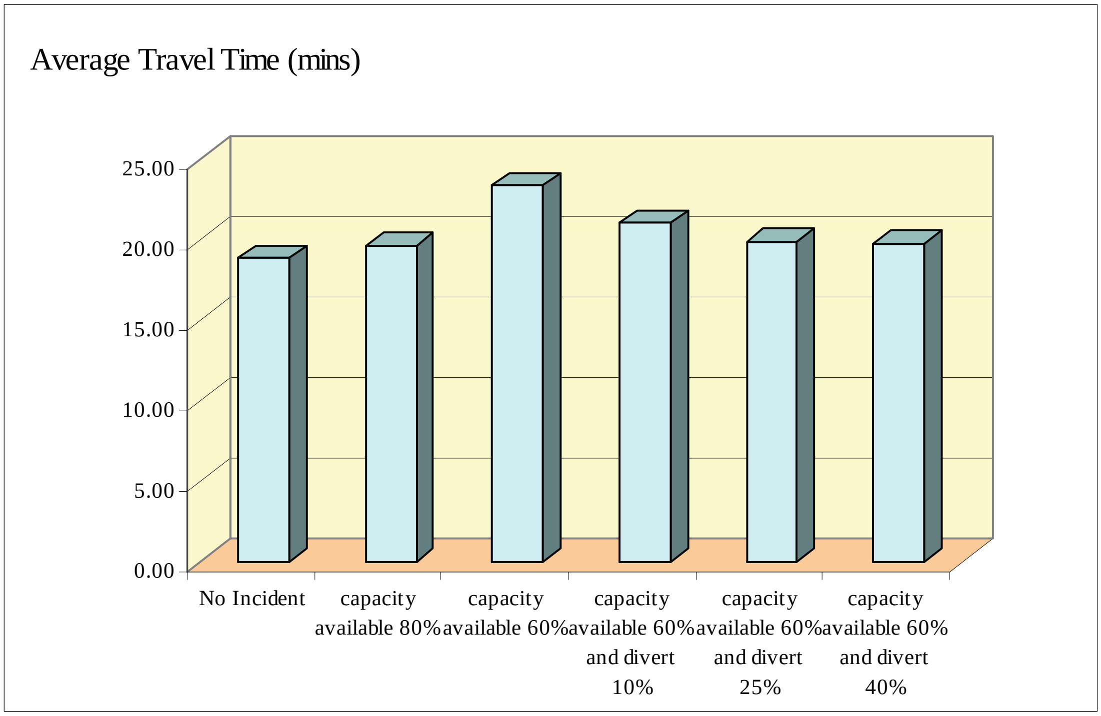


Figure 3.19 Comparison of Average Travel Time

Analysis of network total delay is illustrated in Figure 3.20, which shows the differences among different scenarios. Again, an increase in total delay is found when incident occurs and when it has higher severity. The declining trend of network total delay with an increasing percentage of diversion still remains as expected. However, compared to the other two performance measures, the figure shows remarkable benefits in total delay of encouraging travelers to divert to alternate route with ATIS. The amount of savings in total delay is rather large. For example, given incident severity with 60% capacity remaining, diverting 10% travelers to the alternate route could improve the network performance by 53.3% in terms of total delay, while having 40% travelers diverting to alternate route can reduce total delay by 83.1%, given sufficient capacity on the alternate route. Based on the study results as well as existing literature, the benefits of ATIS, under incident-induced traffic congestion situation, are significant.

These results represent the upper bounds of benefits that can be obtained from providing information. In real-life situations, people can often observe congestion and may divert to alternate routes, even if electronic information is not available. This clearly will reduce the actual benefits obtained from disseminating information. Overall, in addition to using IMAPs, there is potential to divert traffic to alternate routes and reap substantial additional network benefits in incident situations.

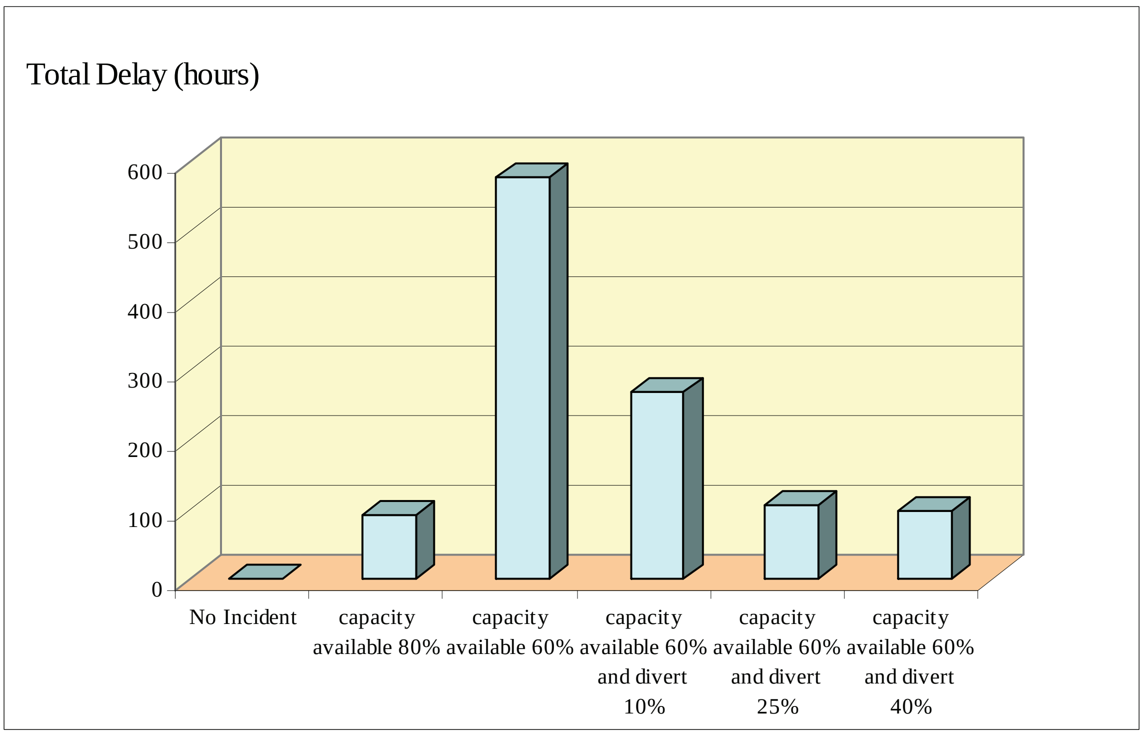


Figure 3.20 Comparison of Total Delay

3.2.4.6 Strengths and Weaknesses

Having changed the IMAP tool to accommodate ATIS can be helpful in estimating benefits. IMAP could act as a convenient but effective tool for ATIS evaluation (CMS/HAR options). On the one hand, it has a very simple interface to implement ATIS evaluation which only needs a few basic road network, traffic flow, and incident information. On the other hand, it can provide network performance measures that directly represent the benefit of ATIS, i.e., total travel time, average travel time, and total delay. For example, it can produce estimates such as delay, travel time, and benefit-cost ratios for situations with and without CMS/HAR.

There are also some weaknesses for the proposed IMAP tool. Firstly, it can be only used in a simple network because it is a facility based modeling tool. Secondly, other performance measures that include late arrival at destination, vehicle costs, and emissions should be considered. ATIS can also benefit commercial users in terms of reducing late incoming/outgoing deliveries or shipments, and the costs of keeping additional inventory by businesses. Finally, it is important to understand particular ATIS needs and benefits to various users, e.g., business users/truck drivers since they usually have a higher value of travel time (VOT) than normal motorists.

3.2.4.7 IMAP with Traveler Behavior Model

The IMAP tool was modified to include a traveler behavior model. The simulation results that would be possible after adding a traveler behavior model which reflects drivers' actual response to traffic congestion information is considered. Such a model will be useful for testing differences in effects of traveler information due to different road user/vehicle characteristics, since different types of road users and vehicles may have distinct traveler behaviors. A behavioral model was chosen based on a survey of travelers (Kattack, 1991). The proposed binary logit model of route choice was estimated using the responses of those who knew about the traffic delays either by observing them or through traffic information. The model parameters can be changed to reflect the local conditions, if behavioral data are available.

Driver attributes such as age and gender were not included in this study, in order to focus on the information effect and simplify the analysis process. The dependent variable (Y) was the decision of staying on the usual route or diverting to an alternate route. The independent variables were information source (X_1 =1 if delay information received electronically, =0 if delay received via observation) and travel time difference (in minutes) between original and alternate routes (X_2). Table 3-6 presents β coefficients of the model as well as a sensitivity analysis of parameters. The constant term, β_0, is the log odds ratio of the diversion probability given that the other two β s are zero. Its value is negative and statistically significant, indicating that travelers prefer to stay on their usual route in unexpected delay situations, all else being equal. This is possibly due to their inertial tendencies (3). The 90% confidence interval for each β is calculated. For each beta, the diversion probabilities are computed for the four scenarios at its lower and upper interval bound, given that the other two betas are fixed. The four scenarios are represented by the four combinations of different values of X_1 and X_2. It turns out that the probability of diversion is quite sensitive to changes in β s, especially β_0 and β_1. It also can be shown that the probability of diversion increases with β i given all other β s fixed.

Table 3-6 Travel Behavior Model and its Parameter Analysis

Variable	β	*t*-statistics	90% Confidence Interval	Scenario	Probability of diversion
Constant	β_0 = -0.717	-4.27	[-0.993, -0.441]	X_1=0;X_2=0	[0.27, 0.39]
				X_1=0;X_2=10	[0.32, 0.45]
				X_1=1;X_2=0	[0.36, 0.49]
				X_1=1;X_2=10	[0.41, 0.55]
Electronic Information	β_1 = 0.407	1.88	[0.051, 0.763]	X_1=0;X_2=0	[0.33, 0.33]
				X_1=0;X_2=10	[0.38, 0.38]
				X_1=1;X_2=0	[0.34, 0.51]
				X_1=1;X_2=10	[0.39, 0.57]
Travel time difference	β_2 = 0.022	3.48	[0.012, 0.032]	X_1=0;X_2=0	[0.33, 0.33]
				X_1=0;X_2=10	[0.35, 0.40]
				X_1=1;X_2=0	[0.42, 0.42]
				X_1=1;X_2=10	[0.45, 0.50]

Note: Summary statistics – Initial log-likelihood L(0) = -257.85, Convergence log-likelihood L(β) = -246.71, N=372.

These coefficients are used in the study for illustration. In the experiments carried out later, two different situations were studied: in the first, commercial carriers behave similarly to motorists (equal diversion probability), while in the second the diversion probability of commercial carriers is assumed to be half that of motorists. Based on the travel behavior model, the probability of person *n* choosing alternate route $P_n(alternate)$ could be calculated, where the probability of person *n* choosing original route $P_n(original) = 1 - P_n(alternate)$. Then, a random number τ is generated between 0 and 1. If τ is not greater than $P_n(alternate)$, then this person is assigned to the alternate route; otherwise this person is assigned to the original route.

A simple incident scenario is used to demonstrate the workings of the tool and how various assumptions can be changed to suit local conditions. The important and interesting findings are:

- Substantial network performance benefits can be obtained from disseminating travel information. Network average travel time and total travel cost can be reduced (up to about 10%) by increasing the percentage of traffic information provided, which shows the benefits of providing travelers traffic information on incident-induced congestion.
- Average travel time and total travel cost increase with an increased percentage of truck flow, because truck traffic usually has a greater impact on traffic flow than passenger cars. There is a demand for broadcasting real-time traffic information under incident-induced congestion situations, as both individual travelers and commercial users benefit.
- The benefits of electronic information are lower if travelers can observe the incident-induced congestion.
- The V/C ratio on alternate routes quickly increases with an increase in traffic information provided to travelers. This indicates the need for providing and updating dynamic traffic information for the transportation system, including traffic conditions on alternate routes.

CHAPTER 4. COST AND EVALUATION DATA SYNTHESIS

4.1 ITS JPO (Joint Program Office) Database

ITS JPO collected and managed the database of ITS benefits and costs. This information is provided to the public through an Internet website. The benefits and costs database provides access to benefit summaries from specific research projects. The benefits database includes the ITS effects from the research in USA and other countries. Some of the research results are from post-deployment field operational tests or surveys. Others are based on simulation results using a variety simulation tools.

The project team gathered and summarized the ATIS benefits in the literature review task. The benefit data from the ITS JPO is included in summary table of ATIS benefits, Appendix C.

ITS JPO also managed costs database. Cost database include ITS unit costs and system costs. The file formats provided are Excel spread sheet files or PDF files. It has two types of data, adjusted cost values and not adjusted cost value. The data collection times of each ITS costs can be different, so adjustments are required to be used for evaluation at certain year. The cost database adjusted for 2004 are included in Appendix D.

4.2 NCDOT Cost Data

Cost data was provided by the Intelligent Transportation Systems Operations Unit and Intelligent Transportation Systems Section. The most significant ATIS investments by the NCDOT to date have involved changeable or dynamic message signs. Therefore the cost data provided is focused on message sign installation and maintenance.

4.2.1 Planning and Installation Costs

Engineer's estimate cost items for message sign installation were provided by the Intelligent Transportation Systems Section. These cost data, presented in Table 4-1 below, are used for developing planning estimates for new installations and replacements.

Table 4-1 ITS Implementation Preliminary Engineer's Estimate Using Fiber Optic and/or Wireless Communication

Item Description	Unit	Unit Price	Notes/Assumptions
One 1-1/4 Inch Conduit	LF	$5.25	1 conduit trenched or plowed; assumed 15% directional drill at $13/ft
Fiber Optic Cable	LF	$2.25	Includes 100' spare cable in every junction box
Junction Box	EA	$650.00	1 over-sized junction box every 2,000 ft; included 1 delineator marker per junction box at $75.00/each
Detector Station	EA	$8,500.00	1 every 2 mile (Average) - Rural Areas every 3 miles, Metro Areas every 1 mile
CCTV	EA	$10,000.00	1 every 3 miles; cost includes assembly, wood poles, transceivers, etc
Tracer Wire	LF	$0.45	
Power	EA	$1,500.00	Per device location
DMS	EA	$150,000.00	Includes sign, assembly, and dialup communications
Hub Building	EA	$20,000.00	Includes, hub building, power, misc. equip
Wind Speed Sensor	EA	$20,000.00	
Wireless Communication	EA	$7,500.00	
Notes: Cost Figures are from Recent 2006 Bid Averages Preliminary Engineering Cost range from 8% to 10%			

4.2.2 Operation and Maintenance Costs

Operations and maintenance costs were provided by the Intelligent Transportation System Operations Unit. The majority of the compiled maintenance costs are presented in Table 4-2.

Table 4-2 ITS Device Maintenance Costs

Item	$ per Year	$ per Month	Replacement	Life Expectancy (Years)
Portable CMS or HAR	$500	$42	$18,000	CMS – 9; HAR - 6
Permanent DMS	$5,000	$417	$80,000	12
CCTV	$2,000	$167	$5,000	7
Permanent HAR	$700	$58	$3,000	Not provided
“Tune to” Sign	$250	$21	$25,000	Not provided
Weather Station	$500	$42	Not provided	Not provided
Reversible Lane Gantry	$4,000	$333	Not provided	Not provided
Detector Station	$200	$17	Not provided	Not provided
Truck Mounted CMS	$250	$21	$11,000	Not provided

The ITS Operations Unit provided the following additional summary information and comments regarding device maintenance –

- Lightning is a major maintenance cost driver
- Maintenance costs are not constant over life cycle. Older devices need more maintenance
- Fiber optic communications maintenance is handled by the divisions
- Permanent DMS sign maintenance can be contracted for $6,700 per sign per year not including parts (As an example, replacement fiber modems are $1,500)
- The Charlotte area spends $100,000 per year for gantry maintenance

In terms of device operations, average power costs are $30 per month and dialup communications costs are $40 per month. The SpeedInfo speed detection devices installed in the Triangle area have a monthly combined operations and maintenance cost of $100 per sensor.

CHAPTER 5. CATALOG CURRENT AND PLANNED ATIS DEPLOYMENTS IN NC

5.1 Statewide ITS Strategic Deployment Plan

The NCDOT has developed the Statewide ITS Strategic Deployment plan (http://www.ncdot.org/doh/operations/dp_chief_eng/its/strategic/plandocuments.html). The purpose of this plan is to enable a structured implementation of ITS projects by addressing the short-term and long-term transportation needs of the state.

NCDOT defined 10 ITS regions according to the ITS needs for North Carolina. Figure 5.1 highlights the 10 ITS regions of NC: Asheville, Eastern (Coastal Rural), Fayetteville, Metrolina, Piedmont, Triad, Triangle, Western (Mountains Rural), Wilmington, and the I-95 Corridor. All these ITS regions except for the I-95 Corridor have their own regional ITS plan. All of the regional plans will be combined to develop a Statewide ITS Deployment Plan that will guide each of the agencies involved as well as the NCDOT in the deployment of ITS in the coming years. The I-95 Corridor will be included in the Statewide Report in the interstate system. All nine regional ITS plan reports are open to public through the NCDOT website.

These regional ITS reports have similar contents. These reports lay out a vision for the development of the regional ITS. The development process of each region follows the requirements and direction of the National ITS Architecture (NIA), a framework that describes ITS components by their functionality and defines how these components are to work together as a system. Each regional report includes a regional overview, description of existing ITS, transportation needs or issues, recommended projects and technologies (short-term projects and long-term projects), and project summary (project outline and expected costs).

Existing ATIS deployments are summarized in Table 5-1. Metrolina, Triad and Triangle have been providing traveler information through various ATIS option and have a TMC

(Transportation Management Center). On the other hand, the Asheville and Western regions have few existing ATIS facilities. The Eastern and Wilmington regions have a proposed ITS deployment plan that includes consideration for coastal evacuation. Table 5-2 summarizes the recommended projects for the nine regions. A thorough overview for these projects along with expected project costs are provided in Appendix E.

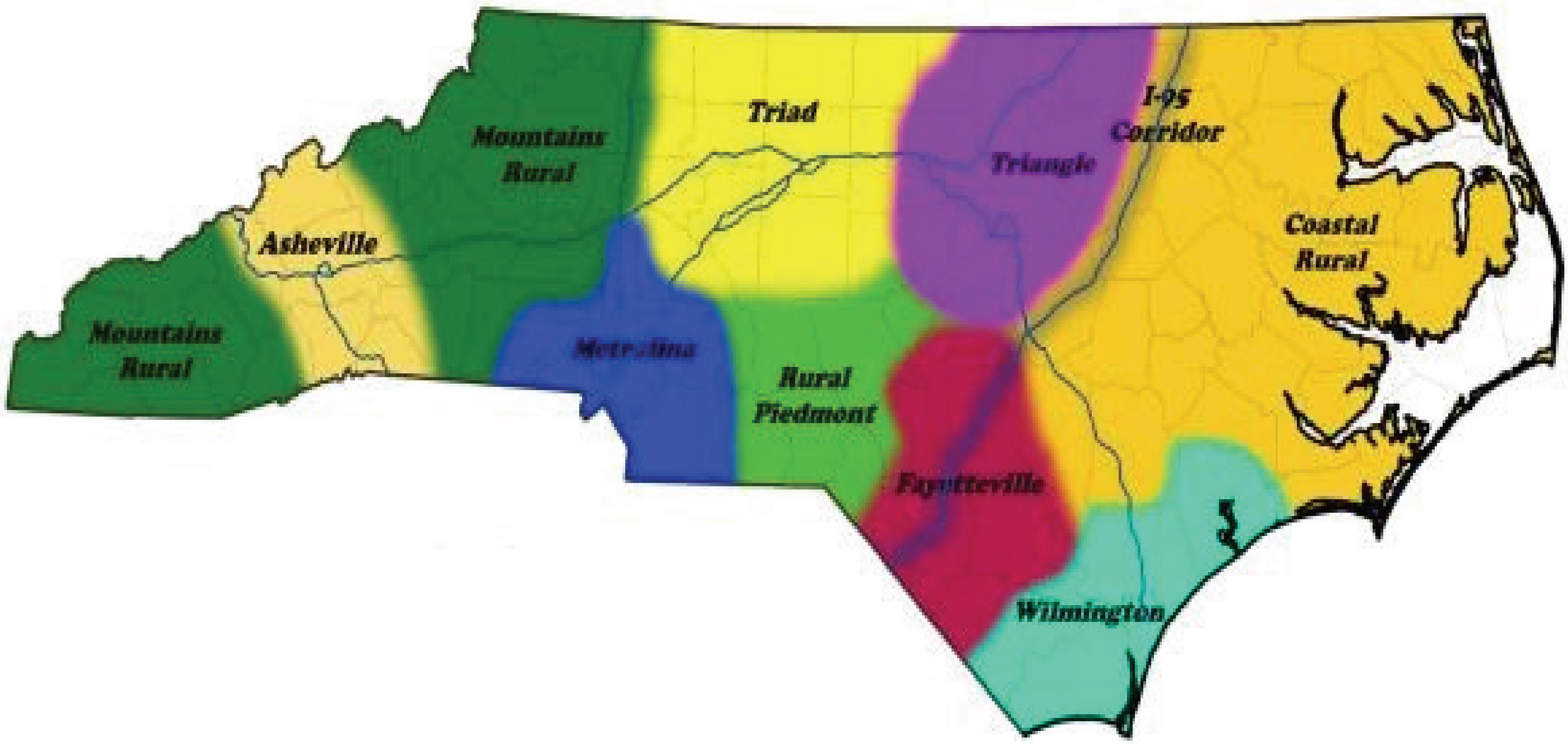


Figure 5.1 North Carolina ITS Regional Map

Table 5-1 Summary of existing ATIS deployments

Region	ATIS deployments
Eastern	Hurricane Evacuation Plan (DMS, HAR, CCTV, count stations, wind gauges, information kiosks, and traffic signal improvements)
Fayetteville	HAR
Metrolina	TMC Web page Charlotte network television station linked to 7 CCTV in the Charlotte CBD
Piedmont	HAR
Triad	Various media source Cable channel
Triangle	Internet Web Sites WRAL-TV online Call-in Telephone Cooperative Agreements for use of live video images– NCSHP, WRAL- TV, WTVD –TV, NBC-17, Time-Warner, and Curtis Media Group Kiosks
Wilmington	Hurricane Evacuation Plan (DMS, HAR, CCTV, count stations, wind gauges, information kiosks, and traffic signal improvements)

Table 5-2 Summary of recommended ATIS projects and technologies

Region	Short term plan (2000~2006)	Long term plan (2006~2011)
Asheville	HAR Website	DMS Kiosks ATIS Enhancements 511 Traveler Information
Eastern	Portable Dynamic Message Signs Road Weather Information Systems Traveler Information Kiosks Internet Traveler Information CCTV Links to Web	Internet Traveler Information System Commercial Vehicle Information Systems and Networks
Fayetteville	HAR Website	DMS Kiosks ATIS Enhancements
Metrolina	Web-based mapping and route identification Broadcast video and data Web-based data and video Traveler information kiosks Portable DMS	Advanced traveler information En-Route access to traffic information Additional deployments of DMS and CCTV
Piedmont	Traveler information kiosks Web based mapping and route identification Web based data, video, and CCTV Portable DMS	En-Route access to traffic information Additional deployments of DMS and CCTV
Triad	Web-based mapping and route identification Broadcast video and data Web-based data and video Traveler information kiosks Portable DMS	Advanced traveler information En-route access to traffic information Additional deployments of DMS and CCTV
Triangle	Website	Kiosk
Western	Traveler information kiosks Web-based mapping and route identification Broadcast video and data Internet travel information system enhancements for region Portable changeable message signs Road weather information systems (RWIS)	Internet travel information system enhancements
Wilmington	HAR Website	DMS Kiosks ATIS Enhancements

CHAPTER 6. GENERAL ATIS EVALUATION

Travel information received from public and private traveler information sources can help travelers make more informed decisions and shorten time spent in congestion. The objective of the general ATIS evaluation was to analyze behavioral response to travel information in the context of the Research Triangle Park area in North Carolina. Several questions related to travel information were asked of the respondents to the 2006 Greater Triangle Household Travel Survey *(NuStats, 2006)*. Using the data from this survey, a statistical analysis was conducted to explore:

- Whether or not travel decision changes (e.g., changes in route, time, mode, or cancel trip) are associated with frequency of electronic travel information use, and various information sources?
- What information technologies are most likely to help people adjust their travel patterns? The information technologies analyzed include the Internet, Commercial radio, Television, VMS (Variable Message Signs), HAR (Highway Advisory Radio), and 511 (Traveler Information Hotline).
- What socio-economic factors are associated with greater traffic information use? What market segments can be targeted to increase awareness of electronic travel information available to general public?
- What are the key reasons for not acquiring electronic travel information?

Descriptive statistics, logit model development, and cross classification analysis were used to seek answers for these questions.

6.1 Survey Design

The 2006 Greater Triangle household travel survey was conducted using state-of-the-art travel survey methods and computer-aided telephone interviewing (CATI) technology. The survey data include demographic and travel behavior characteristics of regional travelers in order to update the current regional model and to develop a new, more robust travel demand model for the 12-county region in North Carolina: Durham, Orange, Wake, Chatham, Lee, Harnett, Johnston, Nash, Franklin, Vance, Granville, and Person. In total, 7,300 households were recruited to participate in the study but only 5,107 provided all details required for inclusion in the final data set. The 5,107 surveyed households represent the 548,539 regional households.

Questions designed to gather ATIS user response data were included in the survey questionnaire. The four additional questions sought information on the type and frequency of use of available traveler information sources and the impact of this information on travel decisions. Table 6-1 presents questions for this ATIS research.

Table 6-1 Key questions for stated preference study about traffic information

Variable Name	Question asked in survey
Frequency of traffic information use (n = 5107)	S6. How often do you and others in your household seek information about traffic and general travel conditions in the region? 1. never 2. At least once a week 3. 2-4 times per week 4. 5+ times per week
Information Sources (n = 2584)	S7. Where do you go to get this information? (multiple response) 1. Internet 2. Commercial radio 3. Television 4. Variable message signs (signs on the side of the road) 5. Highway advisory radio 6. Traveler information hotline (511) 7. Others (specify)
Travel decision changes (Yes/No) (n = 2584)	S8. Have you ever changed your travel plans based on the information you got? 1. Yes 2. No 9. DK/RF
Type of travel decision changes (n = 2584)	S8a. If YES: How? (multiple response) 1. Changed route of travel 2. Changed Time that you started trip (departure time) 3. Changed mode of travel 4. Cancelled trip

Source: The 2006 Greater Triangle Household Travel Survey

6.2 Descriptive analysis

A total of 5,107 households participated in the 2006 Greater Triangle Household Travel Survey, which contains 11,953 household members, as well as 10,245 automobiles in the survey sample. The average household size is 2.34 persons, while household auto ownership is 2.01 vehicles. Median household income was in the category of $50,000 to $74,999 per year. More than 40% respondents stated that they have a bachelors or higher degree. All these descriptive statistics indicate that the population of the Greater Triangle region has relatively higher income and education levels than the general population as a whole. A summary of demographic information is provided in

Table 6-2.

Table 6-2 Descriptive Statistics of Selected Variables

Selected variables	Case number	Median	Mean	Std. Dev.	Range
Household size	5,107	2.00	2.34	1.19	1 - 8
Number of HH Vehicles	5,107	2.00	2.01	1.02	0 - 8
Travel time-commute	8,863	15.0	22.1	30.4	1.0 – 1,224.0
Travel time-non-commute	40,678	14.0	17.9	22.8	1.0 – 791.0

As shown in

Table 6-3 about one-half of the respondents (49%) reported that they did not acquire travel information from different types of electronic sources and never seek regional travel information at all (N=5107). The median of peoples' frequency of travel information usage is at least once per week. And the median of people's reported acquisition from different types of information sources is 1 type of travel information source. In addition, for those who acquire traffic information (2,584), 78.37% of the respondents changed their travel decisions based on information received (i.e., 39.65% of total respondents). Moreover, with travel information, 34.66% of the total survey respondents (1,770 out of 5,107) had changed their travel route.

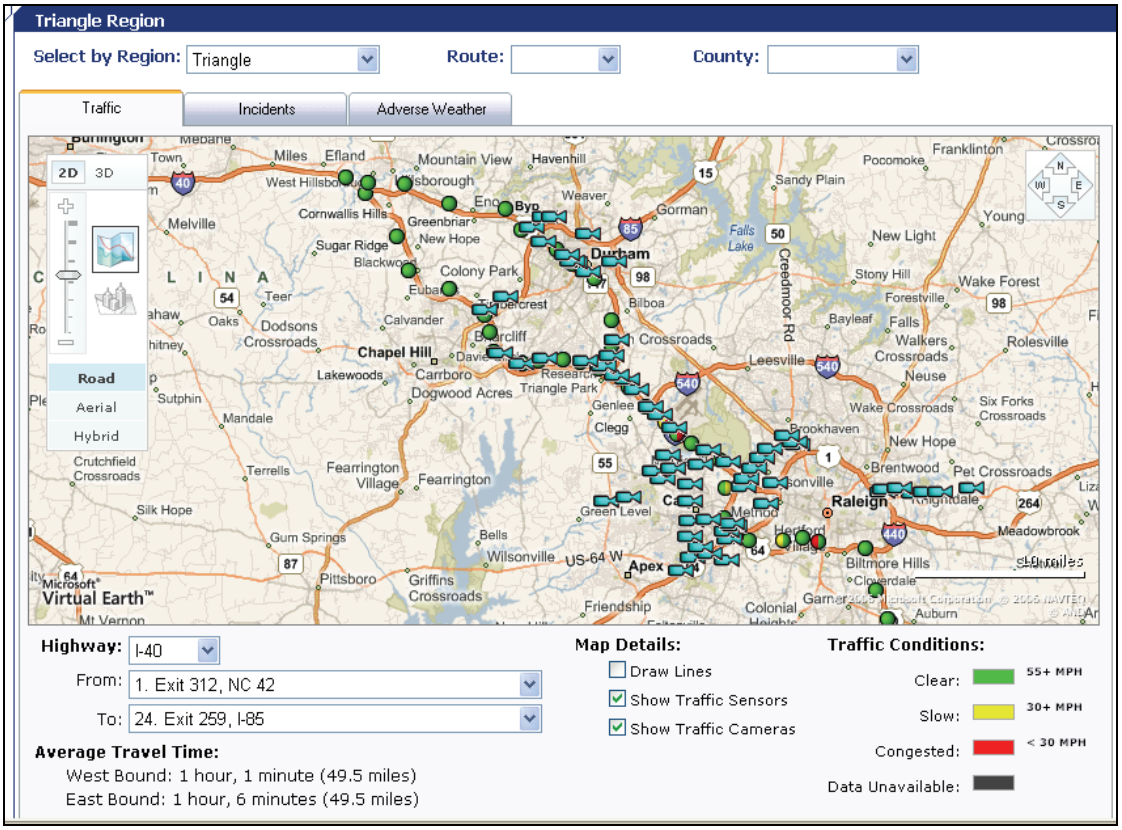
Table 6-3 Frequencies and Descriptive Statistics

Selected Variables	Categories	Frequency	Percentage (%)
Frequency of travel information use (n = 5,107)	Never	2,523	49.40
	At least once per week	504	9.87
	2-4 times per week	438	8.58
	5 or more times per week	1,642	32.15
	Sum	5,107	100.00
Specific information technologies (n = 2,584)	Internet	607	23.49
	Commercial radio	1,245	48.18
	Television	1,762	68.19
	Variable message signs	153	5.92
	Highway advisory radio	52	2.01
	Traveler information hotline (511)	0	0.00
	Others	39	1.51
	Sum	3,858	149.30*
Number of information sources accessed (n = 5,107)	None	2,523	49.40
	1	1,613	31.58
	2	732	14.33
	3	180	3.52
	4	54	1.06
	5 or more	5	0.10
	Sum	5,107	100.00

Note: *Percentages exceed 100% because multiple responses were permitted.
Source: The 2006 Greater Triangle Household Travel Survey.

In terms of specific information technologies, people are more likely to access travel information through Television, and then by Commercial radio, and Internet (see

Table 6-3 for detail). For example, 34.5% of total respondents have used TV for traffic information acquisition, followed by 24.38%, and 11.89% using Commercial radio and the Internet, respectively. Indeed NCDOT disseminates travel information via the Internet, as shown in the figure below (Figure 6.1). The reported acquisition from some of the public information sources that include VMS, HAR, and 511 is relatively low (about 4%).



Source: http://www.ncdot.org/traffictravel/ (accessed 07/2007).

Figure 6.1 Traveler information management **system** (TIMS) by NCDOT.

6.3 Statistic analysis

6.3.1 ATIS effects on travel decision

Two logit models were estimated, one for travel decision changes and the other for whether or not the respondent changed travel route. The logit model formulation is shown below, with Y indicating the dependent variable, X the independent variables, and β the estimated parameter coefficients. Independent variables in both models are frequency of information usage (X_1), and level of information acquisition (X_2). The dependent variable for model 1 (Y_1) is whether travelers change their travel decision (1 = yes, 0 = no). The dependent variable for model 2 (Y_2) is whether travelers change their travel route (1 = yes, 0 = no).

$$Y = Ln\left(\frac{P(Y=1)}{P(Y=0)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n \qquad (6.1)$$

Table 6-4 shows the model results for the entire sample of respondents (N=5107). Statistical software STATA was used for model estimation. The goodness of fit, indicated by Pseudo-R^2 is reasonably high for logit models applied in the traveler behavior field. The goodness of fit for these models is calculated as

ρ^2 or Pseudo-R^2 = 1 – [LL(β)/LL(0)]

(6.2)

The measure is the fraction of the initial log-likelihood, LL(0), explained by the model. LL(β) is the log-likelihood at convergence. For binary choice models the value of Pseudo-R^2 lies between 0 and 1.

Both models show similar results. The constant term is negative indicating that on average people are unwilling to change their travel choices (this is also consistent with the literature). Furthermore, information acquisition from more information devices and greater frequency of information use increases the chances of diversions, as expected. The model parameters cannot be interpreted directly in terms of changes in the dependent variable. The odds ratio and marginal effects are needed for this purpose and are discussed below.

Table 6-4 shows the "odds ratio" which are e^{β} and represent the odds of "success" (changes travel decisions) relative to the odds of "failure" (does not change travel decisions), with a unit change in the independent variable. For example, if frequency of travel information usage increases by 1 time per week, then the odds of changing travel decisions is 1.67 times the odds of not changing (holding all other variables constant) Odds ratios are also difficult to interpret, so it is often clearer to interpret the effects of independent variables in terms of probabilities as shown below.

Table 6-4 Statistical results for two Logit models of travel behavior changes

	Model 1 Travel decision changes (change time, mode, route or cancel trip)		Model 2 Route change only	
	Coefficients	Odds ratio	Coefficients	Odds ratio
Constant	-3.09**	--	-3.12**	--
Frequency of information usage	0.51**	1.67**	0.47**	1.60**
Information acquisition from electronic sources	1.74**	5.70**	1.40**	4.06**
Pseudo-R^2		0.53**		0.44**

Notes:
Case number = 5107
** - P-value <= 0.01
Odds ratio = exp (coefficient)

The variable traffic information acquisition (X_2), is coded as 0 if respondents stated that they never used electronic traffic information before.

Table 6-5 shows the results of the same model specification as

Table 6-4, without the respondents who never seek information about traffic and general travel conditions in the region (N=2584). In this model, the Pseudo-R^2 declines considerably, reflecting that the explanatory variables are not fitting the data when the non-information seekers aer ignored and the models to explain the conditional distribution only are used. Furthermore, the effects of independent variables decrease, given that these are travel information seekers who are pre-disposed to changing their travel behavior. This is partly reflected in the constant which is now statistically insignificant, but positive. The effects of frequency of information usage and information acquisition decline substantially, as indicated by the magnitudes of the coefficients.

Table 6-5 Statistical results for two Logit models of travel behavior changes

	Model 1 Travel decision changes (change time, mode, route or cancel trip)		Model 2 Route change only	
	Coefficients	Odds ratio	Coefficients	Odds ratio
Constant	0.14	--	-0.46**	--
Frequency of information usage	0.16**	1.17**	0.15**	1.16**
Information acquisition from electronic sources	0.39**	1.47**	0.46**	1.58**
Pseudo-R^2		0.02**		0.03**

Notes: Case number = 2584; ** - P-value <= 0.01; Odds ratio = exp (coefficient)

Focusing on route change only (which is based on Model 2 in

Table 6-4), the marginal effects suggest that the chance of changing route decisions increases with higher frequency of information usage. Figure 6.2 illustrates the relationship between travel decision changes and frequency of information usage, while the other independent variable (level of traffic information acquisition) changes from its median value of 1 type information source to a maximum of 5 or more. These results show that the chances of route changes increase more rapidly when respondents use fewer travel information sources.

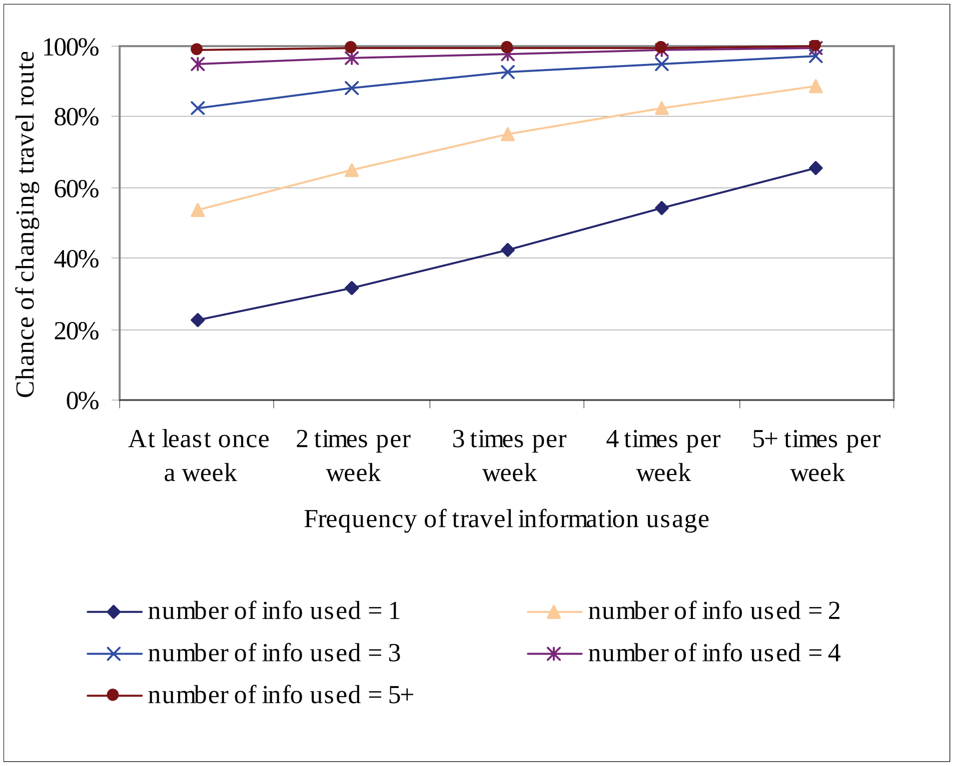


Figure 6.2 Marginal effects for frequency of travel information usage (N=5107)

Similarly, based on Model 2 in Table 6-6 for those who seek information (with the "never" category removed), the marginal effects suggest that the chance of changing route decisions increases with higher frequency of information usage. Figure 6.3 shows that the chances of route diversion are much higher if only respondents who are pre-disposed to changing their decisions are considered. For instance, the chances of route diversion go up from nearly 22% to 52%, when information seekers only are considered (as opposed to considering the entire sample of respondents).

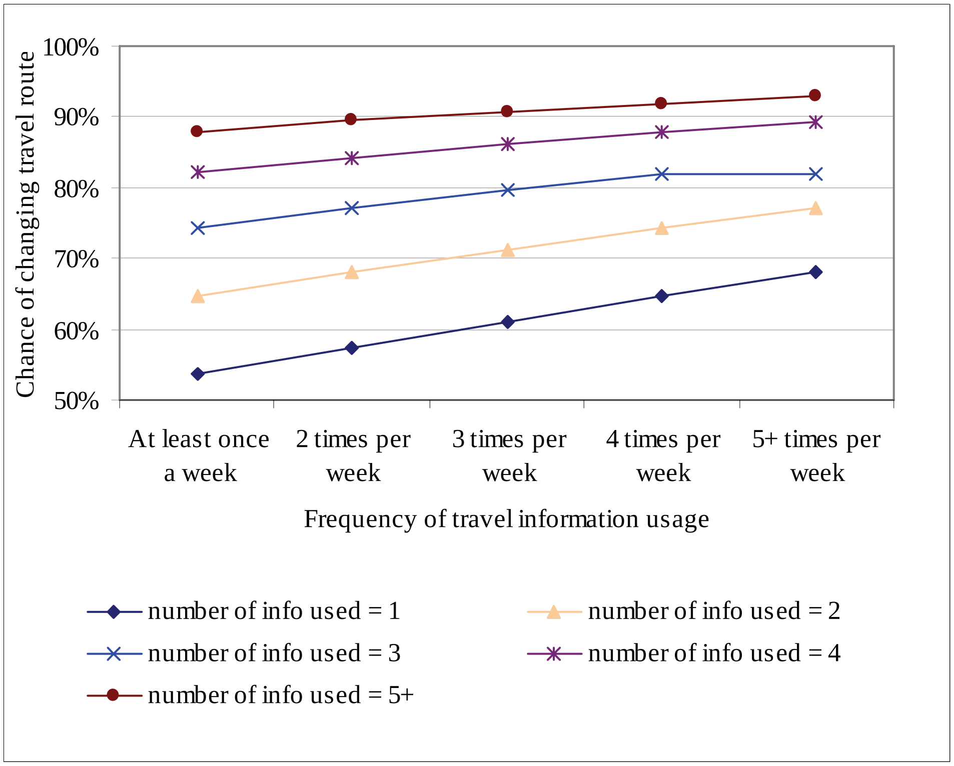


Figure 6.3 Marginal effects for frequency of travel information usage (N=2584)

Marginal effects are calculated by using the following formula:

$$P(ChangeRoute) = \frac{e^{(-3.12+0.47\times X_1+1.40\times X_2)}}{1+e^{(-3.12+0.47\times X_1+1.40\times X_2)}} \qquad (6.3)$$

(X_1 = frequency of information usage; X_2 = level of travel information acquisition)

Figure 6.4 shows the relationship between travel route changes and acquisition from various types of information sources, for different values of the other independent variable (frequency of information usage). The marginal effects suggest that the chance of changing route decision will significantly increase when people acquire information from several devices, i.e., Internet, radio, VMS, TV. Also, the jump in probability of change is considerable when travelers go from using one source to two sources of information. Figure 6.5 shows the same results for people who are information seekers. Clearly, their chances of route changes are higher than when all respondents are considered together.

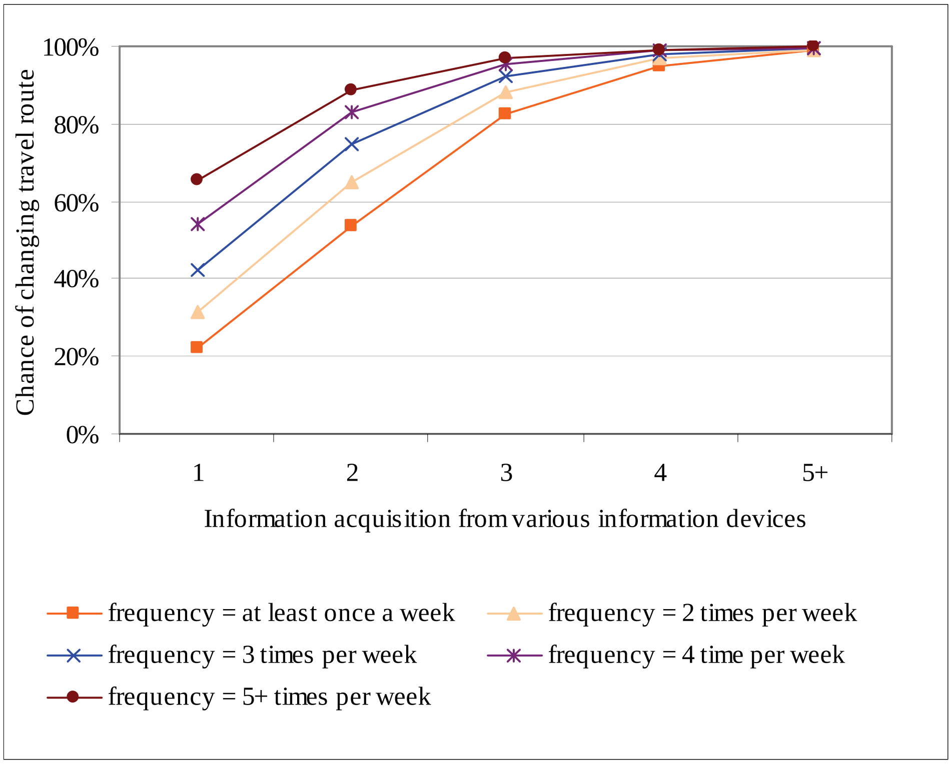


Figure 6.4 Marginal effects for level of traffic information acquisition (N=5107).

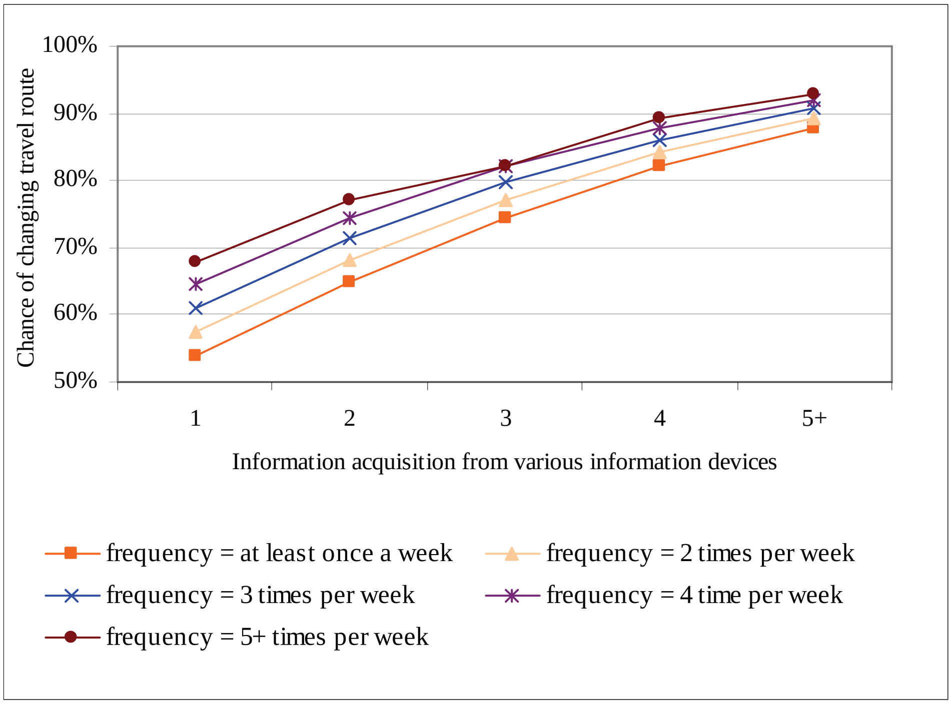


Figure 6.5 Marginal effects for level of traffic information acquisition (N=2584).

Respondents' daily travel time was added as a key control variable, with the expectation that those experiencing longer travel times will be more likely to divert. The variables in the models are further separated by work-related and non-work-related travel time.

Table 6-6 Statistical results for two Logit models of travel behavior changes

	Model 1 Travel decision changes (change time, mode, route or cancel trip)		Model 2 Route change only	
	Coefficients	Odds ratio	Coefficients	Odds ratio
Constant	-3.237***	--	-3.272***	--
Frequency of information usage	0.509***	1.664***	0.467***	1.596***
Information acquisition from electronic sources	1.735***	5.666***	1.397***	4.042***
Work-related travel time (mins)	0.003**	1.003**	0.004***	1.004***
Non-work-related travel time (mins)	0.001*	1.001*	0.001*	1.001*
Pseudo-R^2		0.53***		0.45**

Notes:
Case number = 5107
*** - P-value <= 0.01; ** - P-value <= 0.05; * - P-value <= 0.1
Odds ratio = exp (coefficient)
The variable traffic information acquisition (X_2), is coded as 0 if respondents stated that they never used traffic information before.

Table 6-6 shows the model results including travel time as an explanatory variable. It provides similar results to those in

Table 6-4, in terms of their Pseudo-R^2, sign and magnitudes of independent variables. Furthermore, work-related travel time has a statistically significant effect on people's probability of changing travel decisions (5% level), whereas the effect of non-work-related travel time is only marginally significant at the 10% level. Longer work related travel time has a stronger effect compared with non-work-related travel time. The odds ratios indicate that a 10 minute increase in work travel time increases the chances of diversion by 3% (4% for route diversion). Similarly, a 10 minute increase in non-work-related travel time increases the chances of change by 1%. The results confirm that expectations that with longer travel times, especially commute times, people are more likely change their travel decisions.

6.3.2 ATIS technology effects on travel decision

Table 6-7, Table 6-10 and Table 6-13 provide insights regarding impacts of various information technologies for the entire set of respondents (N=5107). Among information technologies, the Internet is associated with a higher propensity to change travel decisions, followed by the radio and television (as indicated by the magnitude of the coefficients and odds ratios). Presently, the Internet is generally available during the pre-trip stage and hence it seems to influence travel changes relatively more than en-route changes. The radio has greater influence on route changes, owing to its ubiquitous presence in passenger cars.

These results are consistent with the literature and point to potentially greater investments by NCODT in enhancing the Internet-based travel information, e.g., by allowing customization of information to individuals and expanded coverage of traffic through video cameras.

Presently, Variable Message Signs (VMS) and Highway Advisory Radio (HAR) are not statistically significantly associated with travel decision changes, perhaps due to their low levels of deployment. Note that there were a total of 182 observations in this category, with some overlaps between VMS and HAR.

Table 6-8, Table 6-11, and Table 6-14 provide further insights regarding impacts of various information technologies for the entire set of respondents (N=2584). The goodness of fit (Pseudo-R2) for these models declines considerably. The effects of independent variables decrease and the signs of constants change direction, indicating that on average people interested in using traffic information are willing to change their travel choices.

Among information technologies, the Internet is still associated with a higher propensity to change travel decisions (among information seekers), followed by the radio and television. Also, “acquire info from TV or not” is not statistically significant any longer. Again, VMS and HAR are not statistically significantly associated with travel decision changes, even for information seekers.

Table 6-9, Table 6-12, and Table 6-15 provide results with travel time as a key control variable, keeping the sample size at 5107. The results are largely similar to the equivalent models. It was found that travel time has significant positive effect on people's travel decision changes; work-related travels have a stronger effect than non-work-related travel time.

Table 6-7 Statistical results for Logit models (without level of information acquisition)

	Model 1 Travel decision changes (change time, mode, route or cancel trip)		Model 2 Route change only	
	Coefficients	Odds ratio	Coefficients	Odds ratio
Constant	-2.26**	--	-2.40**	--
Frequency of information usage	0.85**	2.33**	0.74**	2.09**
Pseudo-R^2		0.43**		0.36**

Notes: Case number = 5107; ** - P-value <= 0.01; Odds ratio = exp (coefficient)
Variables are coded as 0 if respondents stated that they never used traffic information before.

Table 6-8 Statistical results for Logit models (without level of information acquisition)

	Model 1 Travel decision changes (change time, mode, route or cancel trip)		Model 2 Route change only	
	Coefficients	Odds ratio	Coefficients	Odds ratio
Constant	0.69**	--	0.20*	--
Frequency of information usage	0.16**	1.17**	0.15**	1.16**
Pseudo-R^2		0.01**		0.01**

Notes: Case number = 2584; ** - P-value <= 0.01; * - P-value <= 0.1; Odds ratio = exp (coefficient)

Table 6-9 Statistical results for Logit models (without level of information acquisition)

	Model 1 Travel decision changes (change time, mode, route or cancel trip)		Model 2 Route change only	
	Coefficients	Odds ratio	Coefficients	Odds ratio
Constant	-2.444**	--	-2.592**	--
Frequency of information usage	0.841**	2.319**	0.731**	2.077**
Work-related travel time (mins)	0.003**	1.003**	0.004**	1.004**
Non-work-related travel time (mins)	0.002**	1.002**	0.002**	1.002**
Pseudo-R^2		0.43**		0.36**

Notes: Case number = 5107; ** - P-value <= 0.01; Odds ratio = exp (coefficient)

Variables are coded as 0 if respondents stated that they never used traffic information before.

Table 6-10 Statistical results for information acquisition technologies using Logit models (with three types of information acquisition technologies)

	Model 1 Travel decision changes (change time, mode, route or cancel trip)		Model 2 Route change only	
	Coefficients	Odds ratio	Coefficients	Odds ratio
Constant	-3.16**	--	-3.15**	--
Frequency of information usage	0.54**	1.71**	0.49**	1.63**
Acquire info from Internet or not	2.54**	12.64**	1.67**	5.33**
Acquire info from radio or not	1.93**	6.89**	1.95**	7.06**
Acquire info from TV or not	1.56**	4.76**	1.08**	2.96**
Pseudo-R^2		0.54**		0.46**

Notes: Case number = 5107; ** - P-value <= 0.01; Odds ratio = exp (coefficient)

Variables are coded as 0 if respondents stated that they never used traffic information before.

Table 6-11 Statistical results for information acquisition technologies using Logit models (with three types of information acquisition technologies)

	Model 1 Travel decision changes (change time, mode, route or cancel trip)		Model 2 Route change only	
	Coefficients	Odds ratio	Coefficients	Odds ratio
Constant	0.16	--	-0.34*	--
Frequency of information usage	0.19**	1.21**	0.17**	1.18**
Acquire info from Internet or not	0.84**	2.31**	0.48**	1.62**
Acquire info from radio or not	0.61**	1.83**	0.97**	2.64**
Acquire info from TV or not	-0.04	0.96	-0.08	0.92
Pseudo-R^2		0.04**		0.05**

Notes: Case number = 2584; ** - P-value <= 0.01; * - P-value <= 0.1; Odds ratio = exp (coefficient)

Table 6-12 Statistical results for information acquisition technologies using Logit models (with three types of information acquisition technologies)

	Model 1 Travel decision changes (change time, mode, route or cancel trip)		Model 2 Route change only	
	Coefficients	Odds ratio	Coefficients	Odds ratio
Constant	-3.309***	--	-3.287***	--
Frequency of information usage	0.532***	1.703***	0.484***	1.622***
Acquire info from Internet or not	2.538***	12.654***	1.675***	5.338***
Acquire info from radio or not	1.905***	6.723***	1.931***	6.895***
Acquire info from TV or not	1.572***	4.817***	1.098***	2.999***
Work-related travel time (mins)	0.003**	1.003**	0.003**	1.003**
Non-work-related travel time (mins)	0.001*	1.001*	0.001*	1.001*
Pseudo-R^2		0.54***		0.46***

Notes: Case number = 5107; *** - P-value <= 0.01; ** - P-value <= 0.05; * - P-value <= 0.1;
Odds ratio = exp (coefficient)
Variables are coded as 0 if respondents stated that they never used traffic information before.

Table 6-13 Statistical results for information acquisition technologies using Logit models (with four types of information acquisition technologies)

	Model 1 Travel decision changes (change time, mode, route or cancel trip)		Model 2 Route change only	
	Coefficients	Odds ratio	Coefficients	Odds ratio
Constant	-3.16**	--	-3.15**	--
Frequency of information usage	0.53**	1.70**	0.49**	1.63**
Acquire info from Internet or not	2.55**	12.76**	1.67**	5.34**
Acquire info from radio or not	1.95**	7.02**	1.96**	7.07**
Acquire info from TV or not	1.57**	4.82**	1.09**	2.96**
Acquire info from VMS/HAR or not	-0.25	0.78	-0.02	0.98
Pseudo-R^2		0.54**		0.46**

Notes: Case number = 5107; ** - P-value <= 0.01; Odds ratio = exp (coefficient)

Variables are coded as 0 if respondents stated that they never used traffic information before.

Table 6-14 Statistical results for information acquisition technologies using Logit models (with four types of information acquisition technologies)

	Model 1 Travel decision changes (change time, mode, route or cancel trip)		Model 2 Route change only	
	Coefficients	Odds ratio	Coefficients	Odds ratio
Constant	0.15	--	-0.34*	--
Frequency of information usage	0.19**	1.21**	0.17**	1.18**
Acquire info from Internet or not	0.85**	2.33**	0.47**	1.61**
Acquire info from radio or not	0.62**	1.86**	0.97**	2.63**
Acquire info from TV or not	-0.03	0.97	-0.09	0.92
Acquire info from VMS/HAR or not	-0.14	0.87	0.07	1.07
Pseudo-R^2		0.04**		0.05**

Notes: Case number = 2584; ** - P-value <= 0.01; * - P-value <= 0.1; Odds ratio = exp (coefficient)

Table 6-15 Statistical results for information acquisition technologies using Logit models (with four types of information acquisition technologies)

	Model 1 Travel decision changes (change time, mode, route or cancel trip)		Model 2 Route change only	
	Coefficients	Odds ratio	Coefficients	Odds ratio
Constant	-3.310***	--	-3.288***	--
Frequency of information usage	0.531***	1.701***	0.484***	1.622** *
Acquire info from Internet or not	2.548***	12.784***	1.676***	5.345** *
Acquire info from radio or not	1.924***	6.849***	1.933***	6.911***
Acquire info from TV or not	1.585***	4.881***	1.100***	3.003***
Acquire info from VMS/HAR or not	-0.259	0.772	-0.028	0.972
Work-related travel time (mins)	0.003**	1.003**	0.003**	1.003**
Non-work-related travel time (mins)	0.001*	1.001*	0.001*	1.001*
Pseudo-R^2		0.54***		0.46***

Notes: Case number = 5107; *** - P-value <= 0.01; ** - P-value <= 0.05; * - P-value <= 0.1;
Odds ratio = exp (coefficient)
Variables are coded as 0 if respondents stated that they never used traffic information before.

Sample selection models may be estimated that will be able to fully account for the conditionality that exists between information acquisition and travel decision changes based on travel information.

6.3.3 Socio-economic factors with ATIS

Table 6-16 shows the socioeconomic characteristics of the sample. About 60.1% of the respondents were females. The distribution of respondents in terms of age groups was mostly even, except for the less than 20 and greater then 65 age groups. Almost 80 percent had at least some college experience. About 66.6% have a job. 42.9% have lived in current area more then 10 years.

Table 6-16 Socioeconomic Characteristics

Attribute	Range	Counts	%
Gender	Male	2035	39.9
	Female	3071	60.1
Age	<20	13	0.3
	20 ~ 29	376	7.4
	30 ~ 39	851	16.7
	40 ~ 49	1093	21.4
	50 ~ 64	1674	32.8
	>65	1100	21.5
Education	< High school	226	4.4
	High school graduate	784	15.4
	Some college	712	14.0
	Associate or technical school degree	476	9.3
	Bachelor	1532	30.0
	Graduate	1370	26.9
Employment	Full time	2837	55.6
	Part time	562	11.0
	Not Employed	1708	33.4
Household Income	<$15,000	314	6.5
	$15,000 ~ $24,999	370	7.7
	$25,000 ~ $34,999	406	8.4
	$35,000 ~ $49,999	743	15.4
	$50,000 ~ $74,999	1000	20.7
	$75,000 ~ $99,999	785	16.3
	$100,000 or more	1204	25.0
Length lived	<1 year	432	8.5
	1 ~ 2 years	414	8.1
	2 ~ 5 years	1032	20.2
	5 ~ 10 years	1039	20.3
	More than 10 years	2189	42.9

Travelers can get information from various sources such as TV, commercial radio, Internet, VMS, HAR, 511 and others. Users' socio-economic characteristics would be important factors for their preference on the selecting information sources and travel decision changes. From the survey data, demographic variables including gender, age, education level, employment, income, and length lived in current address were investigated. Cross classification tables were made to see the relationship of each demographic variable with: frequency of information seeking, selection of information source, and travel decision change.

Traveler who got traveler information makes his/her travel decision base on the information. Users' travel decision change could be effected by the types of information sources. The types of information sources are chosen depending on the time when users seek information or the information quality which they want. If drivers who need to arrive work place on time may seek more detail traffic information from more active way. Also, their travel decision might be aggressive. To investigate specific ATIS technologies effects on travelers' decision, cross classification tables were made.

Figure 6.6 shows the relationship between demographic variables and frequency of information seeking. Graphs present higher frequency by higher education, full time worker and higher income. Gender or length lived do not seem to have different on frequency of information seeking. Figure 6.7 depicts the demographic effects on the selection of information source. It shows female, old, lower education, non-worker and low income group prefer TV. Figure 6.8 presents the relationship between demographic variables and travel decision change options. The graphs tell male, ages 30 to 50, lower education, full time worker, low income group prefer to change route. One can guess that the working group prefers to change their route because they have pressure to arrive at their work place on time.

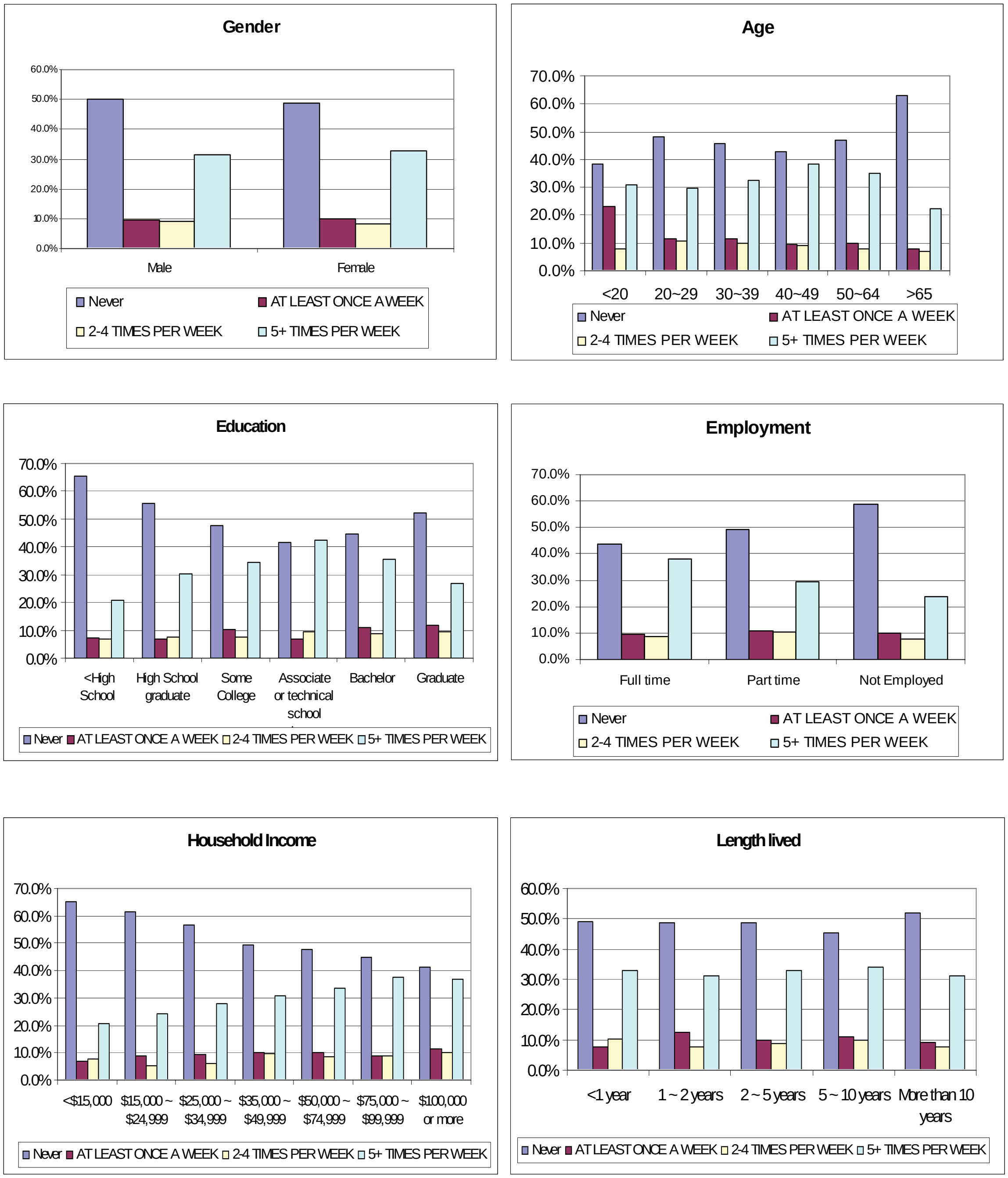


Figure 6.6 Frequency of information seeking

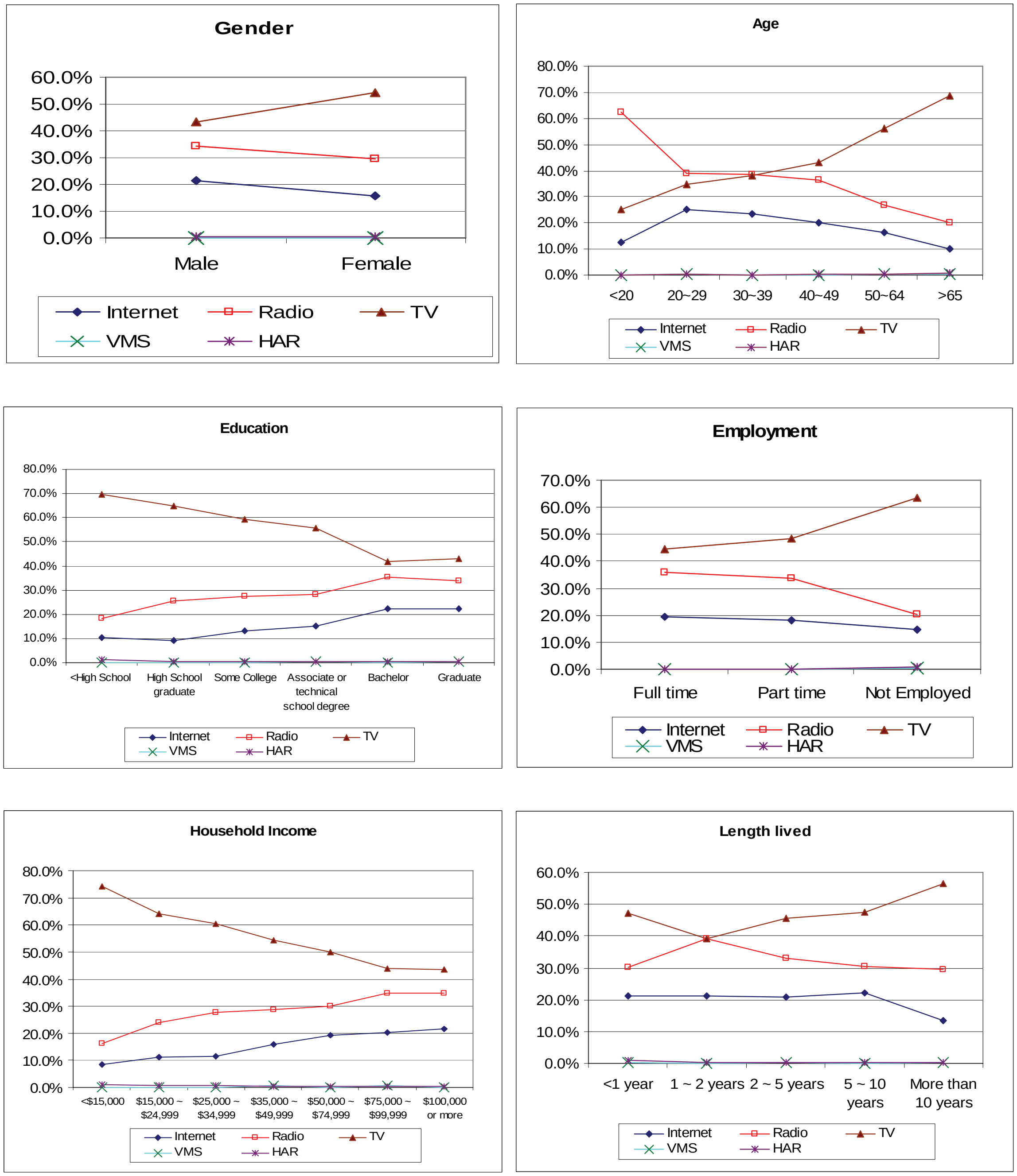


Figure 6.7 Information source preference

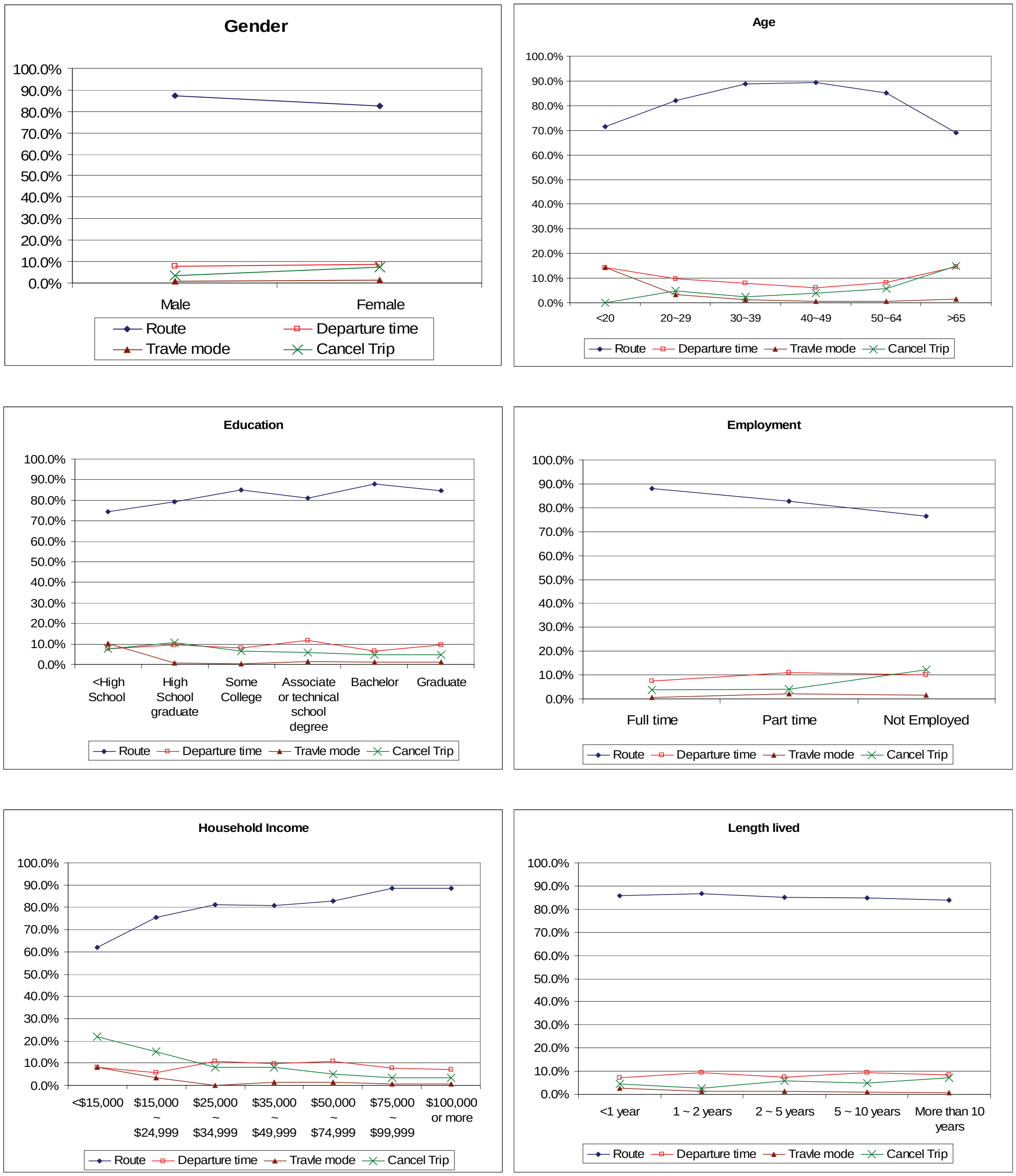


Figure 6.8 Travel decision change

Statistical results shown in Table 6-17,Table 6-18,Table 6-19, and Table 6-20 indicate socio-economic characteristics associated with whether people choose to acquire electronic travel information. Table 6-19 and Table 6-20 test for non-linear effects of income and age on peoples' decisions to acquire electronic information.

In terms of data, note that most of the socio-economic characteristics were in the person file, while the travel information data were contained in the household file. (Clearly, each household will have one or more people.) The individuals in the person file who filled out the household survey questions were first identified. Then their socio-economic characteristics are linked with the corresponding information-related data. Therefore, employment status, number of jobs held, work location, and education level are all for the person who filled the household survey questions (most likely the household head). Some of the other variables are at the household level, including income, household size, and automobile ownership. Education is measured as follows: 1=<high school, 2=high school graduate, 3=some college, 4= associate or technical school degree, 5=bachelor, 6=graduate. These were not recoded and are treated as interval variables in this analysis. Household income was recoded as the median value of the corresponding category intervals, which was treated as interval data. The unit of analysis is a person.

The model in Table 6-17 is statistically significant overall, although the model goodness of fit is on the lower side. The negative constant indicates that on average survey respondents in the Research Triangle area are unwilling to acquire electronic travel information despite the availability of several electronic information sources/devices. Higher propensity to acquire travel information is associated with larger households, higher income levels and automobile ownership, and employment, especially outside the home. In addition, females and younger adults are more likely to acquire travel information.

Table 6-17 Statistical results for the Logit model of socio-economic characteristics

	Frequency of travel information usage (yes=1, no=0)	
	Coefficients	Odds ratio
Constant	-0.346*	--
Household size	0.063**	1.06**
Household vehicle number	0.093***	1.10***
Length lived (years)	0.001	1.00
Household income ($1000)	0.006***	1.01***
Gender (male=1, female=0)	-0.205***	0.81***
Age (years)	-0.008***	0.99***
Employed (yes=1, no=0)	0.216**	1.24**
Number of jobs	0.033	1.03
Work Location (outside home=1, otherwise=0)	0.173**	1.19**
Education (level)	-0.036*	0.96*
Pseudo-R^2		0.03***

Notes: Case number N = 4754;
*** - P-value <= 0.01; ** - P-value <= 0.05; * - P-value <= 0.1;
Odds ratio = exp (coefficient)
When variable "Employed" is no (1,289 cases), then "Work Location" was not specified.
In this case, the Work Location was coded as zero.

Table 6-18 shows us the model results when considering travel time as one of the important predictors on people's travel information acquirement. The results are very similar to those in Table 6-17, although respondents' employment status and education are not statistically significant any more. As expected, travel times are statistically significant, indicating that people who spend more time traveling, especially for work purposes, are more likely to access information.

Table 6-18 Statistical results for the Logit model of socio-economic characteristics

	Frequency of travel information usage (yes=1, no=0)	
	Coefficients	Odds ratio
Constant	-0.346*	--
Household size	0.065**	1.067**
Household vehicle number	0.085**	1.089**
Length lived (years)	0.001	1.001
Household income ($1000)	0.006***	1.006***
Gender (male=1, female=0)	-0.233***	0.792***
Age (years)	-0.007***	0.993***
Employed (yes=1, no=0)	0.148	1.160
Number of jobs	0.017	1.018
Work Location (outside home=1, otherwise=0)	0.184**	1.202**
Education (level)	-0.033	0.967
Work-related travel time (mins)	0.004***	1.004***
Non-work-related travel time (mins)	0.002***	1.002***
Pseudo-R^2		0.04***

Notes: Case number = 4754;
*** - P-value <= 0.01; ** - P-value <= 0.05; * - P-value <= 0.1;
Odds ratio = exp (coefficient)

Table 6-19 tests for non-linear effects by adding squared terms for household income and age to the model specification. Note that income squared is not statistically significant, so the non-linearity hypothesis is not confirmed for in the case of income. However, age effects are non-linear. Very young adults and older people are relatively less likely to acquire electronic travel information compared with those falling in the middle categories. The chances of travel information acquisition (Y-axis) versus age (X-axis) can be represented by an inverted U-shape.

Table 6-19 Statistical results for the Logit model of socio-economic characteristics

	Frequency of travel information usage (yes=1, no=0)	
	Coefficients	Odds ratio
Constant	-1.285***	--
Household size	0.058**	1.06**
Household vehicle number	0.082**	1.09**
Length lived (years)	-0.004	1.00
Household income ($1000)	0.013***	1.01***
Household income-squared	-0.00006	1.00
Gender (male=1, female=0)	-0.195***	0.82***
Age (years)	0.032**	1.03**
Age-squared	-0.0004***	0.9996***
Employed (yes=1, no=0)	0.147	1.16
Number of jobs	0.032	1.03
Work Location (outside home=1, otherwise=0)	0.181**	1.20**
Education (level)	-0.038*	0.96*
Pseudo-R^2		0.03***

Notes: Case number = 4754;
*** - P-value <= 0.01; ** - P-value <= 0.05; * - P-value <= 0.1;
Odds ratio = exp (coefficient)

Table 6-20 provides model results when taking account of the effect of travel time on respondents' travel information acquirement. One the one hand, it shows largely similar results to the equivalent model (Table 6-19). On the other hand, travel time is found to be positively associated with people's travel information acquisition, where work-related travel time has a slightly stronger effect than non-work-related work travels.

Table 6-20 Statistical results for the Logit model of socio-economic characteristics

	Frequency of travel information usage (yes=1, no=0)	
	Coefficients	Odds ratio
Constant	-1.435***	--
Household size	0.060**	1.062**
Household vehicle number	0.075**	1.078**
Length lived (years)	-0.003	0.997
Household income ($1000)	0.012**	1.012**
Household income-squared	-0.00005	0.99994
Gender (male=1, female=0)	-0.222***	0.801***
Age (years)	0.031**	1.031**
Age-squared	-0.0004***	0.9996***
Employed (yes=1, no=0)	0.084	1.088
Number of jobs	0.017	1.017
Work Location (outside home=1, otherwise=0)	0.193**	1.212**
Education (level)	-0.036*	0.965*
Work-related travel time (mins)	0.004***	1.004***
Non-work-related travel time (mins)	0.002***	1.002***
Pseudo-R^2		0.04***

Notes: Case number = 4754;
*** - P-value <= 0.01; ** - P-value <= 0.05; * - P-value <= 0.1;
Odds ratio = exp (coefficient)

These results help identify market segments that can be targeted to increase people's awareness of available travel information sources/devices. For example, informing males and older adults about the availability of travel information may increase the awareness of traveler information services.

6.3.4 Why do people not acquire electronic travel information?

Although a relatively large portion of the respondents to the Research Triangle survey reported not acquiring electronic travel information, the Triangle survey did not ask questions about why people do not acquire information. However, the literature shows that answers to this question exist in other contexts. Specifically, there were two behavioral surveys conducted in the Bay Area, as part of the TravInfo field operational test (*Yim 2001*). Both had sample sizes of 1000 each and were conducted in 1995 and 1998. Approximately one third of the survey participants were classified as non-users of information in the 1998 survey.

The key reasons for not listening to traffic reports were the unavailability of alternate routes and inadequate geographic coverage. Table 17 in the Yim (*2001*) study, reproduced below (Table 7.21), shows further details of the responses to the surveys. The two surveys were done randomly and independently so they do not represent the same individuals. The Table shows that nearly 60% in the 1995 survey and 50% in the 1998 survey said that the key reason is that traffic reports rarely cover their routes. Other reasons included "not being able to understand traffic reports" and "do not usually listen to the radio or television."

In the Bay Area, this was a time when traffic information was rapidly becoming available through several sources. Potentially useful information from these results is that over time, respondents seem to have become more adept at acquiring and using travel information, they seem to have learned about alternate route availability and travel information coverage seems to have improved (as has refusal to answer this question).

A key lesson from the surveys was that in order to attract those who currently do not acquire traffic information, the following strategies should be considered:

- Providing personalized traffic information services (such as telephone services and Information Service Providers)
- Expanded geographic coverage of travel information (including surface streets)
- Providing both static and real time traffic information.

Table 6-21 Reasons for not acquiring traffic information.

Question: Why do not you get traffic or travel reports from radio, television, or over the telephone? (Asked as an open-ended question)

Reasons	1995 Survey Commuters/non-commuters & personal vehicle/transit users (n = 269)	1998 Survey Commuters/non-commuters & personal vehicle/transit users (n = 342)
Do not usually listen to the radio or television	17.7%	18.4%
Traffic report rarely cover the routes I take	54.4%	47.4%
No alternate routes available	5.4%	16.7%
Traffic reports are unreliable	1.9%	7.6%
Cannot understand the traffic report	2.3%	1.2%
Not sure/DK	5.0%	8.2%
Refused/NA	13.1%	0.6%

Source: Table 17 (Yim, 2001).

6.4 Conclusion

Based on the 2006 Triangle survey, the behavioral analysis has provided insights and answers to questions raised in the study. Specific findings include:

- Travel decision changes (change route, time, mode, or cancel trip) are statistically significantly associated with the frequency of traffic information use, and the quantity of information sources used, after controlling for travel times.
- Among information technologies, the Internet is associated with a higher propensity to change travel decisions, followed by radio and television. Presently, Variable Message Signs (VMS) and Highway Advisory Radio are not associated with travel decision changes, perhaps due to their low levels of deployment. The important lesson for NCDOT is that enhancing the SMARTLINK website should receive high priority, e.g., it can be enhanced by providing travelers with personalized traffic information services,

expanded geographic coverage (such as installing video cameras on I-440 in Raleigh), and providing both static and real time traffic information.

- Interestingly, the radio exercises a greater influence on route changes than the Internet does, owing to the ubiquitous presence of the radio in passenger vehicles. Clearly, better provision of (commercial and public sector) radio traffic information can be helpful to users in their navigation decision making.
- Greater traffic information acquisition is associated with females, middle aged adults, and higher income, people who are employed and work outside their home, own more automobiles and live in larger households. The converse of these market segments can be targeted to increase their awareness of electronic travel information available to general public. Based on the literature, the key reasons for not listening to traffic reports were the unavailability of alternate routes and inadequate geographic coverage, indicating that NCDOT might want to review travel information coverage and consider expansion.

CHAPTER 7. CASE STUDY BASED ATIS EVALUATION

In Task 9, the effects of several ATIS deployments were evaluated for a selected real world study area using the two ATIS evaluation tools, DYNASMART-P and FREEVAL. This chapter described the scenarios analyzed and the evaluation results.

7.1 Case study scenarios

7.1.1 Tools Evaluated

DYNASMART-P and IMAP (FREEVAL) emerged as promising ATIS evaluation tools from Task 2. Four incident and two work zone cases were simulated using the two tools.

DYNASMART-P has a dynamic traffic assignment model and a mesoscopic traffic simulator, meaning that it assigns traffic with time varying origin destination (OD) demand and simulates the movement of individual vehicles moving through a network in accordance with macroscopic flow rules (e.g., speed-density relationships). It has several route choice rules including dynamic system optimality, dynamic user optimality, and a bounded rationality rule. The last rule is designed for modeling traveler response to en-route information. Under this rule, drivers receiving en-route information about path conditions will only switch paths if the expected improvement exceeds a threshold amount. The effects of several ATIS alternatives can be estimated by comparing the diversion rates and network performances under the alternatives. Figure 7.1 shows the basic inputs and main outputs of DYNASMART-P.

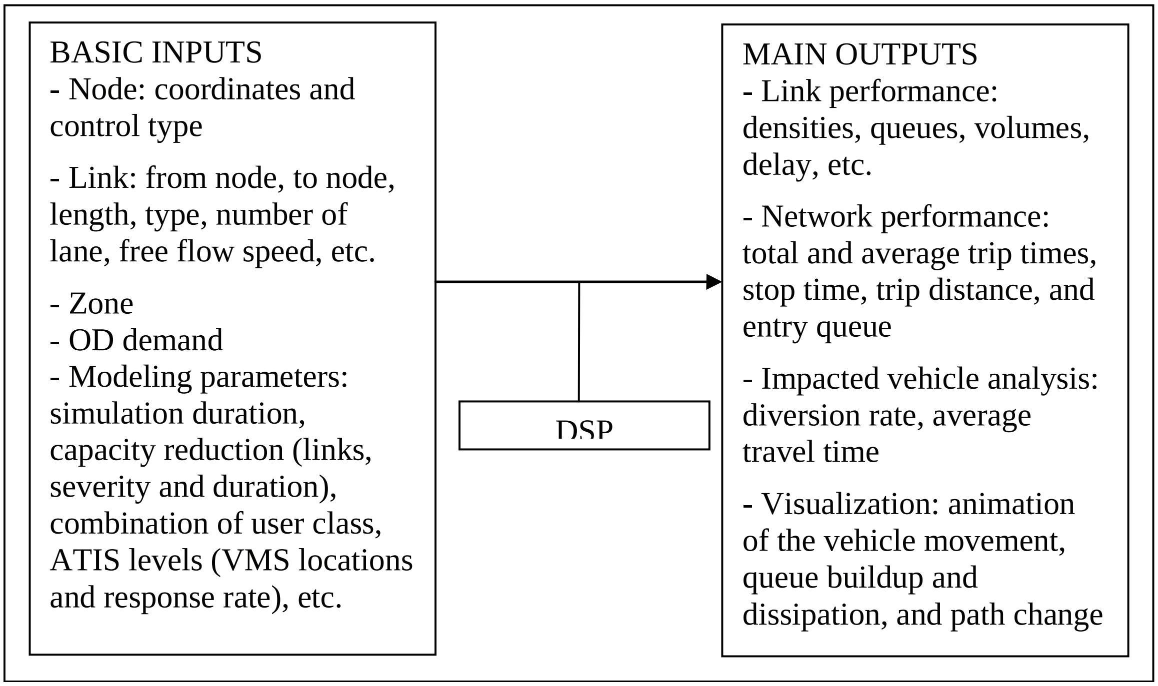


Figure 7.1 DYNASMART-P Inputs and Outputs

FREEVAL replicates the freeway facility methodology in Chapter 22 of the Highway Capacity Manual 2000 (*TRB, 2000*). It can model the effects of incidents / work zones on traffic operations macroscopically. One can model route diversion effects by shifting diverted demand to alternative route. Figure 7.2 shows the basic inputs that FREEVAL requires as well as the major outputs it provides. In this study, special focus was given to selected output performance measures such as total travel time and total delay.

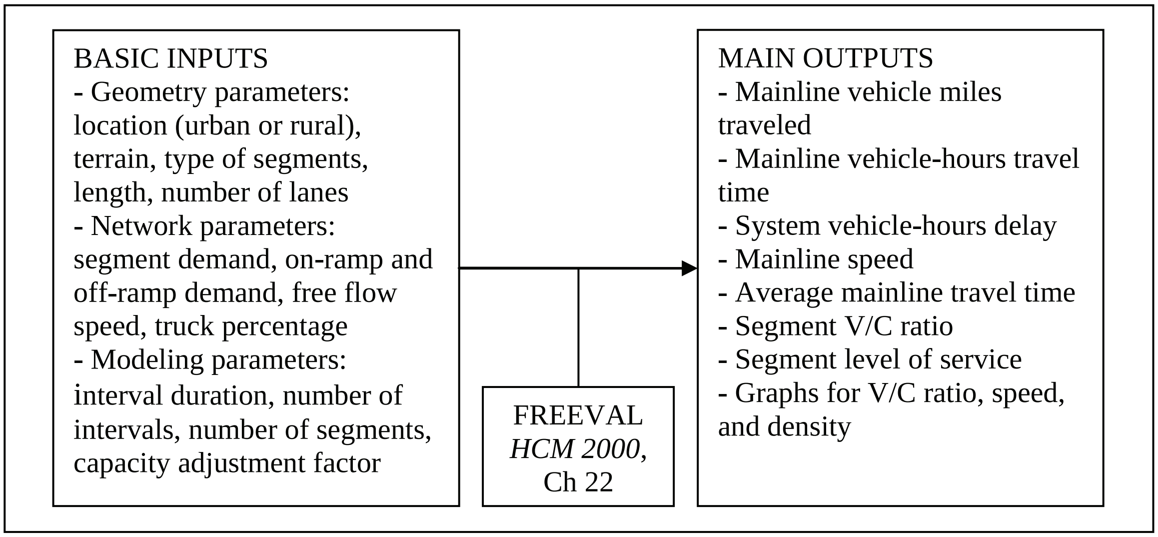
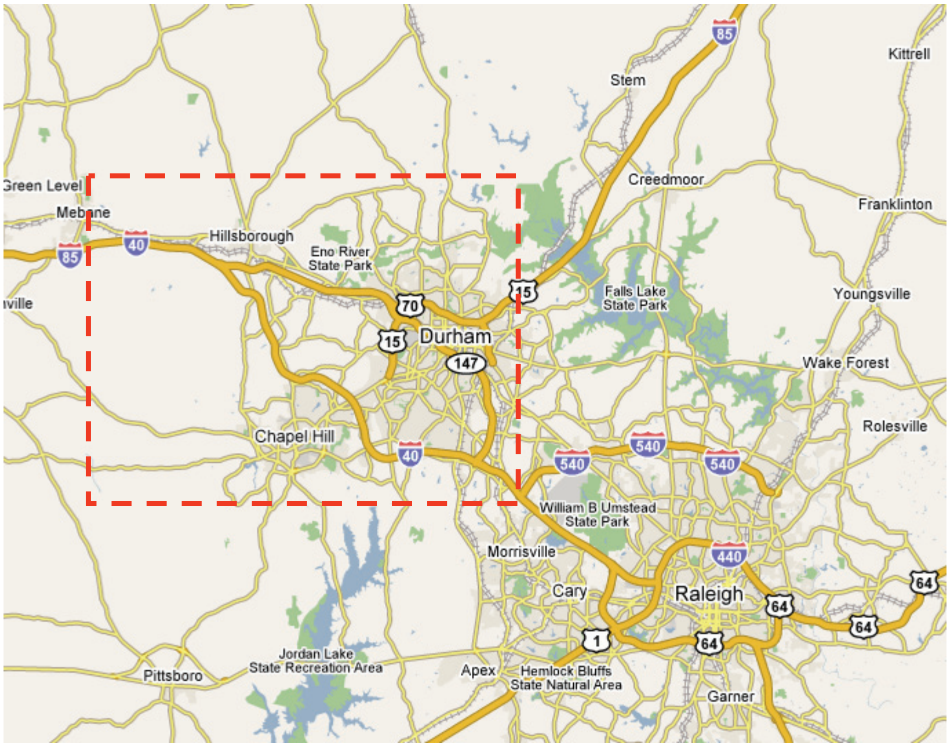


Figure 7.2 FREEVAL Inputs and Outputs

7.1.2 Location of the study network

Figure 7.3 shows the location of the study area, highlighted by the dotted rectangle. I-40, I-85, and NC-147 carry heavy through traffic and commuters in the Triangle region. Raleigh, Durham, and Chapel Hill are the major cities in the study area. The RTP (Research Triangle Park) in the study area is a major source of trip production especially during the AM and PM peak hours. The NCDOT has invested extensive effort to manage traffic in this area. These efforts include the installation of CCTVs and speed detectors to collect information. The NCDOT also provides traveler information through the Internet, 511, HAR, and VMS.



Map Source: Google map (http://maps.google.com)

Figure 7.3 Case Study Area

The selected area is an appropriate location for evaluating the effect of ATIS. A key reason is that route diversion behavior and the effects of the diversion can be measured explicitly because I-40 and I-85 are the best alternative routes for each other. Another reason is that a major repaving project on I-40 was underway during the case study phase of the project. This situation provided a real world work zone case study and enabled a simple speed-based validation of the ATIS evaluation models.

7.1.3 Case study scenarios

Four incidents and two work zones were chosen for the case study. Figure 7.4 shows the locations of the incidents and the work zones in the simplified network of the study area.

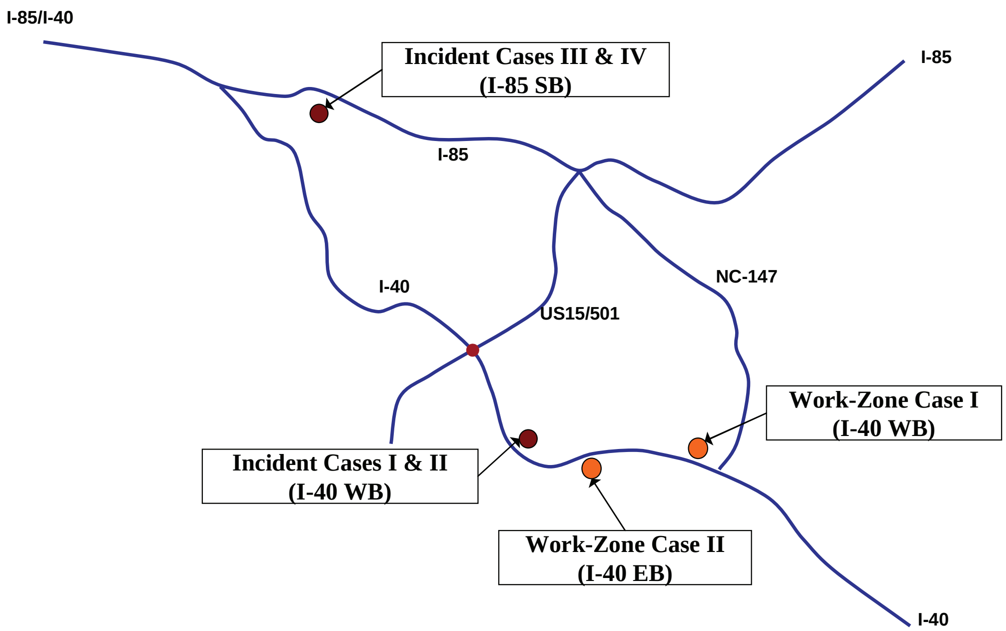


Figure 7.4 Simplified Network (I-40, I-85, NC-147) and Case Locations

Table 7-1 presents the incident parameters used in the case studies. The incident cases were studied during the morning peak hour (7 AM ~ 8 AM) to simulate the most severe impact of an incident. To understand the sensitivity of different levels of ATIS deployment, incident cases with different severities and durations were modeled. Note that Incident I and II affect traffic headed from the southeast to the northwest. Incident III and IV affect traffic headed from the northwest to southeast.

Table 7-1 Incident parameters used in the case studies

Case No.	Time	Location	Severity	Incident Duration
Incident I	AM peak time (7 am-8 am)	WB I-40, East of US-15/501	0.40 (60% capacity remaining)	30 minutes
Incident II			0.75 (25% capacity remaining)	45 minutes
Incident III		EB I-85, West of I-40 split	0.50 (50% capacity remaining)	30 minutes
Incident IV			0.75 (25% capacity remaining)	45 minutes

Severity means capacity reduction ratio due to an incident. The meanings of the severity levels used in the incident studies are as follows:

- Severity 0.40: one of the two lanes is closed, 60% of normal capacity remains
- Severity 0.50: one of the two lanes is closed, 50% of normal capacity remains
- Severity 0.75: two of the three lanes are closed, 25% of normal capacity remains

The location and the major diversion routes of Incident I and II are shown in Figure 7.5. Incident I and II have the same incident location but different incident severities. The location of Incident I and II is on I-40 westbound between Exit 274 and 273. The severities of Incident I and II are set to be 0.40 and 0.75, respectively. As shown in Figure 7.5, drivers before the I-40/NC-147 split on I-40 WB can take NC-147 NB and then take I-85 WB or US-15/501 SB to get back to I-40 WB, or if they get the incident information before they reach the I-40/I-540 junction, they can choose to divert to I-540 and take US-70.

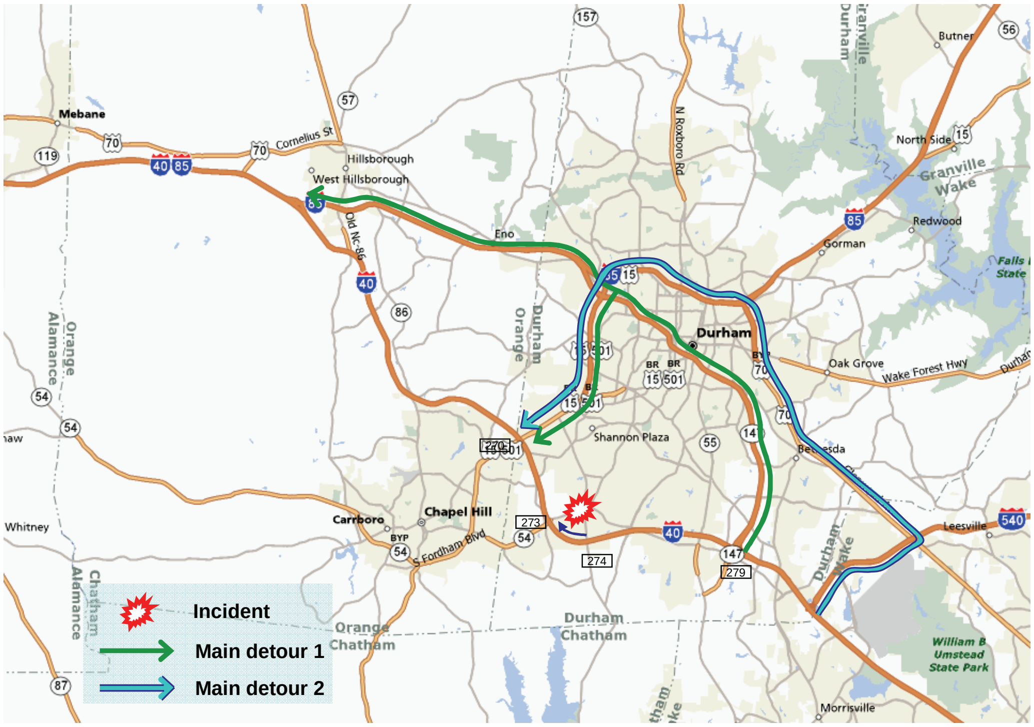


Figure 7.5 Location and Detours of Incident I and II

Figure 7.6 depicts the location and detours of Incident III and IV. The location is near Exit 170 on I-85 eastbound. Incident severities are 0.50 and 0.75 for Incident III and IV, respectively. Drivers who are traveling on I-85 EB, i.e., toward Durham can divert their travel routes based on traveler information. For example, if they get the incident information before they arrive at the I-85/I-40 split, they can take I-40 EB instead of I-85 EB and then take US15/501 to get back to I-85 or to take NC-147 to get to their destinations.

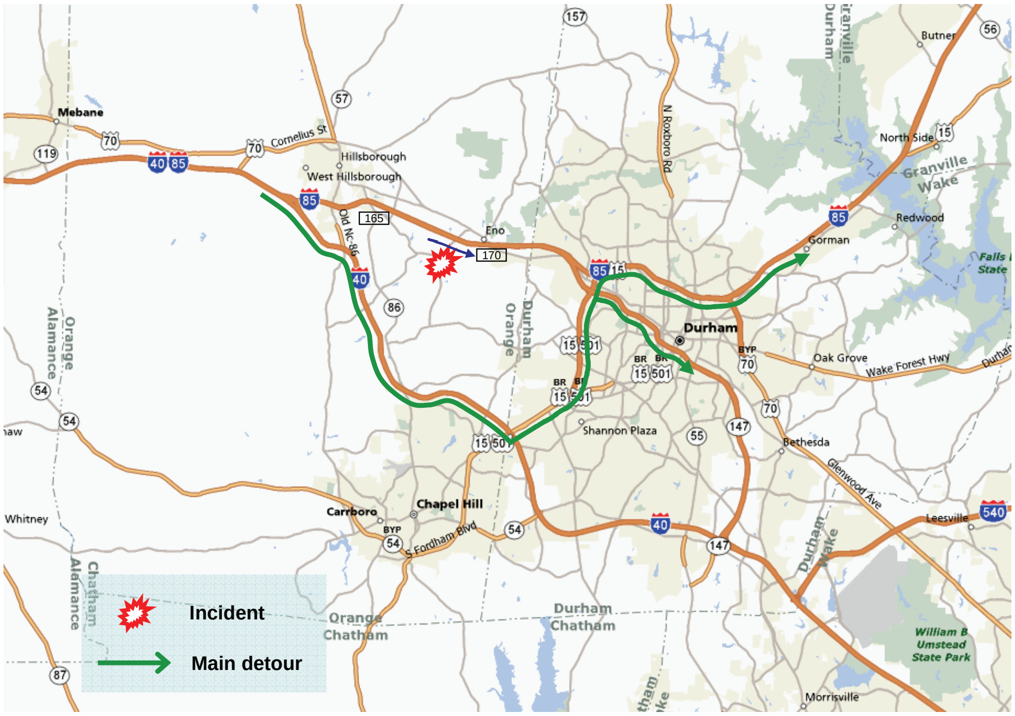
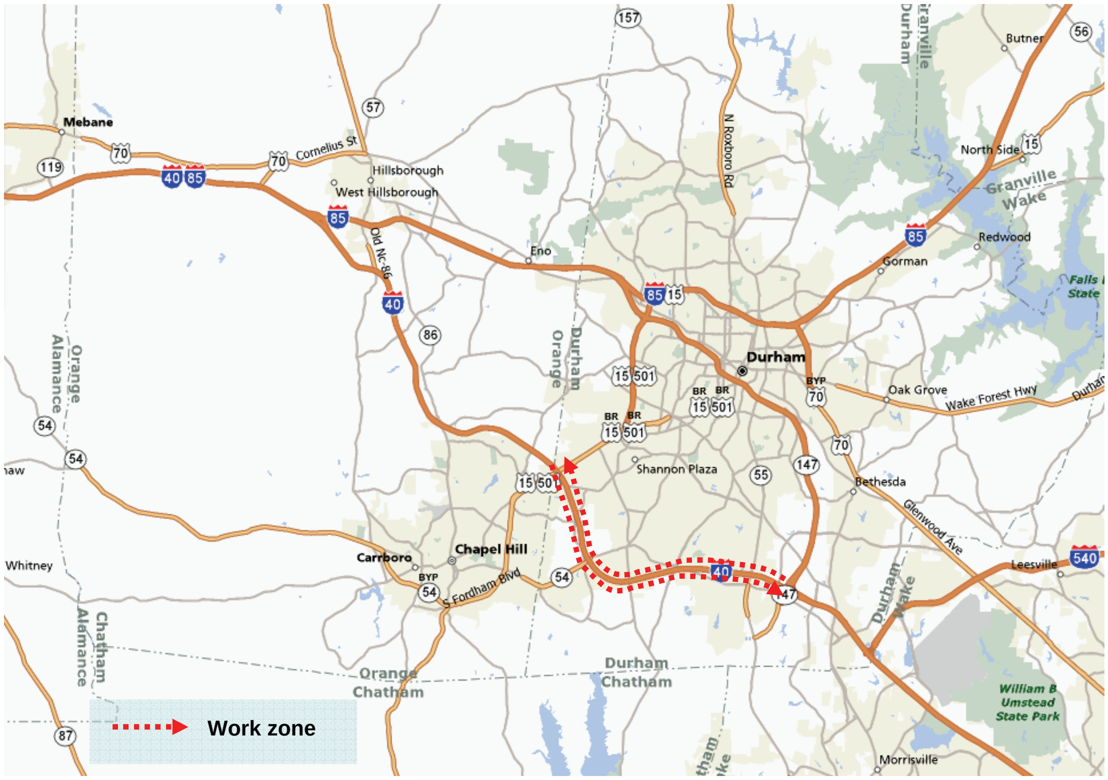


Figure 7.6 Location and Detours of Incident III and IV

For the work zone case studies, the I-40 resurfacing work was selected. The I-40 segment on which the resurfacing work was planned was from just east of the Orange/Durham County Line to just west of NC-147. Dotted lines in Figure 7.7 represent the work zone area. I-85, NC-147, and US-15/501 were used as main detours. Closing parts of lanes or narrowing a lane width was required for the resurfacing work. To avoid serious congestions and to reduce the effects of work on daytime travel, lane closure was limited to the time after 8:00 pm and before 6:00 am on weekday, after 8:00 pm and before 8:00am on Saturday, and after 8:00 pm and before 8:00 am on Sunday.



Map source: Google map

Figure 7.7 Work Zone Area

The construction work was performed in each direction separately and one lane of the three lanes remained open to traffic. As a result of the closure of two of the three lanes, the work zone section lost 75% of its capacity. Table 7-2 shows work zone parameters used in the work zone case studies. The two work zone cases were assumed to have the same capacity reduction and duration, but opposite in directions on I-40. Because weekdays have heavier traffic than weekend days, weekday construction was chosen to model more severe impacts of a construction work on traffic.

Table 7-2 Work zone parameters used in the case studies

Case No.	Effective Time	Location	Severity	Duration
Work Zone I	Weekdays 8 pm-6 am	WB I-40, just E of NC-147	0.75 (25% capacity remaining)	10 hours
Work Zone II		EB I-40, just W of NC-147	0.75 (25% capacity remaining)	

Figure 7.8 depicts the location and major diversion routes of Work zone I. Drivers who do not arrive the I-40/NC-147 split can take NC-147 NB and then take I-85 WB or US-15/501 SB to get back to I-40 WB. Drivers who have not arrived at the I-40/I-540 junction can divert to I-540 and then take US-70 in case of more severe congestion.

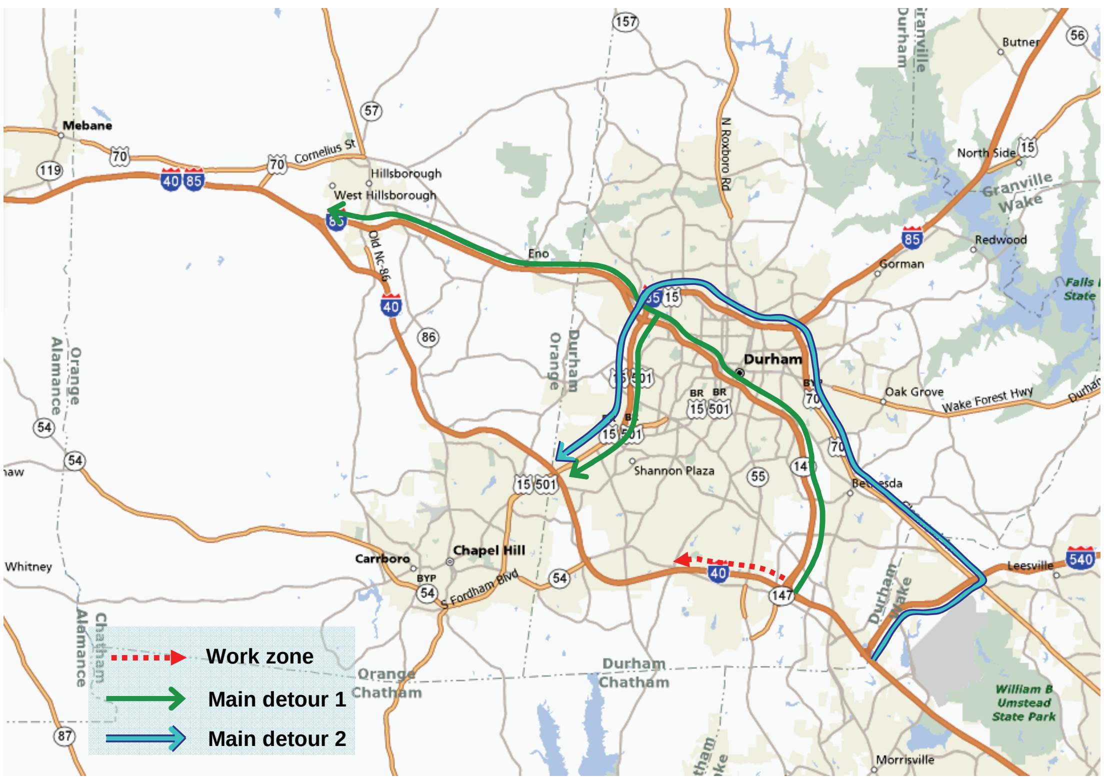


Figure 7.8 Location and Detours of Work Zone I

The location and major diversion routes of Work Zone II are presented in Figure 7.9. As seen in Figure 7.9, drivers who have not passed the I-85/I-40 split can take I-85 NB and then

NC-147 SB to get back to I-40 EB. If they have already passed the I-85/I-40 split traveling on I-40 EB, they could take US-15/501 NB and then NC-147 SB to get back to I-40 EB.

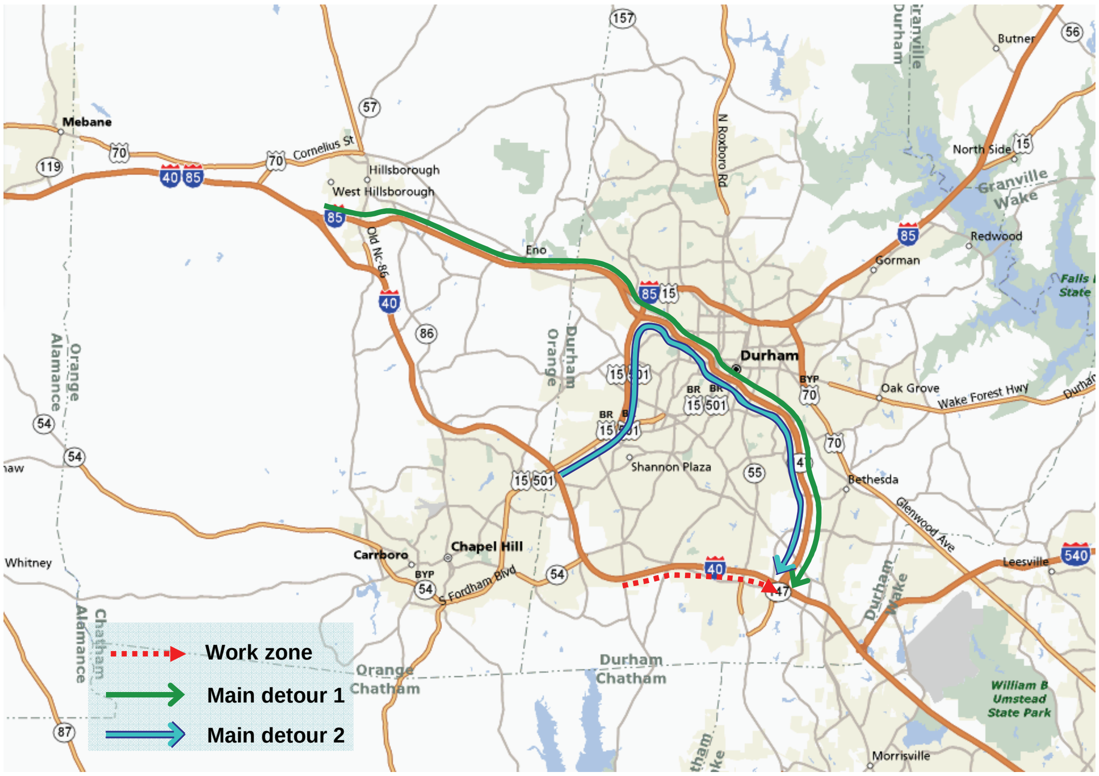


Figure 7.9 Location and Detours of Work Zone II

7.1.4 ATIS Levels Modeled in the Study

Each of the six cases has five scenarios. One of them is ‘no incident or work zone’ scenario which does not have incident nor work zone in network. Each case has four ATIS level scenarios, i.e., No ATIS (no path change), Existing ATIS, Planned ATIS Alternative I, and Planned ATIS Alternative II.

The “No ATIS” scenario refers to a situation that there is incident / work zone on the study network without ATIS deployment. Although travelers might identify incident-induced queues by themselves and take the diversion route if they were familiar with the regional network, the models assume that there is no diversion if there is no ATIS service provided.

According to the literature on some existing ATIS project/deployment, a wide range of diversion rates are associated with incident / work zone scenarios. For example, Khattak (*1991*) found that the diversion rate for delays of 10 minutes or more was about 30% for Chicago commuters. Pesti et al. (2004) reported that traffic condition information displayed on Changeable Message Signs (CMSs) only accounted for 4% diversion of mainline traffic from I-80 in Nebraska to avoid delays in a work zone. Horowitz et al. (2003) showed that the alternative-route selection rates ranged from 7% to 10% of the freeway traffic, depending on the location and the day of the week. Additionally, an automated work zone information system (AWIS), deployed near Los Angeles, California, showed the diversion rates were between 5.3 and 20.2%. (Kim et al. 2005). Generally, higher route diversion rates are observed when the delay on the main route is longer, the alternate route is available and shorter, and information is obtained from electronic sources. The diversion rate for work zone cases and incident cases are actually similar to each other based on the literature review, although one may intuitively expect the diversion rates at work zones to be higher than for incident cases. Therefore, in this study, the same diversion rates were set for incident and work zone scenarios with existing ATIS service, as well as scenarios with different planned ATIS alternatives.

For the scenario with existing ATIS service, the effect of existing ATIS within the study area provided either by the private sector (commercial radios, TV channels, Internet etc.) or by the public sector (SMARTLINK, VMS, HAR, 511 etc.) were modeled. According to the General ATIS evaluation in Task 8, about 30% of the respondents in the 2006 Triangle Travel Survey were willing to change their travel routes based on the traveler information they received. Since the rate of 30% is the upper-bound of the effect of the existing traveler information resources, each case-based diversion rate might be much lower than that upper-bound. Therefore, in this study, a 10% diversion rate was used to conservatively represent the effect of existing ATIS service. For scenarios with different planned ATIS alternatives, 20% and 30% diversion rates were assumed for Alternative I and II, respectively.

7.2 Case study using DYNASMART-P

7.2.1 Network preparation

The TRM (Triangle Regional Model) provides network data such as nodes, links, zones information, and OD demands for building a DYNASMART-P network. Figure 7.10 depicts the TRM network. It has 11,218 nodes, 15,078 links, and 2,389 zones. TRM has three OD matrices: AM peak 4 hours, PM peak 4 hours, and off peak 16 hours. Each OD matrix includes the demand by three vehicle types, i.e., HOV (High Occupancy Vehicle), SOV (Single Occupancy Vehicle), and CV (Commercial Vehicle).

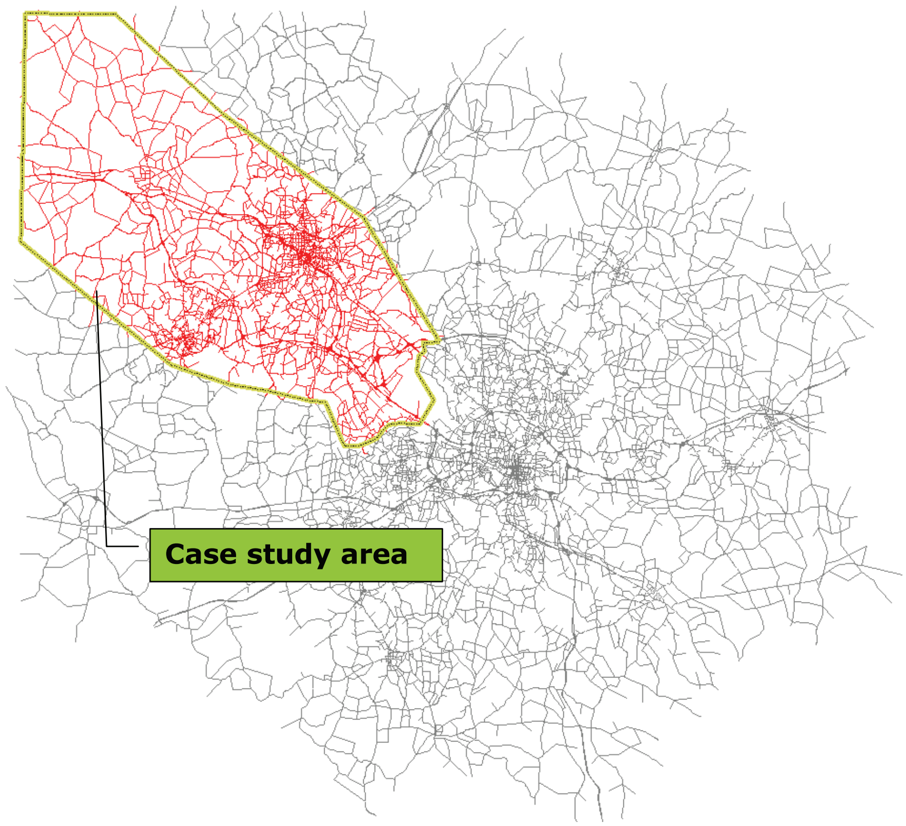


Figure 7.10 TRM Network

The TRM network is developed in TransCAD. TransCAD network data can be transferred to DYNASMART-P network through the DYNASMART-P network preparation steps described in Figure 7.11. Before transferring TRM network data, the study network was carved out using the sub area analysis feature in TransCAD. The study area is a fully contained subset of the TRM network as shown in Figure 7.10. Next, sub-network data were exported from TransCAD to Microsoft Excel files or text files. A spreadsheet program such as Excel and a text editor program were used to edit these files to create the input file for DynaBuilder. The DYNASMART-P input files were generated using DynaBuilder. Next, some errors needed to be corrected. This was done using the DYNASMART-PED which is a very useful tool for creating DYNASMART-P networks. Detailed explanations about how to use sub area analysis feature of

TransCAD, how to prepare DynaBuilder input data, and several tips to correct errors are described in Appendix F.

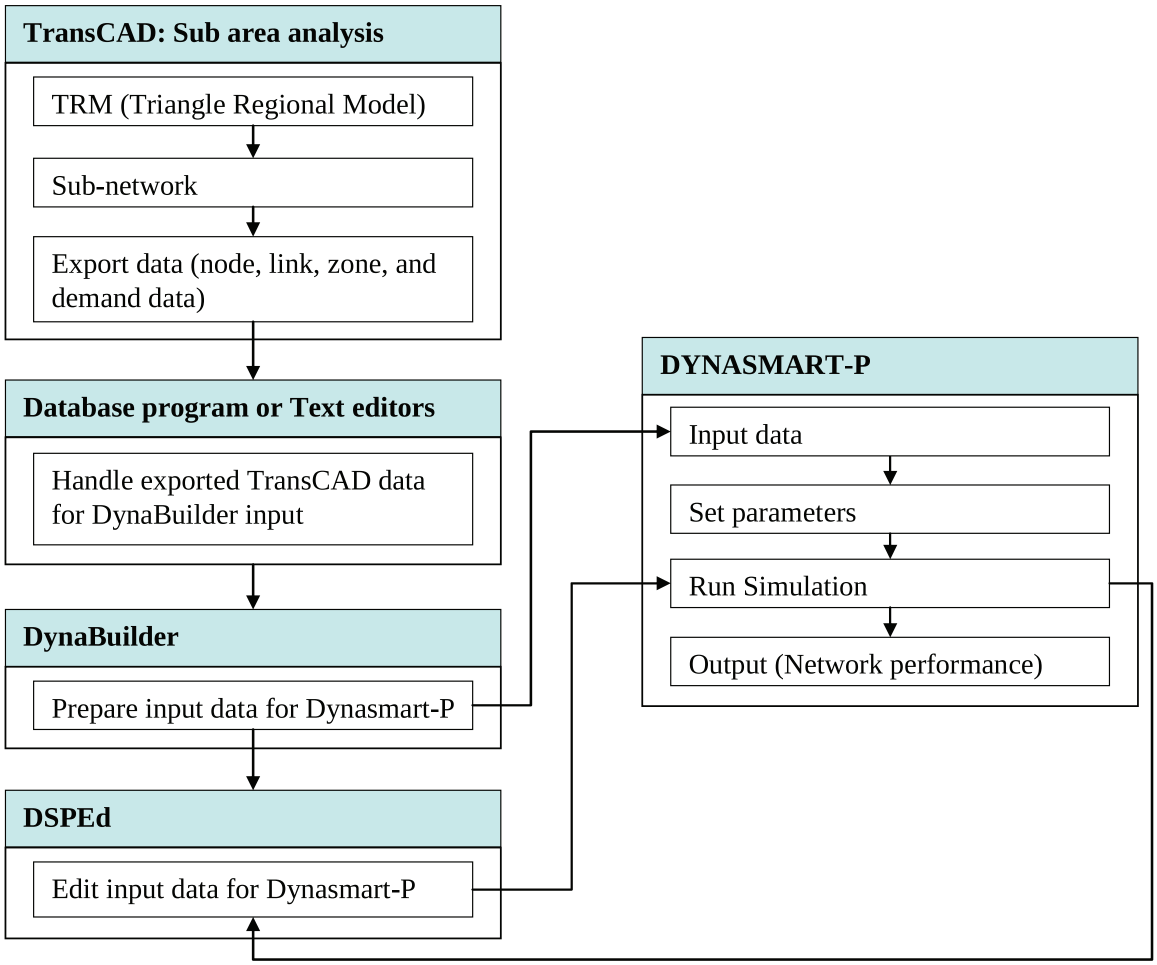


Figure 7.11 DYNASMART-P Network Preparation

7.2.1.1 Network characteristics

The sub-network consists of 806 zones, 3,985 nodes, and 9,508 links. Figure 7.12 shows this sub-network. Two time periods of demand profile were prepared: AM peak demand for the incident cases and off peak demand for the work zone cases. Two vehicle types of OD matrix were prepared. Passenger car demand was the sum of HOV and SOV demand and truck demand was identical with CV demand.

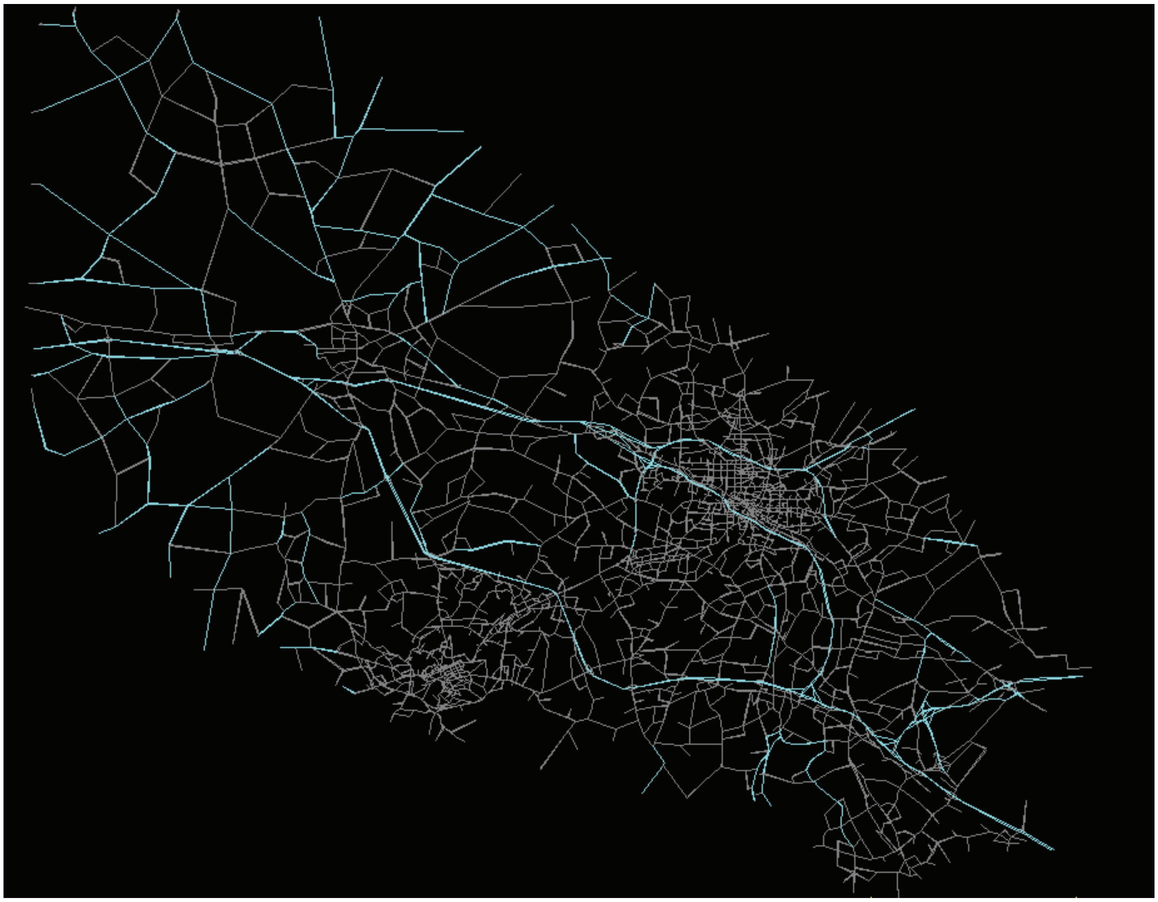


Figure 7.12 DYNASMART-P Network

DYNASMART-P allows user to input detail node and link data. If users have access to actual traffic control plans and link characteristics, the DYNASMART-P network can be coded to reflect more realistic traffic control and flow. However, the larger a network is, the more difficult it is to collect and code the detailed network data.

In the case studies, some network data assumptions were required. Traffic control types of intersections were decided based on the "control density" field in the TRM TransCAD network data. If nodes were centroids or were nodes on freeway links or centroid connectors, the traffic controllers for these intersections were deleted. Among 3,985 nodes, 534 nodes were signalized and 3,451 nodes were unsignalized intersections. Because detailed information on the traffic control plan data were not acquired for each intersection, the 534 signalized intersections were set as actuated traffic signals. DynaBuilder generated traffic signal plans for all the signalized intersections. The default values given by DynaBuilder, 100 seconds of Maximum green, 10 seconds of Minimum green, and 5 seconds of Amber, were used. DynaBuilder originally set all signal phase plans to use permissive left turn control. When the demand level was not so high, this phasing created no problems. However, when the demand level was high, or when vehicles were generated using the vehicle file and path file, heavy conflicting flow resulted in insufficient left turn capacity. In these cases, queued left turn vehicles eventually blocked the all other movements. To solve this problem, all permissive left turn phasing was changed to protected left turn phasing. As another solution, one could try increasing the minimum left turn capacity for permissive left turns.

Properties of links and geometric configurations are important factors for the traffic simulation module in DYNASMART-P. All 9,508 links in the study network were divided into freeway links or arterial links according to the posted speed limits. If the posted speed limit of a link is equal or greater than 55mph, this link was classified as a freeway link while a link having posted speed limit of less than 55mph was classified as an arterial link. The number of the two link types and the settings for those are as follows:

- 973 Freeway links (posted speed limit >=55)
  - Maximum service flow rate: 2000 pcphpl
  - Saturation flow rate: 2200 vphpl
  - Speed limit 65 (+5) mph
- 8, 535 arterial links (posted speed limit <55)
  - Maximum service flow rate: 2000 vphpl
  - Saturation flow rate: 1800 vphpl

- Speed limit 45 (+5) mph

The maximum service flow rate was the maximum capacity of a given lane providing the upper limit of the flow rate through a section under any conditions. The saturation flow rate applied to downstream vehicles discharging from a queue. Actual free-flow speeds were assumed base on the posted speed limits; in this study, the free flow speeds of the freeway and arterial links were set to be 70 mph and 50 mph, respectively.

Some geometric configurations were also assumed as follows;

- all links allow u-turn movements
- all links have one left turn bay and no right turn bay, and
- all links have 0% grade.

To increase the capacity of the generation or destination links, the number of lanes of the centroid connectors was set to be nine.

7.2.1.2 Preparing Origin Destination Demand

DYNASMART-P has two vehicle generation methods. The first method generates vehicles based on OD demand matrix. This method is used at the first simulation run which produces a vehicle and a path file as outputs. The second method uses these two files for another simulation run with the same vehicles and paths but for a different network condition like incidents, work zones, or different ATIS's. In other words, this method uses these two files to generate the same vehicles generated in the first run and to have these vehicles use the same paths they used in the first run. This method, therefore, can be used to evaluate ATIS strategies. More specifically, in a second simulation run, if the same drivers began their travels at the same times and used the same paths as they did in the first run, DYNASMART-P can tells us how much a traffic event such as an incident or an ATIS affects their initial trip. For an ATIS scenario run, the second vehicle generation method was used, and the user groups which tell what information they used can be specified. If an unresponsive group is created who use the initial path without any route diversion and other user groups who have a choice to change their path based on traveler information (pre-trip information, VMS, or IVIS), then ATIS users' route change behavior can be modeled.

The two time periods (AM peak and off peak time) and two vehicle types (passenger car and truck). Thus, four OD demand matrices were developed.

- AM peak time demand for passenger cars,
- AM peak time demand for trucks,
- weekday night time (off peak demand) for passenger cars, and
- weekday night time (off peak demand) for trucks.

The AM peak period demand profile has three OD matrices each of which was made by multiplying hourly distribution factor to the TRM four hours AM peak demand matrix. The Hourly distribute ratios were derived from the traffic count data from the I-85 ATR station A3101.

Table 7-3 and Figure 7.13 explain how the AM peak period demand profile was developed. An incident was set to occur during the most congested time period, i.e., between 7:00 AM to 8:00 AM. To measure the exact incident and ATIS policy affects, vehicles were generated one hour before the incident time and one hour after incident period ended. The first period generated vehicles for filling the network. The second period had incidents and generated vehicles by the highest demand level among the four periods. The third period generated vehicles for preventing incident effect disappearing due to zero demand. The fourth period did not generate any vehicles. This period was for waiting until all generated vehicle finished their travel.

Table 7-3 Demand profile for the incident cases

Period	Time	Hourly ratio	Simulation Time	Multiplier	Others
1	6:00~7:00	0.175	0~ 60 min	0.175	For filling network
2	7:00~8:00	0.295	60~120 min	0.295	Incident I (60~90 min) Incident II (60~105 min)
3	8:00~9:00	0.268	120~180 min	0.268	
4	9:00~	0	180~300 min	0	For clearing network

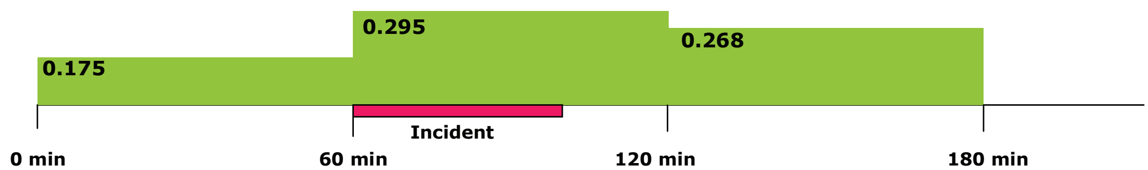


Figure 7.13 Demand Profile for the Incident Cases

The demand profile for the work zone cases was prepared using in a similar way as that for the demand profile of the incident case study. Weekday night time demand profile had four OD matrices; each matrix was made by multiplying hourly distribution factor to the TRM 16 hour off peak demand matrix. The hourly distribute volume distributions were derived from traffic count data from the I-85 ATR Station 3101.

Table 7-4 and Figure 7.14explain how the off peak period demand profile looks like. Construction work was scheduled to be active between 8:00 PM to 6:00 AM. Vehicles were generated for one hour before construction work begins. The second, third, and fourth periods were work zone period, which had aggregated demand level for two hours (8:00 pm to 10:00 pm), another two hours (10:00 pm to 12:00 am), and six hours (12:00 am to 6:00 am), respectively. Figure 8.14 shows average hourly demand level. For example, the multiplier of the second period was 0.143 for two hours, which meant that the hourly demand level of this period was 0.0715. In the work zone case, additional vehicle generation periods were not required. Since from midnight on the demand was very low, work zone impacts were not supposed to transfer to the next time period. The fifth period did not generate any vehicles. This period was designed to clear the network.

Table 7-4 Demand profile for the work zone case

Period	Time	Hourly ratio	Simulation Time	Multiplier	Others
1	19:00~20:00	0.094	0~ 60 min	0.094	For filling network
2	20:00~21:00	0.077	60~180 min	0.143	Construction (60~660 min)
	21:00~22:00	0.066			
3	22:00~23:00	0.050	180~300 min	0.091	
	23:00~24:00	0.041			
4	00:00~06:00	0.140*	300~660 min	0.140	
5	06:00~	0	660~800 min	0	For clearing network

*: Sum of hourly ratio for six hours = 0.028+0.019+0.018+0.019+0.022+0.034 =0.140

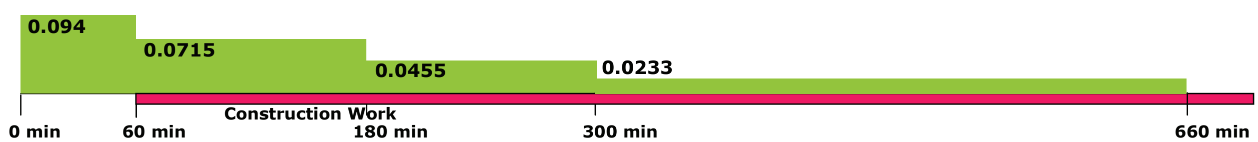


Figure 7.14 Demand Profile for the Work Zone Study

7.2.1.3 Calibration of demand levels

There are several calibration elements of DYNASMART-P. The network links characteristics and traffic controls at intersections were calibrated during the network preparation step. Errors were fixed and some calibration parameters adjusted according to the results of the trial runs. Calibration of traffic flow model was a major calibration factor. In this study, however, the default traffic flow model was used. If speed and density data are available from detectors, appropriate traffic flow models for each links could be estimated, and more realistic simulation results may be possible.

In this study, the project team focused on calibrating the demand level by comparing the estimated traffic volumes from DYNASMART-P run with the observed traffic volumes. The observed volume was used as the input traffic volume in the ATIS evaluation study using IMAP (FREEVAL run). The traffic counts of 28 links on I-85 and I-40 were estimated based on 2005 ADT data and ATR data on I-85. How to get observed volumes is shown in Appendix G.

The following criteria were used to decide which demand level is most desirable;

RMSE (Root mean squared error)

The mean-squared error is one of the most commonly used measures of success for numeric prediction. This value is computed by taking the average of the squared differences between each computed value (c_i) and its corresponding correct value (a_i). The root mean-squared error is simply the square root of the mean-squared-error. The root mean-squared error gives the error value the same dimensionality as the actual and predicted values. This value can be calculated by the following equation:

$$\text{RMSE} = \sqrt{\frac{(a_1 - c_1)^2 + (a_2 - c_2)^2 + \ldots + (a_n - c_n)^2}{n}} \qquad (7.1)$$

MAE (Mean absolute error)

Mean absolute error is the average of the difference between predicted and actual value in all test cases; it is the average prediction error. This value can be calculated by the following equation:

$$\text{MAE} = \frac{|a_1 - c_1| + |a_2 - c_2| + ... + |a_n - c_n|}{n} \qquad (7.2)$$

Mean % Absolute Deviation

Percent deviation is commonly used to assess accuracy, which is the measure of how close a measured value is to the true or expected value. This value can be calculated by the following equation:

$$\text{Mean \% Absolute Deviation} = \frac{|a_1 - c_1|/a_1 + |a_2 - c_2|/a_2 + ... + |a_n - c_n|/a_n}{n} \times 100 \qquad (7.3)$$

DYNASMART-P allowed us to handle demand level by adjusting the multiplication factor in "demand.dat" and "demand_truck.dat" file. DYNASMART-P magnified the OD demand matrices with this factor.

For the incident cases, the project team simulated the scenarios under no incident and no information with various multiplication factors from 1.0 to 1.4. As shown in Table 7-5, when the demand level was increased, the criteria were improved through some point from which the criteria became worse back. The multiplication factor 1.3 was optimal value based on this result. This demand level had no unexpected congestion based on the queue display. Any of link volume didn't exceed the maximum capacity.

For work zone case, the project team simulated no work zone scenario with various multiplication factors from 1.1 to 1.5. Table 7-6 shows the calibration criteria of the work zone cases which have similar pattern as that shown in Table 7-5. Multiplication factor 1.4 was considered as the best value according to this result. This demand level had no unexpected congestion based on the queue display. Any of the link volumes didn't exceed the maximum capacity of the link.

Table 7-5 Calibration criteria of the incident cases

Multiplication factors	MAE	RMSE	Mean % Absolute Deviation
1.0	301.67	342.65	30%
1.1	257.24	304.58	26%
1.2	225.48	274.16	23%
1.3	214.34	268.27	22%
1.4	223.88	274.45	23%

Table 7-6 Calibration criteria of the work zone cases

Multiplication factors	MAE	RMSE	Mean % Absolute Deviation
1.1	103.5	123.28	30%
1.2	88.54	110.77	26%
1.3	77.91	105.18	23%
1.4	75.18	108.04	22%
1.5	78.28	117.85	22%

7.2.1.4 Modeling incident/work zone and ATIS deployments

Four incident cases and two work zone cases were designed for this study. Each case had 5 scenarios. The five runs for these scenarios using DYNASMART-P were as follows;

- The first run: no incident/no work zone,
- The second run: incident/work zone without ATIS (no path change),
- The third run: incident/work zone with existing ATIS (max 10% diversion),
- The fourth run: incident/work zone with planned ATIS (max 20% diversion), and
- The fifth run: incident/work zone with planned ATIS (max 30% diversion).

Figure 7.15 presents how to set these five scenarios in DYNASMART-P. There were two possible options to do traffic assignment. Iterative consistent assignment (equilibrium) might give us better results than those of one-shot simulation assignment. In this case study, however, the network size was too large to run the former option because it required a huge amount of memory. One-shot simulation assignment, therefore, was the recommended option for ITS evaluation by DYNASMART-P.

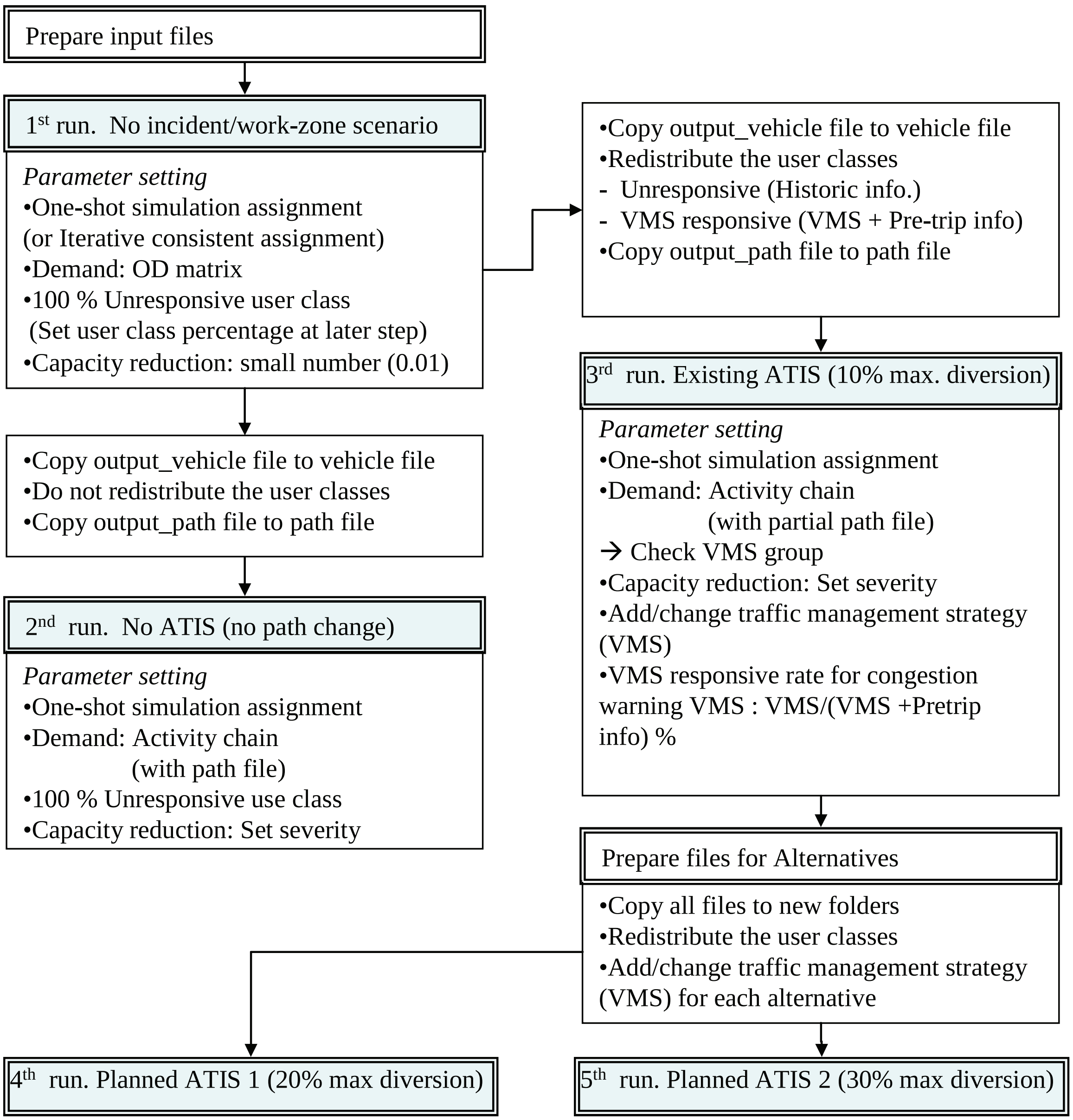


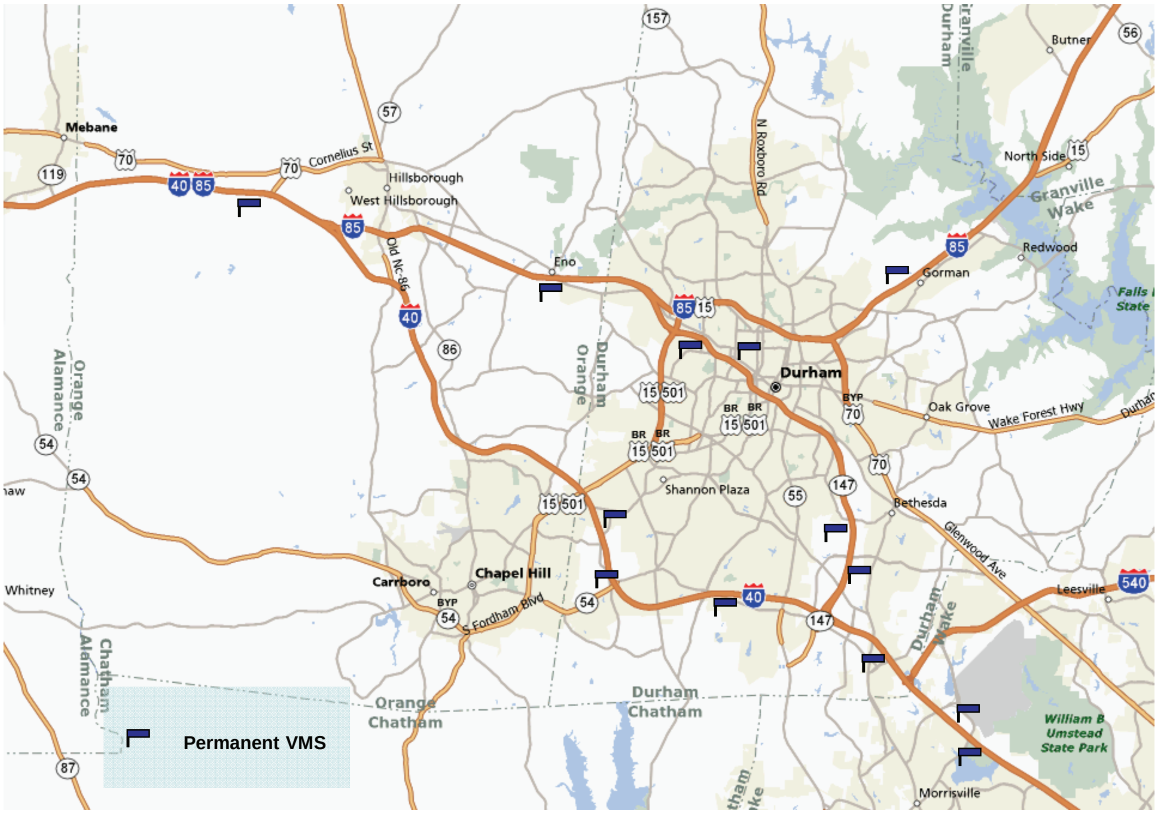
Figure 7.15 DYNASMART-P Simulation Steps

The first run was made assuming the original vehicle path with incident or work zone. To extract the impacted vehicle analysis results, however, a very small capacity reduction

was input on the locations which were planned for incident/work zone in other runs. In the third, fourth, and fifth run, the project team included incidents and work zones as shown in

Table 7-1 and Table 7-2.

In the first and second run, all of vehicles were classified into an unresponsive user group. This group didn't have ATIS or didn't comply with the information. It was assumed that no vehicle would change their path in the second run. From the third run, some vehicles were assumed to have ATIS and respond to it. In this study, the project team used a 10% diversion rate to conservatively represent the effects of the existing ATIS service. Diversion rates of 20% and 30% were assumed for ATIS alternative I and II, respectively. However, diversion rates cannot be directly handled in DYNASMART-P. It followed the user's path change rule and route diversion was decided by network condition. Assumed diversion rates were modeled by adjusting the combination of information user group and VMS response rate. This diversion rate is not an actual diversion rate but can be considered as the rate of willingness to divert. The various information sources were classified into two groups; pre-trip information and VMS. The percentages of the user groups were set as 10% (8% pre-trip and 2% VMS), 20% (15% pre-trip and 5% VMS), and 30% (15% pre-trip and 15% VMS) for existing ATIS, planned ATIS I, and planned ATIS II, respectively. Existing VMS locations shown in Figure 7.16 were inputted into the DYNAMSART-P network.



Map source: Google map

Figure 7.16 VMSs in Case Study Network

In the first run, vehicles were generated according to the OD demand matrix. After vehicle file and vehicle path file were generated from the first run, the activity chain option can be used. This option generated vehicles using the vehicle and path file generated from the first run. The vehicle file contained the start time and the vehicle characteristics including information class for every vehicle. The path file had each vehicle's path. In the second run, the activity chain option with path file is used. It made every vehicle hold to their original path generated at the first run. From the third to the fifth run, the activity chain with partial path file was used and checked only the VMS group as a group acquired path from simulator. Other groups including unresponsive group got their path from the copied "outpath.dat" file from the first run. In other words, VMS group got a new path based on network condition when they began to travel and also VMS groups could get a new path where VMS was installed and part of them responded to VMS information. From the second to the fifth run, the vehicle and the path file were copied from the first run output. DYNASMART-P provided a chance to redistribute the combination of information user group in step for copying "output_vehicle" file. For example, to model 8% pre-trip information group and 2% VMS information group, 100% unresponsive group was redistributed to 90% unresponsive group and 10% VMS group. When 20% VMS response rate was inputted, 2% of all vehicles were supposed to response to VMS information. Table 7-7 shows the information group setting parameters for scenarios.

Table 7-7 Network-wide MOEs of Incident I

Scenarios / Info group setting	No incident	Incident/work zone (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Unresponsive group	100%	100%	90%	80%	70%
VMS group (Pre-trip +VMS)	0%	0%	10%	20%	30%
VMS responsive rate	N/A	N/A	20%	25%	50%

7.2.2 Results

The results of DYNASMART-P simulation are reported in four aspects, namely, (a) behavior of the impacted vehicles, (b) link performances of the two major facilities (I-40 and I-85), (c) overall network, and (d) travel time saving benefits.

First, the project team examined the effects of ATIS on the impacted vehicles generated during the statistics collection period. The impacted vehicles were defined as those vehicles that have paths passing through any incident or work zone link. For the comparison purposes, a very small capacity reduction (0.01 or less) was set for no incident or no work zone scenarios in the same location as each of the scenarios. DSPEd has an "impacted vehicle analysis tool" which identifies the impacted vehicles and reports their paths and travel times. The improvements on the impacted links were estimated by comparing the number of the impacted vehicles and their travel times in each scenario. Another major function of the tool is to report the route diversion behavior of the initial impacted vehicles that traveled along the impacted links in the first run. Some of the impacted vehicles had traveler information and therefore changed their route to a new optimal path. Vehicles with no information followed their original path. Therefore, this function isolates the ATIS effects on the impacted vehicles' route diversion and travel time savings.

Next, link performances on the two major roads, I-40 and I-85 (NC-147) were investigated. These statistics were used for comparing the DYNASMART-P results with the FREEVAL results. The FREEVAL network contained only these two major routes, and the directions along the routes were modeled separately. Also, the analysis duration was focused on the time of the most severe conditions, i.e., 7 am to 8 am for the incident cases and 8 pm to 12 am for the work zone cases. Link performances of these routes were extracted using "export link performance tool" in DYNASMART-PED. VMT (Vehicle Mile Traveled), VHT (Vehicle Hour Traveled), and average travel time were calculated using the following equations:

$$\text{VMT (miles)} = \sum v_i l_i \tag{7.4}$$

$$\text{VHT (hours)} = \sum v_i \frac{l_i}{s_i} \tag{7.5}$$

$$\text{Space mean speed (mph)} = \frac{VMT}{VHT} \tag{7.6}$$

$$\text{Average travel time (minutes)} = \frac{\sum l_i}{space\ mean\ speed} \times 60 \tag{7.7}$$

where,

v_i = volume of link i

l_i = link length of link i

s_i = speed of link i

The equations above were also used to calculate the average travel time for the individual links. The following equation was used to find the overall average travel times for the two major routes:

$$\text{ATT for two freeway facilities} = \frac{\frac{\text{VMT}_1}{\text{L}_1} \times ATT_1 + \frac{\text{VMT}_2}{\text{L}_2} \times ATT_2}{\frac{\text{VMT}_1}{\text{L}_1} + \frac{\text{VMT}_2}{\text{L}_2}} \quad (7.8)$$

Where,
VMT = Vehicle Miles Traveled for the facility
L = Length of facility
ATT = Average Travel Time reported for the facility.

This equation was also used to calculate the combined space mean speed for the two facilities.

Third, the effects of the various ATIS alternatives on the entire network during the analysis period were compared. The 'Summarystat.dat' file includes simulation statistics for all vehicles generated during data collection period. The time period for filling the network was excluded from the data collection period. Average travel time, stop time, and average trip distance were chosen as MOEs for evaluating network performance.

Finally, the benefits of ATIS were estimated. In this case study, travel time savings were calculated using the following equation:

$$\text{Travel time savings} = \text{N} \times \Delta t \times W \quad (7.9)$$

Where,
N: the number of vehicles in network
Δt : travel time reduction per vehicle
W: average hourly wages

The average hourly wage for North Carolina was available from U.S. Department of Labor (Bureau of Labor Statistics) website 'http://www.bls.gov/'. Examples of the mean hourly earnings in the Triangle region of North Carolina are:

- Raleigh - Durham - Chapel Hill, NC, March 2004: $21.74/hr
- Raleigh - Durham - Chapel Hill, NC, March 2003: $21.07/hr

The most recent available data was selected for the benefit estimation.

In the following sections, the results of DYNASMART-P simulation study for the four incident cases and the two work zone cases are described.

7.2.2.1 Incident case I

Incident I had relatively small capacity reduction, and the direction of the incident was opposite to the peak direction. As shown in Table 7-8, the number of impacted vehicles for the scenario 'incident (no diversion)' was decreased due to the capacity reduction, but the reduction amount was very small. Also, as shown in Table 7-9, the average travel times of the scenarios shows the fact that Incident I did not cause any congestion. Therefore, the initial impacted vehicles might not feel any needs to change their initial paths. A very small diversion rate can be seen in the ATIS scenarios. The average travel times of the diverted and non-divert vehicles were almost same.

Table 7-8 Impacted link analysis results for Incident I

Scenarios / MOEs	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
# of impacted vehicles	859	855	859	865	903
Difference in vehicles on impacted links (#)	..	..	4	10	48
Difference in vehicles on impacted links (%)	..	..	0%	1%	6%
Average travel time on impacted links (min)	22.1	22.29	22.32	22.36	22.21

Table 7-9 Impacted vehicle analysis results for Incident I

Scenarios / MOEs	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Number of vehicle					
Total Impacted vehicles	859	859	859	859	859
Non-diverted vehicles	..	859	859	848	851
Diverted vehicles	..	0	0	11	8
Diversion rate	..	0.0%	0.0%	1.3%	0.9%
Average Travel Time (min)					
Total Impacted vehicles	22.1	22.29	22.29	22.47	22.4
Non-diverted vehicles	..	22.29	22.29	22.49	22.45
Diverted vehicles	..	..	..	21.11	17.59

As shown in Table 7-10, MOEs for the two major routes did not show significant differences between the five scenarios. Nevertheless, the planned ATIS II scenario is the best alternative based on these results. It had the highest VMT, the highest average speed, and the smallest average travel time among the five scenarios including the no incident case. One could guess that the VMS responsive group which made up 15% of all users could choose better routes, which made resulted in a small enhancement in the network (the two major routes) performance.

Table 7-10 MOEs for the I-40 and I-85 for Incident I

Scenarios / MOEs	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
VMT (Volumes)	80,358.20	80,903.63	80,447.63	80,875.12	81,076.86
VHT (hours)	1,157.25	1,159.98	1,154.81	1,164.22	1,162.30
Average Speed (mile/hour)	69.44	69.75	69.66	69.47	69.76
Average Travel Time (min)	21.07	20.98	21.01	21.06	20.95

Table 7-11 shows the network-wide MOEs for the Incident I case. It reveals a similar pattern to Table 7-10. The network wide MOEs for the ‘incident (no diversion)’ scenario were not much different from those for ‘no incident’ scenario. The estimated travel time savings are presented in Table 7-12.

Table 7-11 Network-wide MOEs for Incident I

Scenarios / MOEs	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Average Travel Time (min)	14.32	14.59	14.39	14.05	13.89
Stop time (min)	3.20	3.34	3.29	3.04	2.99
Average trip distance (mile)	8.52	8.52	8.52	8.52	8.51

Total generate vehicle: 343,331, Tagged vehicle: 262,080 (8:00pm ~6:00am)

Table 7-12 ATIS benefits for Incident I

Scenarios / Travel time savings	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Total vehicle number	262,080	262,080	262,080	262,080	262,080
Average Travel Time (min)	14.32	14.59	14.39	14.05	13.89
Travel time savings per vehicle (min)			0.20	0.54	0.70
Total travel time savings (hour)			888.45	2,348.67	3,067.65
Total travel time savings ($)			**19,314.93**	**51,060.16**	**66,690.63**

7.2.2.2 Incident case II

Incident II had a larger capacity reduction and a longer incident duration than Incident I. The number of impacted vehicles was higher (859 in Incident I versus 1422 in Incident II). Table 7-13 indicates a capacity reduction for Incident II of 760 vehicles (53%) of the throughput for the incident links and an increase in average travel time. Congestion due to the incident was not mitigated very much in the ATIS scenarios because the throughput of impacted vehicle and average travel time of ATIS scenarios was still very close to the incident (no diversion) scenario.

As presented in Table 7-14, the diversion rate was increased when the percentage of vehicles belonging to the ATIS group was increased. Diverted vehicles reduced their travel time by selecting the detour. However, in Planned ATIS II (Pre 15%, VMS15%), diverted vehicles had a longer travel time. In this case, the alternate route became congested because of the increased demand from the diverted vehicles. In contrast, the non-diverted vehicle's average travel time was decreased.

Table 7-13 Impacted link analysis results for Incident II

MOEs \ Scenarios	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
# of impacted vehicles	1,422	662	676	673	689
Difference in vehicles on impacted links (#)	..	..	14	11	27
Difference in vehicles on impacted links (%)	..	..	2%	2%	4%
Average travel time on impacted links (min)	23	36.74	36.69	36.54	36.57

* Data collection period: 7:00 ~9:00 am

Table 7-14 Impacted vehicle analysis results for Incident II

Scenarios / MOEs	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Number of vehicle					
Total Impacted vehicles	1,422	1,422	1,422	1,422	1,422
Non-diverted vehicles	..	1,422	1,331	1,224	1,112
Diverted vehicles	..	0	91	198	310
Diversion rate	..	0%	6.4%	13.9%	21.8%
Average Travel Time (min)					
Total Impacted vehicles	23	39.85	37.97	36.32	38.15
Non-diverted vehicles	..	39.85	38.59	37.59	36.81
Diverted vehicles	..	..	28.94	28.52	42.94

* Data collection period: 7:00 ~9:00 am

In Table 7-15, the Planned ATIS II scenario was the best alternative from the standpoint of I-40 and I-85. It had the highest VMT, the highest average speed, and the lowest average travel time among the five scenarios. However, Table 7-16 shows that the Planned ATIS II was the worst alternative from a network-wide perspective. The high diversion rate resulted in a network performance worse than for planned ATIS I. These results point out the potential pitfalls of diverting high percentages of freeway vehicles to surface routes. Conditions on surface routes can deteriorate rapidly and recover slowly. It should be noted however, that actual drivers often have a stronger reluctance to divert to surface street routes than is reflected in the simulation model. Estimated travel time savings are included in Table 7-17.

Table 7-15 MOEs for the I-40 and I-85 for Incident II

Scenarios / MOEs	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
VMT (Volumes)	76,674.31	72,883.49	73,606.05	73,657.62	73,694.73
VHT (hours)	1,107.78	1,117.55	1,123.03	1,121.98	1,117.34
Average Speed (mile/hour)	69.21	65.22	65.54	65.65	65.96
Average Travel Time (min)	21.20	22.42	22.30	22.26	22.13

* Data collection period: 7:00 ~8:00 am

Table 7-16 Network-wide MOEs for Incident II

MOEs \ Scenarios	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Average Travel Time (min)	14.32	14.94	14.45	14.28	14.90
Stop time (min)	3.24	3.61	3.25	3.17	3.77
Average trip distance (mile)	8.52	8.52	8.52	8.52	8.52

* Data collection period: 7:00 ~9:00 am

Table 7-17 ATIS benefits for Incident II

Travel time savings \ Scenarios	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Total vehicle number	261,874				
Average Travel Time (min)	14.32	14.94	14.45	14.28	14.90
Travel time savings per vehicle (min)			0.48	0.66	0.03
Total travel time savings (hour)			2,112.89	2,879.30	150.58
Total travel time savings ($)			45,934.16	62,596.08	3,273.56

* Data collection period: 7:00 ~9:00 am

7.2.2.3 Incident case III

In Table 7-18, the number of impacted vehicle for the incident (no diversion) scenario was not decreased. So, it appears that the capacity reduction did not affect throughput for the incident link under incident case III. As the ATIS usage percentage went up, route diversion resulted in a decrease in the throughput of the incident link. However, the congestion due to the incident was still in place at can be seen by looking at average travel time, which did not improve as diversion increased. As shown in Table 7-19, the diversion rate increased as the percentage of vehicles in the ATIS group increased. However, there was a relatively small diversion rate for the ATIS scenarios. A key question was why the diversion rate was relatively small, even though impacted vehicles could have saved travel time by changing their route. The answer is that in this case many of the impacted vehicles needed to continue through on the impacted link in order to reach their destination.

Table 7-18 Impacted link analysis results for Incident III

Scenarios / MOEs	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
# of impacted vehicles	1,134	1,134	1,126	1,117	1,096
Difference in vehicles on impacted links (#)	..	--	-8	-17	-38
Difference in vehicles on impacted links (%)	..	..	-1%	-1%	-3%
Average travel time on impacted links (min)	23.01	48.10	49.05	48.88	49.55

* Data collection period: 7:00 ~9:00 am

Table 7-19 Impacted vehicle analysis results for Incident III

Scenarios / MOEs	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Number of vehicle					
Total Impacted vehicles	1,134	1,134	1,134	1,134	1,134
Non-diverted vehicles	..	1,134	1,109	1,075	1,033
Diverted vehicles	..	0	25	59	101
Diversion rate	..	0%	2.2%	5.2%	8.9%
Average Travel Time (min)					
Total Impacted vehicles	23.01	48.08	48.34	47.32	46.82
Non-diverted vehicles	..	48.08	48.89	48.46	48.91
Diverted vehicles	..	..	24.07	26.58	25.46

* Data collection period: 7:00 ~9:00 am

In

Table 7-20, the Planned ATIS I scenario was the best alternative for the I-40 and I-85 routes. It had the highest VMT, the highest average speed, and the smallest average travel time among the five scenarios. However, Table 7-21 shows that the Planned ATIS I scenario was worst alternative from a network perspective. In Planned ATIS I, route diversion was created congestion on the non-freeway links. This impact was not included in two major road statistics.

When the usage rate of VMS was increased under Planned ATIS II, this congestion disappeared. So, in terms of network wide performance, Planned ATIS II scenario is the best scenario. Travel time savings are estimated and presented in Table 7-22.

Table 7-20 MOEs for the I-40 and I-85 for Incident III

MOEs \ Scenarios	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
VMT (Volumes)	131,909.53	121,156.62	121,202.74	121,354.39	122,171.96
VHT (hours)	1,917.45	2,046.28	2,047.73	2,049.63	2,065.76
Average Speed (mile/hour)	68.79	59.21	59.19	59.21	59.14
Average Travel Time (min)	21.19	24.85	24.86	24.84	24.87

* Data collection period: 7:00 ~8:00 am

Table 7-21 Network-wide MOEs for Incident III

MOEs \ Scenarios	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Average Travel Time (min)	13.83	14.93	14.61	16.17	14.20
Stop time (min)	2.93	3.16	2.93	4.39	2.84
Average trip distance (mile)	8.50	8.50	8.50	8.50	8.50

* Data collection period: 7:00 ~9:00 am

Table 7-22 ATIS benefits for Incident III

Travel time savings \ Scenarios	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Total vehicle number	262,082				
Average Travel Time (min)	13.83	14.93	14.61	16.17	14.20
Travel time savings per vehicle (min)			0.32	-1.24	0.73
Total travel time savings (hour)			1,390.78	-5,416.36	3,179.49
Total travel time savings ($)			30,235.60	-117,751.70	69,122.14

* Data collection period: 7:00 ~9:00 am

7.2.2.4 Incident case IV

In Table 7-23, the number of the impacted vehicles for the incident (no diversion) scenario is significantly decreased. The capacity reduction resulted in a severe impact on the incident link throughput. Average travel time was increased in incident (no diversion) scenario and not improved significantly in the ATIS scenarios. The incident induced congestion continued in the ATIS scenarios. The extreme capacity impact of Incident IV overwhelms the ability of the network to handle the demand through route diversion. In Table 7-24, it can be seen that the diversion rate increased as the percentage of vehicles in the ATIS group increased. Diverted vehicle were able to save travel time.

Table 7-23 Impacted link analysis results for Incident IV

MOEs \ Scenarios	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
# of impacted vehicles	1,888	396	399	399	405
Difference in vehicles on impacted links (#)	..	..	3	3	9
Difference in vehicles on impacted links (%)	..	..	1%	1%	2%
Average travel time on impacted links (min)	24.21	55.52	55.78	55.41	56.23

* Data collection period: 7:00 ~9:00 am

Table 7-24 Impacted vehicle analysis results for Incident IV

MOEs \ Scenarios	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Number of vehicle					
Total Impacted vehicles	1,888	1,888	1,887	1,888	1,888
Non-diverted vehicles	..	1,888	1,741	1,551	1,396
Diverted vehicles	..	0	146	337	492
Diversion rate	..	0%	7.7%	17.8%	26.1%
Average Travel Time (min)					
Total Impacted vehicles	24.21	58.52	56.12	52.09	50.44
Non-diverted vehicles	..	58.52	58.43	56.7	57.8
Diverted vehicles	..	..	28.65	30.87	29.58

* Data collection period: 7:00 ~9:00 am

In Table 7-25, the Planned ATIS II scenario is best alternative for I-40 and I-85 route performance. It had the highest VMT, the highest average speed, and the smallest average travel time among five scenarios. However, Table 7-26 shows similar pattern with Table 7-25.

Planned ATIS I performed worse than the No ATIS scenario. Route diversion resulted in severe congestion in the network. As with Incident III, when VMS information use increased under Planned ATIS II, this congestion was relieved. Travel time savings are estimated and presented in Table 7-27.

Table 7-25 MOEs for the I-40 and I-85 for Incident IV

MOEs \ Scenarios	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
VMT (Volumes)	126,972.77	112,337.00	114,822.36	116,359.73	118,366.89
VHT (hours)	1,844.85	2,006.79	2,029.66	2,055.72	2,076.34
Average Speed (mile/hour)	68.83	55.98	56.57	56.60	57.01
Average Travel Time (min)	21.17	26.35	26.07	26.04	25.85

* Data collection period: 7:00 ~8:00 am

Table 7-26 Network-wide MOEs for Incident IV

MOEs \ Scenarios	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Average Travel Time (min)	14.38	16.03	18.21	14.78	14.52
Stop time (min)	3.30	3.88	6.35	3.25	3.16
Average trip distance (mile)	8.50	8.50	8.46	8.51	8.52

* Data collection period: 7:00 ~9:00 am

Table 7-27 ATIS benefits for Incident IV

Travel time savings \ Scenarios	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Total vehicle number	262,129				
Average Travel Time (min)	14.38	16.03	18.21	14.78	14.52
Travel time savings per vehicle (min)			-2.18	1.25	1.51
Total travel time savings (hour)			-9,537.13	5,442.23	6,596.91
Total travel time savings ($)			-207,337.14	118,314.19	143,416.89

* Data collection period: 7:00 ~9:00 am

7.2.2.5 Work zone case I

Because the work zone duration is 10 hours, the number of impacted vehicle is much higher than the incident cases. The results of the work zone cases shows similar pattern to those of the incident cases. As shown in Table 7-28, the number of impacted vehicles for the work zone (no diversion) scenario was significantly decreased. The capacity reductions have a severe effect on the throughput of the work zone link. Average travel time was increased in the work zone (no diversion) scenario and decreased with increasing percentage of information users. Even though construction was at night when demand is low, the long duration of the lane closure resulted in severe congestion. ATIS provides some relief, but severe congestion continues to exist. As presented in Table 7-29, the diversion rate increased as the percentage of vehicles in the ATIS group increased. Diverted vehicles could save a significant amount on their travel time.

Table 7-28 Impacted link analysis results for Work zone I

Scenarios / MOEs	No work zone	Work zone (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
# of impacted vehicles	10,220	8,753	8,766	8,972	8,448
Difference in vehicles on impacted links (#)	..	..	13	219	-305
Difference in vehicles on impacted links (%)	..	..	0%	3%	-3%
Average travel time on impacted links (min)	18.08	137.94	122.78	103.56	67.09

* Data collection period: 8:00 pm ~6:00 am

Table 7-29 Impacted vehicle analysis results for Work zone I

Scenarios / MOEs	No work zone	Work zone (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Number of vehicle					
Total Impacted vehicles	10,220	10,220	10,220	10,220	10,220
Non-diverted vehicles	..	10,220	9,284	8,480	7,847
Diverted vehicles	..	0	936	1,740	2,373
Diversion rate	..	0%	9.2%	17.0%	23.2%
Average Travel Time (min)					

Total Impacted vehicles	18.08	142.79	113.20	94.64	59.69
Non-diverted vehicles	..	142.79	122.17	109.03	70.30
Diverted vehicles	..	..	24.26	24.51	24.58

* Data collection period: 8:00 pm ~6:00 am

In Table 7-30, Planned ATIS II scenario has the highest VMT and the smallest average travel time among the five scenarios but its average speed was not highest for I-40 and I-85. However, Table 7-31 shows that the planned ATIS II scenario is the best alternative from a network perspective. It has the lowest average travel time and stop time among of the ATIS scenarios. Travel time savings are estimated and presented in Table 7-32.

Table 7-30 MOEs for the I-40 and I-85 for Work zone I

MOEs \ Scenarios	No work zone	Work zone (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
VMT (Volumes)	202,011.77	156,408.22	162,909.08	166,110.06	175,931.84
VHT (hours)	2,886.25	2,967.29	3,310.56	3,075.01	3,398.81
Average Speed (mile/hour)	69.99	52.71	49.21	54.02	51.76
Average Travel Time (min)	20.89	27.44	29.38	26.74	27.90

* Data collection period: 8:00 pm ~12:00 am

Table 7-31 Network-wide MOEs for Work zone I

MOEs \ Scenarios	No work zone	Work zone (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Average Travel Time (min)	8.72	15.75	12.87	11.77	10.07
Stop time (min)	1.11	6.52	4.10	3.29	1.95
Average trip distance (mile)	6.98	6.98	6.98	6.98	6.98

* Data collection period: 8:00 pm ~6:00 am

Table 7-32 ATIS benefits for Work zone I

Travel time savings \ Scenarios	No work zone	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Total vehicle number	454,621				
Average Travel Time (min)	8.72	15.75	12.87	11.77	10.07
Travel time savings per vehicle (min)			2.88	3.98	5.68

Total travel time savings (hour)			21,807.41	30,126.22	43,002.60
Total travel time savings ($)			474,093.13	654,943.99	934,876.53

* Data collection period: 8:00 pm ~6:00 am

7.2.2.6 Work zone case II

Work zone II had more severe congestion than Work zone I. Capacity reduction on I-40 freeway created several bottlenecks. Spillback from these bottlenecks blocked movements on arterial routes. Therefore, 10% of generated vehicles remained in the network at the end of the simulation time. Therefore, in Table 7-34, some of initial impacted vehicles were exclude from statistics because they could not complete their travel. This fact resulted in an underestimation of average travel time in the work zone (no diversion) scenario and in the existing ATIS scenario in Table 7-33, Table 7-34, Table 7-36, and Table 7-37. As presented in Table 7-34, the diversion rate increased as the percentage of vehicles in the ATIS group increased. Diverted vehicles could realize significant travel time savings. As the diversion rate increased under Planned ATIS II, congestion was reduced and average travel time was increased.

Table 7-33 Impacted link analysis results for Work zone II

MOEs \ Scenarios	No work zone	Work zone (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
# of impacted vehicles	9,442	3,129	4,387	8,481	8,091
Difference in vehicles on impacted links (#)	..	..	1,258	5,352	4,962
Difference in vehicles on impacted links (%)	..	..	40%	171%	159%
Average travel time on impacted links (min)	17.61	91.38	94.71	76.39	55.06

* Data collection period: 8:00 pm ~6:00 am

Table 7-34 Impacted vehicle analysis results for Work zone II

Scenarios / MOEs	No work zone	Work zone (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Number of vehicle					
Total Impacted vehicles	9,442	1,764	5,696	9,442	9,442
Non-diverted vehicles	..	1,764	4,812	7,955	7,313
Diverted vehicles	..	0	884	1,487	2,129
Diversion rate	..	N/A	N/A	15.7%	22.5%
Average Travel Time (min)					
Total Impacted vehicles	17.61	102.23	118.29	71.2	50.81
Non-diverted vehicles	..	102.23	135.12	80.1	56.68
Diverted vehicles	..	..	26.66	23.59	23.8

* Data collection period: 8:00 pm ~6:00 am

Network performance results of the Work Zone II have a very similar pattern to Work Zone I. In Table 7-35, Planned ATIS II scenario has the highest VMT and the smallest average travel time among the five scenarios but not the highest average speed for I-40 and I-85. However, Table 7-36 shows that planned ATIS II scenario is the best alternative from a network perspective. It has the lowest average travel time and stop time among ATIS scenarios. Travel time savings are estimated and presented in Table 7-37. However, the benefit calculation is not correct because the average travel time of no work zone scenario did not include the average travel time of the vehicles that remained in the network.

Table 7-35 MOEs for the I-40 and I-85 for Work zone II

Scenarios / MOEs	No work zone	Work zone (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
VMT (Volumes)	184,852.23	159,480.43	163,009.23	164,329.02	166,110.40
VHT (hours)	2,641.06	3,415.68	3,374.15	3,564.03	3,606.19
Average Speed (mile/hour)	69.99	46.69	48.31	46.11	46.06
Average Travel Time (min)	20.73	30.73	29.71	31.08	31.09

* Data collection period: 8:00 pm ~12:00 am

Table 7-36 Network-wide MOEs for Work zone II

Scenarios / MOEs	No work zone	Work zone (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Average Travel Time (min)	8.71	66.87	39.22	11.52	9.90
Stop time (min)	1.10	54.84	29.02	2.96	1.72
Average trip distance (mile)	6.98	6.29	6.54	6.99	6.98

* Data collection period: 8:00 pm ~6:00 am

Table 7-37 ATIS benefits for Work zone II

Scenarios / Travel time savings	No work zone	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Total vehicle number	454,296				
Average Travel Time (min)	8.71	66.87	39.22	11.52	9.90
Travel time savings per vehicle (min)			27.66	55.36	56.97
Total travel time savings (hour)			209,425.16	419,141.82	431,370.71
Total travel time savings ($)			4,552,902.89	9,112,143.13	9,377,999.22

* Data collection period: 8:00 pm ~6:00 am

7.2.3 Conclusions from DYNASMART-P Case Study

DYNASMART-P is an excellent tool to investigate driver's response to ATIS. It could model driver's path change behavior according to their information type and network conditions. Also, it provides various outputs to help interpret the simulation results from multiple prospective. The project team could get network wide performance and selected link performance and also see impacted vehicle's diversion behavior and travel time savings. In this case study, DYNASMART-P seemed to generate quite reasonable results. Route diversion rates increased as the percentage of ATIS users increased. Generally ATIS reduced congestion due to incidents or work zones.

However, the current DYNASMART-P model revealed several shortcomings. It required significant input data. It was not easy to prepare network data, calibrate demand level, and to calibrate the traffic flow model. The OD demand matrix should be included or developed. It was difficult to calibrate demand level and observed link volumes. It took a long time to run simulation for a large network and long simulation duration like the work zone cases (it took about 5 hours for actual 12 hour duration to simulation). Also, it was difficult to get actual information usage rate and response rate in a network.

While carrying out this case study, several items were revised and added to assist network preparation and calibration.

- Function for increasing capacity of centroid connectors: To increase the capacity of generation or destination link, it set centroid connectors have 9 lanes.
- Function for demand level calibration: It compares observed link volume and simulated one and calculates MSE and MAE.

In addition, two tools were developed with support from an external consultant to extract output and understand the simulation results.

- Export link performance tool: This tool makes analysis work for specific major routes and speed measurement a lot easier.
- Impacted vehicle analysis tool: This tool enables direct analysis of the route diversion behaviors of impacted vehicles and the travel time savings of impacted vehicles under ATIS.

The impacted vehicle analysis tool was especially helpful for examining ATIS effects. It looks for the impacted vehicles and reports their paths and travel times. By comparing the number of impacted vehicles and their travel times for each scenario, improvement on impacted links was estimated. Another major function of the tool is reporting the route diversion behavior of vehicles that traversed the impacted links in base case, no incident or work zone run. Some of initial impacted vehicles have traveler information, so they change their path to new shortest path.

Others have no information will stick to their original path. So, this function helped us to see ATIS effects on impacted vehicles' route diversion and travel time saving. To use this function, it was necessary to save an impacted vehicle file after loading the base case simulation results. Impacted vehicles are vehicles that satisfy the following three conditions:

(a) Pass through the work zones/incidents or incidents during the intervals defined by the corresponding starting time and end time,

(b) Complete their trips and

(c) Depart during the statistics collection interval

The tool collates the saved impacted vehicle file with the vehicle trajectory file of the other scenarios and reports the number of non-diverted and diverted vehicles along with their average travel time and details on which information group the vehicles belong to.

7.3 FREEVAL Case Study

In order to compare different incident / work zone scenarios with and without Advanced Traveler Information Systems (ATIS), comprehensive case studies in FREEVAL simulation software were conducted. The simulation results are described in this section.

7.3.1 Network Preparation

The following network in FREEVAL demonstrates the simplified and actual road networks (see Figure 8.4 for the simplified network and Figure 8.3 for the actual network). Based on NCDOT recommendation, the study area chosen is Durham, Chapel Hill and Hillsborough in North Carolina, where I-40, I-85 and NC-147 intersect. Travelers could have used other routes for diversion purpose if one route had active incident or work zone events. This portion of I-40 is about 20 miles, and the number of lanes per direction ranges from 2 to 4. At the relevant portion of I-85 & NC-147, the length is about 21 miles with two lanes per direction. All routes have a free flow speed in 65-70 mile per hour. To the extent possible, the team utilized real-world data in the analysis. For instance, the 2005 average daily traffic (ADT) data was extracted from the 2005 run of the Triangle Regional Model (TRM); the weekday/weekend factor and directional factor were based on count data from an Automatic Traffic Recorder (ATR) station in the corridor of study. Then weekday/weekend hourly traffic volume was estimated based on these field data.

To be clear, two routes were modeled in FREEVAL. As shown in Figure 7.4, one route was I-85 and NC-147. Another route included the extra link on the upper-left corner (where I-40 and I-85 run together), I-40 continuing to the link on the lower-right corner.

7.3.2 Results

Table 7-38 presents the modeling results of different performance measures under different scenarios of Incident case study 1. The first two columns show the performance measures when there are no incidents versus when there is an incident but no diversions. So column 1 represents the upper bound in terms of ATIS mitigation strategies, i.e., the best the NCDOT may be able to achieve in terms of the performance measures reported in column 1. Note that in this particular case, the FREEVAL software provides performance measures that are the same. The reason is that, with low incident severity (minor capacity reduction), there is no remarkable incident-induced queue/delay that can be identified. So essentially, diversions are not expected to improve the situation, as modeled macroscopically in FREEVAL.

Calculation of one of the performance measure requires special mention. The equations used to Average Travel Time (ATT) are shown below, as they involved calculating the space mean speed for two facilities. Given that FREEVAL reports ATT for individual links, one approximation used to find overall ATT was as follows:

$$\text{ATT for two freeway facilities} = \frac{\frac{\text{VMT}_1}{\text{L}_1} \times ATT_1 + \frac{\text{VMT}_2}{\text{L}_2} \times ATT_2}{\frac{\text{VMT}_1}{\text{L}_1} + \frac{\text{VMT}_2}{\text{L}_2}} \tag{7.10}$$

Where,

VMT = Vehicle Miles Traveled

L= Length of facility

ATT = Average Travel Time reported for the facility.

Another approximation (based on space mean speed) was:

$$\text{ATT for two freeway facilities} = \frac{\frac{\text{VMT}_1}{\text{L}_1} \times ATT_1 + \frac{\text{VMT}_2}{\text{L}_2} \times ATT_2}{2 \times \frac{\text{VMT}_1 + \text{VMT}_2}{\text{L}_1 + \text{L}_2}} \tag{7.11}$$

There was no essential difference between two approximations, therefore, the first equation above was used to calculate the average travel time and report it. The last column reports the percentage changes relative to the incident or work zone base case. Thus, all percentages are based on the second column of each table. (It is possible to use another column as a base/denominator.)

7.3.2.1 Incident Cases

The total travel time and delays increase slightly with more diversions (i.e., 0%, 10%, 20%, and 30%). For example, the total delay with 30% diversion is nearly 40% higher compared with the base case. In other words, the network performance for the case with low incident severity but a relatively high road network demand/volume worsens with more route diversions. The increase in total travel time and total delay is mainly due to the rapid increase of delays on the alternative route due to additional diverted travelers (to I-85). In addition, the alternate route in this simulation is slightly longer than the normal route, which is another factor that contributes to the increasing total delay. However, practical relative differences in total travel times are below 1%. In short, this incident case does not require any diversions (largely because the effect of the incident is negligible).

Modeling results for incident case study set 2 are shown in Table 7-39. Notice that the VMT for volume is less than VMT for demand, which indicates that incident-induced queue still remains inside the simplified road network even at the end of the simulation modeling (60 minutes for this incident case). It is obvious from Table 7-39 that for higher levels of diversion, the incident-induced queue shortens compared to the base case where travelers do not have traveler information and do not divert. In addition, total travel time and total delay decrease remarkably with additional diversions. For example, compared to the base case, total travel time and total delay for planned ATIS alternative 2 (30% diversion rate), shows a 13% and 32% reduction, respectively. Therefore, in situations with high incident severity and a high demand volume, diversions can be beneficial.

Table 7-40 displays the modeling results for incident case study 3, where an incident with low severity occurs on I-85 as indicated in Figure 7.4 (the alternative route is shorter than the usual route). The first two columns have the same values, implying that there is essentially no difference between the no-incident and incident scenarios, and the potential for ATIS is non-existent.

There are no queues left at the end of all scenarios. These results are quite different from case study 1. Total travel time decreases slightly with more route diversions and total delay first decreases with more diversions and then increases when the diversion rate goes up to 30%. Basically, when the incident occurs on the facility that is slightly more congested, diversions can be beneficial. However, the opposite was true in case study 1, where the incident occurred on the less congested facility and route diversion increased traffic demand on the more congested facility.

Modeling results for incident case study 4 (Figure 7.4) are shown in Table 7-41. Similar to incident case 2 the incident-induced queue decreases when more diversions take place. All network performance measures, e.g., total travel time and total delay, improve with more diversions (ATIS deployment). However, the magnitudes are relatively less than those for case study 2.

7.3.2.2 Incident Cases

The total travel time and delays increase slightly with more diversions (i.e., 0%, 10%, 20%, and 30%). For example, the total delay with 30% diversion is nearly 40% higher compared with the base case. In other words, the network performance for the case with low incident severity but a relatively high road network demand/volume worsens with more route diversions. The increase in total travel time and total delay is mainly due to the rapid increase of delays on the alternative route due to additional diverted travelers (to I-85). In addition, the alternate route in this simulation is slightly longer than the normal route, which is another factor that contributes to the increasing total delay. However, practical relative differences in total travel times are below 1%. In short, this incident case does not require any diversions (largely because the effect of the incident is negligible).

Modeling results for incident case study set 2 are shown in Table 7-39. Notice that the VMT for volume is less than VMT for demand, which indicates that incident-induced queue is still remains inside the simplified road network even at the end of the simulation modeling (60 minutes for this incident case). It is obvious from Table 7-39 that for higher levels of diversion, the incident-induced queue shortens compared to the base case where travelers do not have traveler information and do not divert. In addition, total travel time and total delay decrease remarkably with additional diversions. For example, compared to the base case, total travel time and total delay for planned ATIS alternative 2 (30% diversion rate), shows a 13% and 32% reduction, respectively. Therefore, in situations with high incident severity and a high demand volume, diversions can be beneficial.

Table 7-40 displays the modeling results for incident case study 3, where an incident with low severity occurs on I-85 as indicated in Figure 7.4 (the alternative route is shorter than the usual route). The first two columns have the same values, implying that there is essentially no difference between the no-incident and incident scenarios, and the potential for ATIS is non-existent.

There are no queues left at the end of all scenarios. These results are quite different from case study 1. Total travel time decreases slightly with more route diversions and total delay first decreases with more diversions and then increases when the diversion rate goes up to 30%. Basically, when the incident occurs on the facility that is slightly more congested, diversions can be beneficial. However, the opposite was true in case study 1, where the incident occurred on the less congested facility and route diversion increased traffic demand on the more congested facility.

Modeling results for incident case study 4 (Figure 7.4) are shown in Table 7-41. Similar to incident case 2 the incident-induced queue decreases when more diversions take place. All network performance measures, e.g., total travel time and total delay, improve with more diversions (ATIS deployment). However, the magnitudes are relatively less than those for case study 2.

Table 7-38 Modeling results for incident case study 1

	No Incident	Base (no diversions)	Existing ATIS (10% diversion)		Planned ATIS Alternative 1 (20% diversion)		Planned ATIS Alternative 2 (30% diversion)	
	Value	Value	Value	Percent Change	Value	Percent Change	Value	Percent Change
VMT (Demand) (mile)	112039.44	112039.44	112180.28	0.13%	112320.69	0.25%	112461.53	0.38%
VMT (Volume) (mile)	112039.44	112039.44	112180.28	0.13%	112320.69	0.25%	112461.53	0.38%
Total Travel Time (hour)	1739.38	1739.38	1742.05	0.15%	1745.72	0.36%	1752.13	0.73%
Total Delay (hour)	15.70	15.70	16.20	3.22%	17.71	12.82%	21.96	39.88%
Average Speed (mile/hour)	64.41	64.41	64.40	-0.03%	64.34	-0.11%	64.19	-0.35%
Average Travel Time (min)	22.42	22.42	22.13	-1.30%	21.86	-2.51%	21.62	-3.58%

Table 7-39 Modeling results for incident case study 2

	No Incident	Base (no diversions)	Existing ATIS (10% diversion)		Planned ATIS Alternative 1 (20% diversion)		Planned ATIS Alternative 2 (30% diversion)	
	Value	Value	Value	Percent Change	Value	Percent Change	Value	Percent Change
VMT (Demand) (mile)	112039.44	112039.44	112180.28	0.13%	112320.69	0.25%	112461.53	0.38%
VMT (Volume) (mile)	112039.44	103166.38	108933.30	5.59%	112283.57	8.84%	111740.36	8.31%
Total Travel Time (hour)	1739.38	2675.65	2604.21	-2.67%	2471.90	-7.62%	2323.12	-13.18%
Total Delay (hour)	15.70	1088.47	928.31	-14.71%	744.46	-31.61%	735.53	-32.43%
Average Speed (mile/hour)	64.41	38.56	41.83	8.49%	45.42	17.81%	48.10	24.75%
Average Travel Time (min)	22.42	35.21	32.59	-7.44%	30.28	-14.01%	28.41	-19.31%

Notes: If VMT (Volume) is less than VMT (Demand), then there is a queue remaining inside the road network at the end of the modeling duration (60 minutes for this incident case).

Table 7-40 Modeling results for incident case study 3

	No Incident	Base (no diversions)	Existing ATIS (10% diversion)		Planned ATIS Alternative 1 (20% diversion)		Planned ATIS Alternative 2 (30% diversion)	
	Value	Value	Value	Percent Change	Value	Percent Change	Value	Percent Change
VMT (Demand) (mile)	124766.54	124766.54	124695.26	-0.06%	124623.54	-0.11%	124552.26	-0.17%
VMT (Volume) (mile)	124766.54	124766.54	124695.26	-0.06%	124623.54	-0.11%	124552.26	-0.17%
Total Travel Time (hour)	1934.21	1934.21	1933.05	-0.06%	1932.01	-0.11%	1931.09	-0.16%
Total Delay (hour)	14.73	14.73	14.67	-0.41%	14.72	-0.02%	14.90	1.17%
Average Speed (mile/hour)	64.51	64.51	64.51	0.00%	64.50	0.00%	64.50	-0.01%
Average Travel Time (min)	22.45	22.45	22.59	0.61%	22.73	1.24%	22.88	1.87%

Table 7-41 Modeling results for incident case study 4

	No Incident	Base (no diversions)	Existing ATIS (10% diversion)		Planned ATIS Alternative 1 (20% diversion)		Planned ATIS Alternative 2 (30% diversion)	
	Value	Value	Value	Percent Change	Value	Percent Change	Value	Percent Change
VMT (Demand) (mile)	124766.54	124766.54	124695.26	-0.06%	124623.54	-0.11%	124552.26	-0.17%
VMT (Volume) (mile)	124766.54	122551.52	124650.93	1.71%	124622.77	1.69%	124552.26	1.63%
Total Travel Time (hour)	1934.21	2595.86	2589.68	-0.24%	2535.41	-2.33%	2477.24	-4.57%
Total Delay (hour)	14.73	710.45	671.97	-5.42%	618.13	-12.99%	561.05	-21.03%
Average Speed (mile/hour)	64.51	47.21	48.13	1.96%	49.15	4.11%	50.28	6.50%
Average Travel Time (min)	22.45	31.46	31.04	-1.32%	30.57	-2.83%	30.01	-4.62%

Notes: If VMT (Volume) is less than VMT (Demand), then there is a queue remaining inside the road network at the end of the modeling duration (60 minutes for this incident case).

7.3.2.3 Work Zone Cases

On busy urban freeways in North Carolina, road construction is usually carried out during weekend nights, but sometimes roadwork is done on weekday nights. Therefore, in the work zone case studies, the weekday off peak hours from 8 pm-12 am was used. There were two considerations for choosing this time period:

- On average, there was low traffic volume during 12 am-6 am (only about 7% of ADT), whereas traffic volume during 8 pm-12 am was higher at about 12% of ADT.
- Work zone operating on weekdays 8 pm-12 am may have more severe effects than those during weekend because weekday 8 pm-12 am traffic volume (about 12% of ADT), which is slightly larger than weekend 8 pm-12 am traffic volume (about 11% of ADT).

Table 7-2 shows work zone parameters used in the work zone scenarios. Two work zone cases were modeled during weekday off peak time (8 pm-12 am). They were assumed to have the same capacity reduction and same duration, but in different directions on I-40. Correspondingly, different work zone scenarios would have different diversion plans when a traveler information system was available.

Table 7-42 displays the modeling results for work zone case study 1, where a work zone with 75% capacity reduction occurs on the northwest corner of I-40, effecting WB traffic. The total travel time and total delay decline dramatically with ATIS deployment. With highest ATIS deployment (guiding 30% travelers from usual route to alternative route), total travel time and total delay reduces by 30%, and 98%, respectively, compared with the base case. Interestingly, planned ATIS alternative 2 has virtually the same network performance measures than planned ATIS alternative 1. In other words, higher AITS deployment in this case may not the marginal benefits in terms of the performance measures.

Modeling results for work zone case study 2 are shown in Table 7-43, where a work zone with 75% capacity reduction occurs on the southeast corner of I-40, effecting EB traffic. Similar to work zone case set 1, total travel time and total delay decrease significantly with more diversions (ATIS deployment). For example, compared to the base case, total delay is reduced by 71% when 30% travelers are divert from usual route to alternative route, presumably by acquiring electronic traveler information.

Table 7-42 Modeling Results for Work zone Case Study 1

	No Work Zone	Base (no diversions)	Existing ATIS (10% diversion)		Planned ATIS Alternative 1 (20% diversion)		Planned ATIS Alternative 2 (30% diversion)	
	Value	Value	Value	Percent Change	Value	Percent Change	Value	Percent Change
VMT (Demand) (mile)	202244.73	202244.73	202509.12	0.13%	202773.52	0.26%	203037.92	0.39%
VMT (Volume) (mile)	202244.73	202244.75	202509.15	0.13%	202773.52	0.26%	203037.92	0.39%
Total Travel Time (hour)	3134.26	4502.43	3716.20	-17.46%	3143.08	-30.19%	3147.65	-30.09%
Total Delay (hour)	22.80	1390.97	600.68	-56.82%	23.49	-98.31%	23.99	-98.28%
Average Speed (mile/hour)	64.53	44.92	54.49	21.32%	64.51	43.62%	64.50	43.60%
Average Travel Time (min)	22.41	30.66	25.57	-16.62%	21.81	-28.85%	21.53	-29.78%

Table 7-43 Modeling Results for Work zone Case Study 2

	No Work Zone	Base (no diversions)	Existing ATIS (10% diversion)		Planned ATIS Alternative 1 (20% diversion)		Planned ATIS Alternative 2 (30% diversion)	
	Value	Value	Value	Percent Change	Value	Percent Change	Value	Percent Change
VMT (Demand) (mile)	206642.00	206642.00	206775.93	0.06%	206908.99	0.13%	207042.91	0.19%
VMT (Volume) (mile)	206642.00	206641.99	206775.91	0.06%	206908.97	0.13%	207042.91	0.19%
Total Travel Time (hour)	3200.11	5150.45	4513.26	-12.37%	4130.18	-19.81%	3745.09	-27.29%
Total Delay (hour)	21.00	1971.34	1332.09	-32.43%	946.96	-51.96%	559.81	-71.60%
Average Speed (mile/hour)	64.57	40.12	45.82	14.19%	50.10	24.86%	55.28	37.79%
Average Travel Time (min)	22.41	33.96	29.96	-11.77%	27.49	-19.04%	25.06	-26.21%

7.3.3 Conclusions from FREEVAL Case Studies

To represent the effects of different levels of ATIS deployment under either incident or work zone situations, FREEVAL simulation modeling software was used. Realistic case studies were developed for the purpose of modeling and obtaining insights into network performance with increasing levels of ATIS deployment and associated diversions. The network around Hillsborough, Chapel Hill and Durham region in NC was simulated.

Certain assumptions were made about the network (e.g., the values of traffic flow parameters, incident parameters, and work zone parameters) and traveler behavior (e.g., route diversion rates associated with ATIS deployment levels). Key findings about ATIS deployment are:

- In general, higher levels of ATIS deployment (and associated higher levels of route diversions) produce more benefit (in terms of travel time performance measures) to the individual traveler. For example, total travel time and total delay declined significantly with more ATIS deployment in most of the simulated cases in the network, especially for those with high incident/work zone severity.
- In some cases, lower diversion rates associated with the assumed moderate ATIS deployment might be sufficient compared with high ATIS deployment (see Table 8.42 for an example). This implies that, in order to avoid unnecessary deployment, operation and maintenance costs of ATIS, it is useful to determine which level of ATIS deployment will be more appropriate for certain incident/work zone situation.
- With low incident/work zone severity but a relatively high freeway traffic demand/volume, ATIS deployment may not provide much value, i.e., the deployment may have a low impact, or even negative impact in terms of performance measures considered (see Table 7-40 for detail).

7.4 Further Study on the Work Zone Case II

In sections 7.1 and 7.2, DYNASMART-P and FREEVAL were applied to case study based ATIS evaluation. The results from the two evaluation tools reveal that traveler information can improve network performance by providing increased opportunities for route diversion based on the information. The results also showed that the delay and travel time were decreased and the average speed was increased due to the provision of traveler information. However, the results from the two tools were not in total agreement. More specifically, the simulation results showed significant differences in vehicle mile traveled (VMT) and average speed between the two tools. One of the reasons was that the vehicle generation methods of the two simulation tools were different. Hence, it is not reasonable to compare the results from the two tools.

Another issue was that the lane closure length of the I-40 resurfacing work was much smaller than that set in this study. To compare the speed measurement of the work zone from field and the simulators, the work zone section length set in the simulation tasks should be adjusted (shortened) to the real value.

Therefore, adjustments were made for the items described above. First, the lane closure settings for Work zone II case and the demand volumes were synchronized between the two tools to the greatest degree possible. The results from the two tools were compared after these adjustments. The speed measurements from the two tools and from the field were also compared. Finally, the project team conducted an ATIS benefit cost analysis for the revised Work zone II.

7.4.1 Comparison DYNASMART-P with FREEVAL

Even though same network, same analysis time period, and same scenario were used in the two simulators, the results from them showed significant differences in vehicle mile traveled (VMT) and average speed. The main reason of the differences in VMT was that it was not possible to simulate exactly the same link volume in the two tools. Traffic count data were estimated values for input link volumes of the two tools. In FREEVAL, the traffic count data were input directly. However, because DYNASMART-P generates vehicle demand using an OD demand matrix, the TRM OD demand matrix (AM peak 4 hours OD and off peak 16 hours OD) provided the demand input. Next, an attempt was made to calibrate link volumes by using a multiplication factor at the network demand level. It was difficult to match the volumes from traffic assignment and traffic count data. Actually, traffic counts were estimated based on the AADT data and the weekly, directional, and hourly distribution from a single permanent count location in network. In the traffic count estimation step, directional distributions of WB45%/EB55% for the AM peak period and WB49%/EB51% for the off peak period were assumed. However, the traffic assignment results from TRM OD matrix were different from these assumed values. Specifically, the eastbound traffic was heavier than the assumed distribution. For the Incident I and II cases, the effects of ATIS on Westbound (or Northbound) travels were evaluated while for Incident III and IV cases, Eastbound (or Southbound) travel was considered. VMT for Incident I and II in the DYNASMART-P results were much smaller than those of the FREEVAL results. VMT for Incident III and IV in the DYNASMART-P results are little higher than those of the FREEVAL results. If the VMT of Incident I and II are increased, the VMT of Incident III and IV will also be increased. Therefore, it is difficult, if not impossible to match VMTs of the two tools by modifying demand levels in DYNASMART-P. If, however, FREEVAL uses new input volumes which were derived from DYNASMART-P under an assumption that DYNASMART-P assignment results are reasonable, similar VMTs could be derived.

One of the reasons for the difference in average speed was that different free flow speeds were used in the two tools. In DYNASMART-P, 70mph (posted speed limit of 65 mph + 5 mph) was set as the free flow speed on the freeways while 65mph was set in FREEVAL. To compare two tools, the two tools should have a same free flow speed.

Therefore, to enable a more valid comparison of the results from the two tools, the link volumes and free flow speeds should be set to be the same. The work zone location was modified to be identical to the location of the real construction work to compare the simulation results using speed data. According to the I-40 construction report given by NCDOT, June 6th was chosen for the work zone scenario. The location and direction of the work at that day were similar to those of Work zone II, but the lane closure section length was about 1 mile from Exit 274 to 275 (EB).

The Work zone II settings were adjusted to have the same construction location of this selected day, and DYNASMART-P was rerun. The FFS was set to 68 mph for this run because based on NCDOT speed data shown in Appendix G, 68 mph was a reasonable FFS for the freeway links in the network. In FREEVAL, the same construction section and the same FFS, 68mph, were used. Also, new FREEVAL input volumes for the baseline case were derived from the DYNASMART-P assignment results in order to match the demand level. Route diversion method followed the initially used method in FREEVAL. 10%, 20%, and 30% of the whole impacted vehicles from I-40 to I-85/ NC-147 route were diverted.

The revised Work zone II case showed less severe congestion than the original Work zone II case as expected. Vehicles kept in the network were not shown any more. In Table 7-45, all of the initial impacted vehicles were included in the statistics because they could complete their travel. Diversion rates again increased as the percentage of vehicles belonging to the ATIS group increased. Table 7-44 presents the fact that as ATIS percentage increases, diversion rates also increase causing decreasing throughput in the work zone link. Diverted vehicles again realize significant travel time savings. Non-diverted vehicles average travel time also decreases. As shown in Table 7-46 and Table 7-47, ATIS reduced congestion and average travel time.

Table 7-44 Impacted link analysis results for the revised Work zone II

MOEs \ Scenarios	No work zone	Work zone (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
# of impacted vehicles	7,447	7,446	7,201	6,848	6,571
Difference in vehicles on impacted links (#)	..	..	-245	-598	-875
Difference in vehicles on impacted links (%)	..	..	-3%	-8%	-12%
Average travel time on impacted links (min)	20.7	70.96	61	49.25	37.62

* Data collection period: 8:00 pm ~6:00 am

Table 7-45 Impacted vehicle analysis results for the revised Work zone II

MOEs \ Scenarios	No work zone	Work zone (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Number of vehicle					
Total Impacted vehicles	7,447	7,447	7,447	7,447	7,447
Non-diverted vehicles	..	7,447	6,900	6,382	5,979
Diverted vehicles	..	0	547	1,065	1,468
Diversion rate	..	0%	7.3%	14.3%	19.7%
Average Travel Time (min)					
Total Impacted vehicles	20.7	70.96	59.89	47.39	36.36
Non-diverted vehicles	..	70.96	62.71	51.72	39.28
Diverted vehicles	..	..	24.38	24.12	24.44

* Data collection period: 8:00 pm ~6:00 am

Table 7-46 DYNASMART-P MOEs for I-40 and I-85 for the revised Work zone II

MOEs \ Scenarios	No work zone	Work zone (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
VMT (Volumes)	187,134.55	178,890.61	179,464.04	180,268.16	181,102.25
VHT (hours)	2,752.36	3,247.07	3,218.25	3,193.14	3,104.62
Average Speed (mile/hour)	67.99	55.09	55.76	56.45	58.33
Average Travel Time (min)	21.33	26.23	25.89	25.54	24.67

* Data collection period: 8:00 pm ~12:00 am

Table 7-47 Network-wide MOEs for the revised Work zone II

Scenarios / MOEs	No work zone	Work zone (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Average Travel Time (min)	8.97	10.19	9.83	9.50	9.27
Stop time (min)	1.11	1.99	1.72	1.46	1.29
Average trip distance (mile)	6.96	6.96	6.96	6.96	6.96

* Data collection period: 8:00 pm ~6:00 am

Table 7-48 shows the FREEVAL results for the revised Work zone II. It had similar VMT to that of DYNASMART-P as shown in Table 7-46. DYNASMART-P showed smaller VMT because DYNASMART-P reflected the capacity reduction effects on the throughput amount and the diversion to other routes which were not included in the statistics for two major routes. In the FREEVAL results, because 10% diversion was still not enough to make the link demand on the work zone link be under capacity, the work zone links had congestion and the average travel speed was less than those of other ATIS scenarios. In the 20% and 30% diversion scenarios the demands on the work zone link were under the reduced capacity. The average speed approached 67 mph.

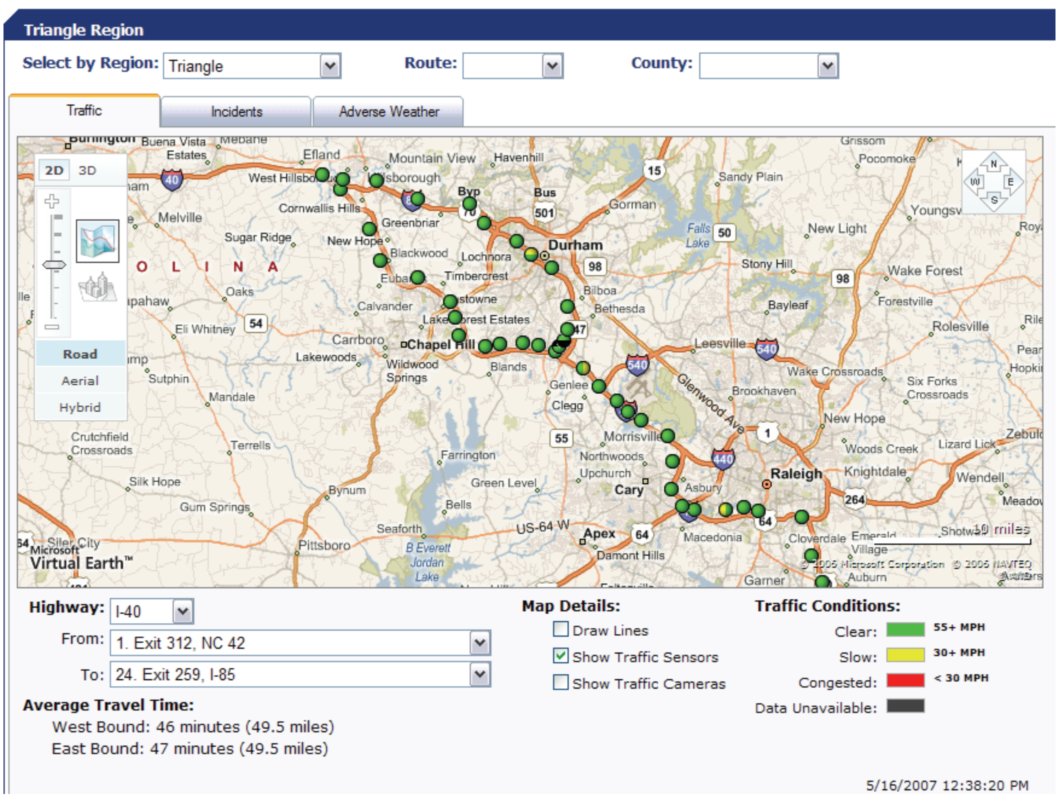
Table 7-48 FREEVAL results for the revised Work zone II

Scenarios / MOEs	No work zone	Work zone (No diversion)	Existing ATIS (10% diversion)	Planned ATIS I (20% diversion)	Planned ATIS II (30% diversion)
VMT (Demand) (mile)	192,712.03	192,712.03	192,346.37	191,980.70	191,615.05
VMT (Volume) (mile)	192,712.03	192,712.03	192,346.38	191,980.70	191,615.05
Total Travel Time (hour)	2,861.40	3,385.96	3,211.07	2,875.49	2,869.63
Total Delay (hour)	27.40	526.11	357.55	28.31	28.79
Average Speed (mile/hour)	67.35	56.92	59.90	66.76	66.77
Average Travel Time (min)	21.15	24.17	23.07	21.07	20.96

* Data collection period: 8:00 pm ~12:00 am

7.4.2 Speed measurements

The NCDOT Traveler Information Management System (TIMS) website provides real time information about travel, incident, and adverse weather. TIMS manages and distributes travel information to ten ITS regions (Asheville vicinity, Eastern Mountains, Metrolina, Northern Coastal, Rural Piedmont, Southern Coastal, Triad, Triangle, and Western Mountains). The case study area is in the Triangle region. The web site traveler information panel shows traffic condition based on speed detector information and video images from CCTVs. Figure 7.17 shows the location of speed detectors in the Triangle region. The project team downloaded the raw speed data (one-minute average speeds). Hence, measured speed from the field can be compared with synthetic speed from the simulation tools.



http://apps.dot.state.nc.us/tims/RegionSummary.aspx?re=1

Figure 7.17 NCDOT TIMS Web Service

As mentioned in a previous section, June 6th, 2007 was selected for modeling the revised Work zone II case. This day's lane closing direction was eastbound and two of three lanes were closed from mile marker (MM) 274 to 275. To examine the effect of ATIS on the upstream and downstream of the work zone, speed data from MM 270 to MM 285 were collected during construction period (June 6th 8:00 PM ~ June 7th 6:00 AM). One minute average speeds for every 15 minute interval were picked out (8:00~8:01 pm, 8:15~8:16 pm, 8:30~8:31 pm … 5:30~5:31 am, and 5:45~5:46 am). The link performance export tool in DYNASMART-PED was used to extract speed data from the DYNASMART-P results. Simulated links at the same locations where the detectors were installed were selected. Figure 7.18 shows the locations of the speed detectors around the revised work zone case II. In the FREEVAL run, one hour average speed was available because analysis time period was one hour. Each scenario had four data sets (8:00~9:00 pm, 9:00~10:00 pm, 10:00~11:00 pm, and 11:00 pm ~12:00 am).

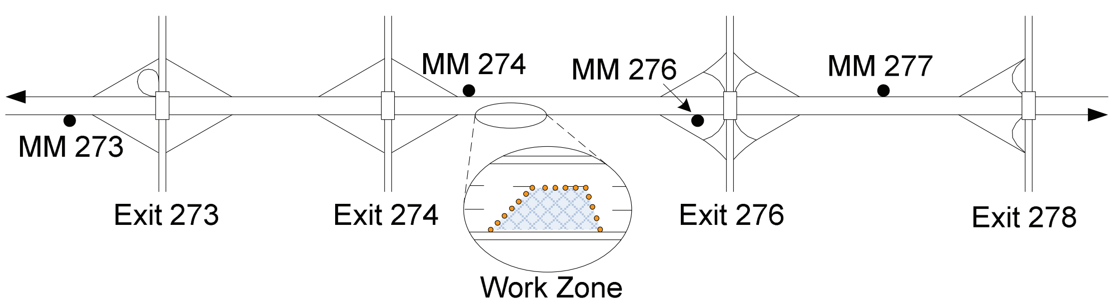


Figure 7.18 The Locations of the Speed Detectors around the Work Zone

Figure 7.19 through Figure 7.22 provided comparison of the field speeds and DYNASMART-P link speeds in the revised Work zone II. The scale of y axis is % of Free Flow

Speed (FFS). Most of the field speeds showed some fluctuations. One of the reasons of these fluctuations is that the detector locations were near exit ramps (on or off ramps).

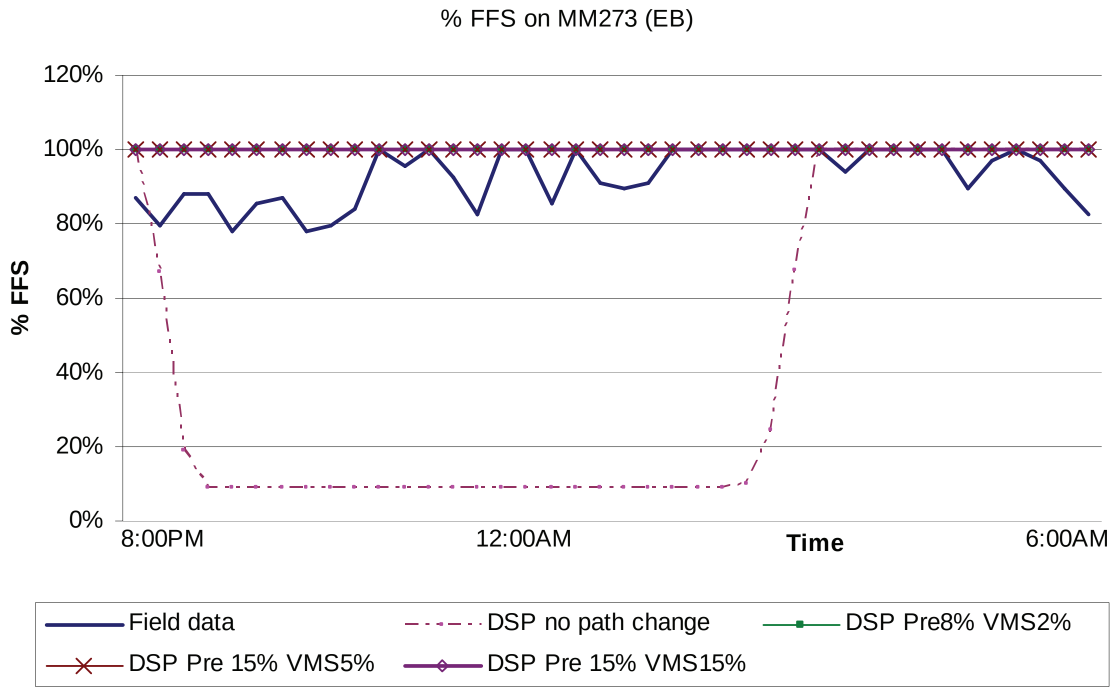


Figure 7.19 Speed Measurements on MM 273 from Field and DYNASMART-P

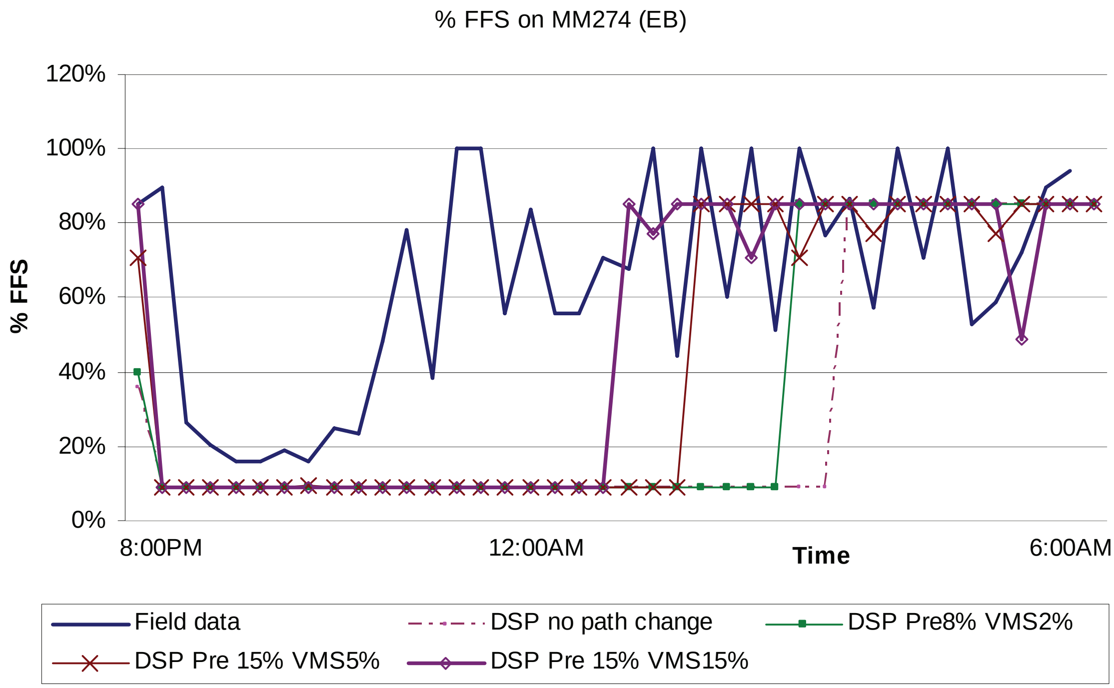


Figure 7.20 Speed Measurements on MM 274 from Field and DYNASMART-P

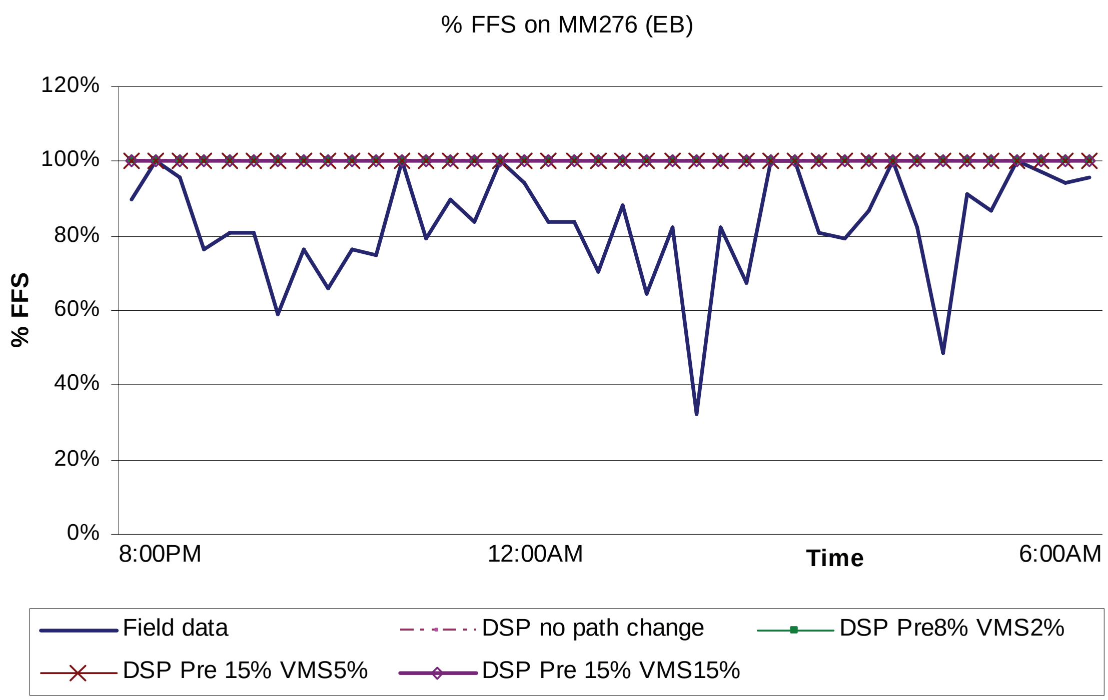


Figure 7.21 Speed Measurements on MM 276 from Field and DYNASMART-P

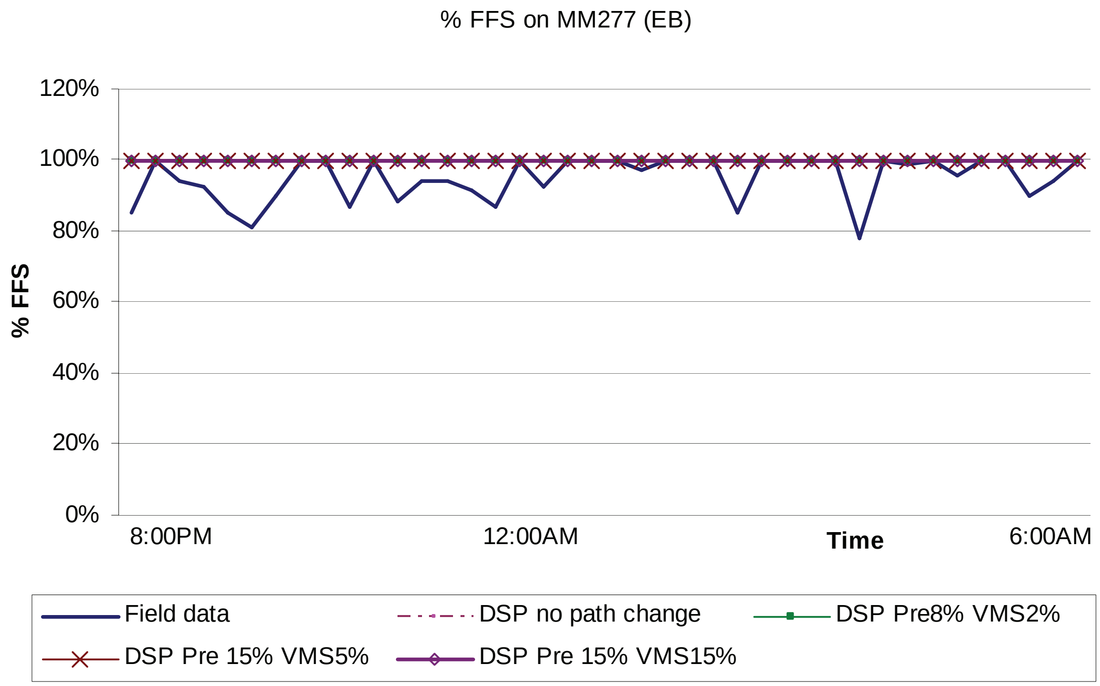


Figure 7.22 Speed Measurements on MM 277 from Field and DYNASMART-P

MM 273 is located upstream of the work zone. 'DYNASMART-P no path change' scenario in Figure 7.19 shows very low speeds during the work time period. This indicates that the upstream link had heavy congestion and long queues. The congestion disappeared at about 3:00 AM. Very low demand helped dissipate the queues. The significant congestion due to the construction work was not present in the DYNASMART-P ATIS scenarios. Field speeds fluctuate near the FFS as expected because ATIS was deployed in the study area at that time. Field speeds could be compared to the results from an ATIS scenario.

The construction work occurred around MM 274. Figure 7.20 shows the speeds on this location. The MM 274 detector was also located on right after the on-ramp. This fact could be a reason for the large speed fluctuation during the time period of lane closure. The speed data showed the congestion due to the lane closure and the time this congestion began to be mitigated.

As the percent of information user increased, the speeds recovered earlier. The 15% pre-trip information and 5% VMS scenarios gave the similar results to those from the field data.

Figure 7.21 and Figure 7.22 present the speeds on the downstream of the work zone. The speeds from DYNASMART-P on downstream of the work zone were at free flow speed. Because the bottleneck reduced the throughput, even the speeds of the no path change scenario reached free flow speed. However, the field speeds on MM 276 showed some speed reduction. In fact, the speeds of MM 276 should be less than free flow speed because vehicles needed acceleration time. DYNASMART-P cannot reflect this fact. However, the field speeds on MM 276 showed severe fluctuation. There is a possibility that one of the three lanes was closed in this area to make a temporary taper.

Figure 7.23 through Figure 7.26 depict the field speeds and FREEVAL link speeds in the revised Work zone II. In FREEVAL, one hour average speeds during four hours were available as a result of setting one hour as the time analysis period and setting the simulation duration for four hours. In Figure 7.23 and Figure 7.24, the no diversion and 10% diversion scenarios had similar speed outputs. Because 10% diversion was still not enough to bring the link demand on the work zone link under capacity, the work zone links were congestion, and the average travel speed was less than those of other ATIS scenarios. The number of diverted vehicle was estimated by multiplying diversion rate to the volume in the first link after the split point of the two major roads. The numbers in parentheses are diversion rates compared to average link volume. The demand in the work zone in the 20% and 30% diversion scenarios became less than the reduced capacity. As shown in Figure 7.22, the upstream speeds of the 20% and 30% diversion scenarios were not affected by the work zone. Figure 7.24 shows that the speeds of the 20% and 30% diversion scenarios follow the work zone speed limits (55 mph) on MM 274.

Figure 7.25 and Figure 7.26 show the FREEVAL speeds on the downstream of the work zone. The speeds of FREEVAL on the downstream of the work zone were free flow speed. Because the bottleneck reduced the throughput, the speeds of the downstream became near free flow speed.

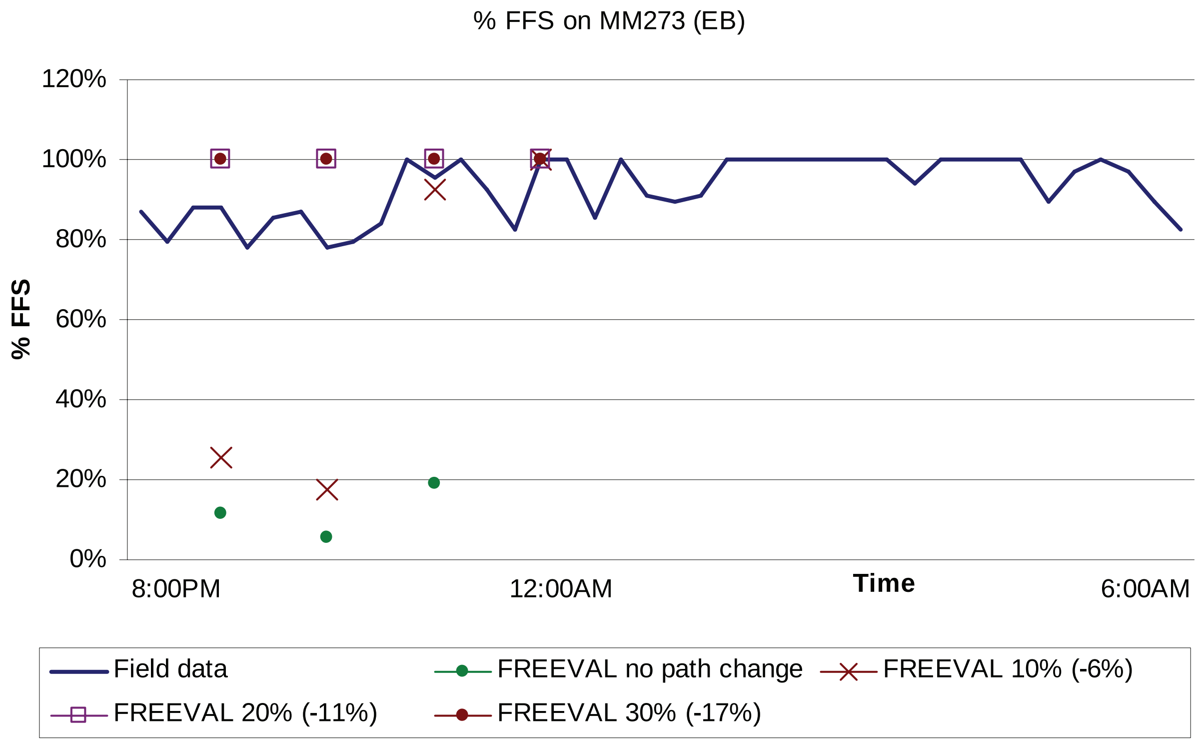


Figure 7.23 Speed Measurements on MM 273 from Field and FREEVAL

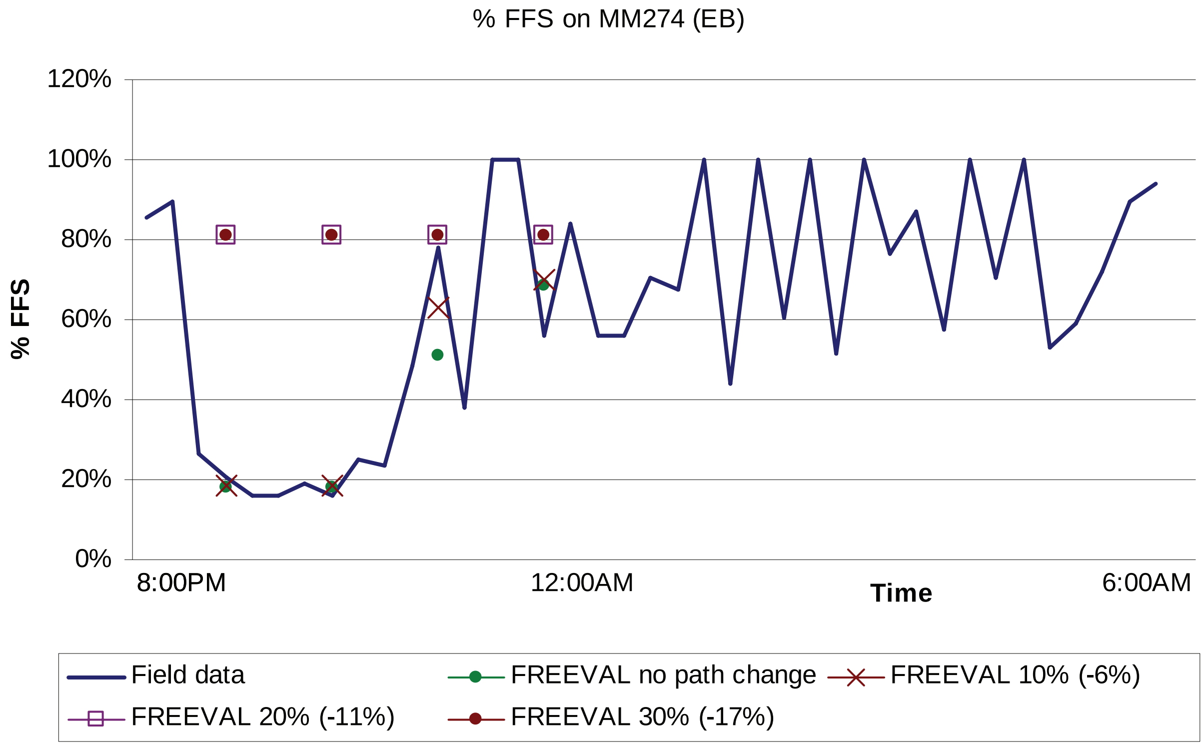


Figure 7.24 Speed Measurements on MM 274 from Field and FREEVAL

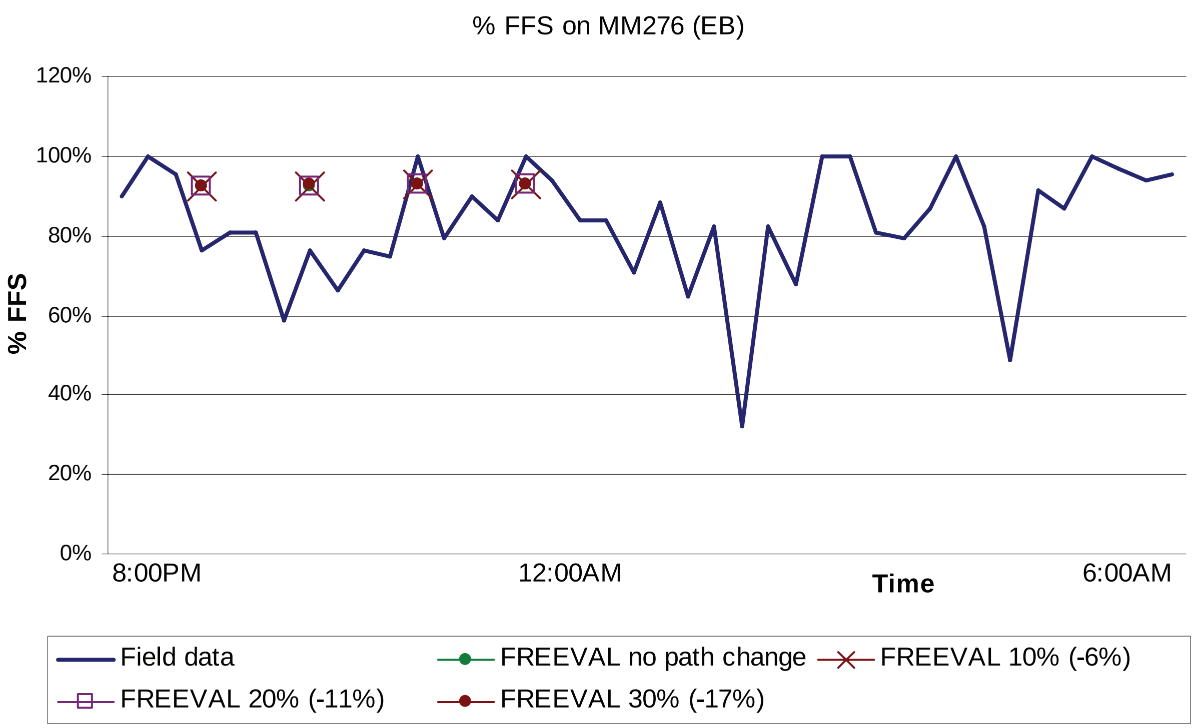


Figure 7.25 Speed Measurements on MM 276 from Field and FREEVAL

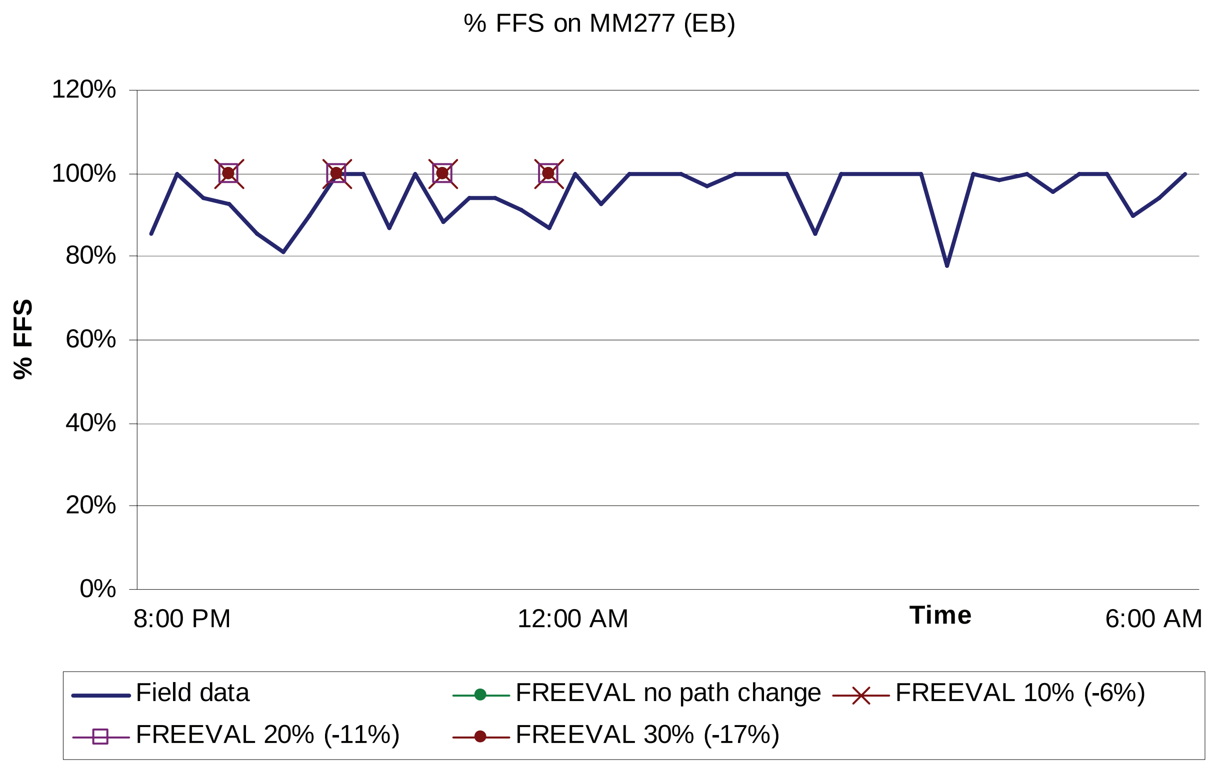


Figure 7.26 Speed Measurements on MM 277 from Field and FREEVAL

7.4.3 Benefit cost analysis

Benefit cost analysis can be a helpful tool for selecting a best alternative. It is not simple, however, to do this kind of analysis for ATIS evaluation studies. For example, it is not easy to define benefit types, spatial range, and time duration according to the investment of ATIS facilities. Some of qualitative benefits such as users' satisfaction are hard to measure. The benefit of additional investment is more than difficult to separate from the effects of the entire ATIS facilities. Furthermore, it is hard to define user's responsive rate to ATIS. This section provides the results of a benefit cost analysis for the revised Work zone II case. Some assumptions were made to address the difficulties described above.

NCDOT has been collecting data using CCTVs and providing traveler information by Internet, 511, TV, and HAR. Recently, NCDOT installed speed detectors, permanent VMSs, and portable VMSs in the Triangle area. Furthermore, there was a significant effort to inform travelers about construction work through various pre-trip information sources such as TV and Internet. In the study network, the planned ATIS II equipment were defined as 29 speed detectors, 10 permanent VMSs, and six portable VMSs (auxiliary equipment was not considered). Table 7-49 shows the initial investment costs per unit, the annual operation and maintenance (O&M) costs per unit, and the life cycles for these equipment investments. The capital cost was calculated by multiplying the number of units by the initial investment cost per unit. The annualized capital costs were estimated based on the initial cost of the equipment, a 5% interest rate, and the life cycle. The annual O&M costs were calculated by multiplying the numbers of units and O&M costs per unit. Total annual cost is the sum of the annualized capital costs and the annual O&M costs. As shown in Table 7-49, total annual cost was estimated as $281,027.

Table 7-49 Costs of additional investment for planned ATIS II

Devices	Number of units	Initial investment cost per unit ($)	Annual operation and management cost per unit ($)	Life Cycle (year)	Capital Cost ($)	Annualized Capital Cost ($)	Annual O & M Cost ($)	Total Annual Cost ($)
Speed detector	29	8,500	200	10	246,500	**31,922**	**5,800**	**37,722**
Permanent VMS	10	150,000	5,000	12	1,500,000	**169,200**	**50,000**	**219,200**
Portable VMS	6	25,000	500	9	150,000	**21,105**	**3,000**	**24,105**
Total annual cost								**281,027**

Note: 1. Estimations of initial investment, annual O&M costs are based on NCDOT cost data and cost database from ITS Joint Program Office (http://www.benefitcost.its.dot.gov).
2. Annualized Capital cost = P(A/P, i, n), where, P: first cost of equipment, A: annualized capital cost, i: interest, and n: life cycle of equipment.
(A/P, 5%, 10) = 0.13, (A/P, 5%, 12) = 0.11, (A/P, 5%, 9) =0.14

The revised Work zone II case was simulated using one day of the real I-40 resurfacing work day. The work location changed day by day, but work zone duration, the number of closing lane, and the lane closure length was kept similar. Therefore, one could assume that the effect of the revised Work zone II represented one day of the ATIS effect of I-40 resurfacing work. The re-pavement work was planned as one year work. The number of construction work days was assumed to be 150 days (the winter season (about 4 months) and rainy days were excluded). Only travel time saving benefits were considered.

Table 7-50 shows the calculated benefit for one year of the ATIS implementation for the revised Work zone II.

Table 7-50 ATIS benefits of the revised Work zone II

Scenarios / Travel time savings	No incident	Incident (No diversion)	Existing ATIS (Pre 8%, VMS2%)	Planned ATIS I (Pre 15%, VMS5%)	Planned ATIS II (Pre 15%, VMS15%)
Vehicles on network	454,199	454,199	454,199	454,199	454,199
Average Travel Time (min)	8.97	10.19	9.83	9.50	9.27
Travel time savings per vehicle (min)			0.35	0.69	0.92
Total travel time savings per day (hour)			2,678	5,187	6,943
Total travel time savings per day ($)			58,225	112,780	150,944
Total travel time savings per year ($)			11,645,075	22,556,161	30,188,984
Benefit of additional investment per year ($)			-	8,183,314	13,907,932

Note: 1. Average wage = $21.74
2. The number of work zone is set to 150 days per year.
3. Data collection period: 8:00 pm ~6:00 am

The benefit of ATIS alternatives could be estimated by calculating the increase of the travel time saving of ATIS alternatives in comparison to the travel time saving of the No ATIS scenario. In Table 7-7, the second row from the bottom shows the amount of the benefits of ATIS alternatives.

Then, one could estimate the benefit of the recent investment by calculating the increase of the travel time saving of planned alternatives in comparison to the travel time saving of the existing ATIS. Last row of

Table 7-50 shows the benefit of the recent investment. The benefit of Planned ATIS I was about 8 million dollars. The benefit of Planned ATIS II was about 14 million dollars.

According to the speed measurement results in the previous section, Planned ATIS II (15% pre trip and 15% VMS) fitted the speed data from the field relatively well. Then, one could say that the 0.28 million dollars investment produced 14 million dollars benefit on one year of the I-40 resurfacing work. If the benefit of reducing the impact of incidents and recurring congestion were added to the benefit calculation, the benefit of the recent investment should be increased.

CHAPTER 8. EVALUATION FRAMEWORK RECOMMENDATIONS

As envisioned by task 10 of the Effectiveness of Traveler Information Tools project, the culmination of the research is a recommended framework for NCDOT's ongoing ATIS project selection and evaluation activities. This chapter presents this recommended framework along with describing and supporting the project team's recommendation that the DYNASMART-P software program be used as the integrating tool for implementing the framework. This chapter begins with a high level description of the framework followed by a discussion of DYNASMART-P's recommended integration role. Also included is a brief description of the supplemental role that simpler, corridor focused tools such as FREEVAL will play in the ATIS evaluation framework. Summary recommendations related to the framework, along with broader recommendations engendered by the project are provided in Chapter 10 – Recommendations.

8.1 Framework Description

Figure 8.1 provides a concise illustration of the recommended ATIS evaluation framework. Although simplified, it highlights the key components and information flows. In the center of the diagram is the evaluation methodology encapsulated within an integrative evaluation tool. Inputs flow into the evaluation from the elements that define the physical network context, the ATIS alternatives under consideration, and the travel demand and driver response conditions. The evaluation results in turn provide decision support for ongoing ATIS deployment and enhancement decisions directly and through ongoing evaluation of ATIS deployments. A discussion of the individual components follows.

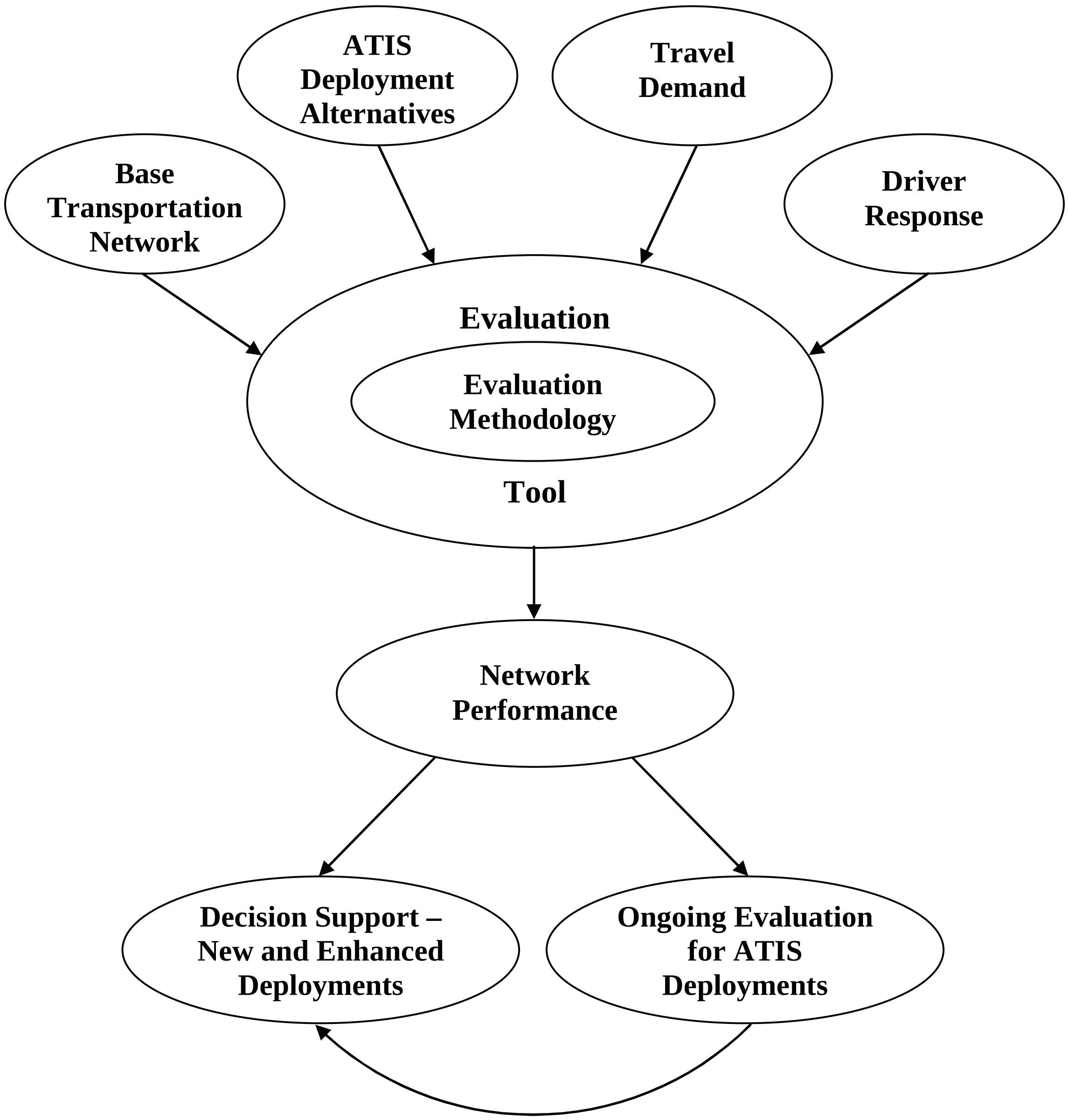


Figure 8.1 ATIS Evaluation Framework

8.1.1 Framework Inputs

Base Transportation Network – This framework element relates to the physical transportation network and its operational characteristics. It does not include the ATIS components in place and/or the ATIS deployment alternatives under consideration. It does include network impacts for any work zone configurations that may be the subject of evaluation.

The network must be represented in a format that is compatible with the specified evaluation tool.

ATIS Deployment Alternatives – Full specification of this element involves the definition of all ATIS deployment alternatives that are being considered both in the case of new deployments where no ATIS components are currently in place or in the case where enhancement of current ATIS systems are being contemplated. The relative richness of the evaluation tool's capability to accurately model the deployment alternatives is an important determinant of the quality and usefulness of the evaluation results.

Travel Demand – Accurate representation of the travel demand during the time period or periods to be evaluated is directly related to the accuracy of the evaluation results. For ATIS, a clear understanding of travel demand under recurrent and incident induced congestion situations is needed. Behavioral surveys and socioeconomic data are needed to assess travel demand. Specific recommendations on traffic data sources and systems are included in Chapter 10.

Driver Response – Future research may provide driver response models that can be embedded in integrative evaluation tools. However, this will require specialized behavioral surveys and modeling of behavioral responses to various types of information. The cross classification and driver response modeling conducted for this project and discussed in Chapter 6, represent early steps in this direction. When such models are sufficiently mature and included directly in evaluation tools, the input would be driver demographic and travel characteristics and prediction of driver decisions would be internal to the evaluation methodology.

However, in the current state of the practice, driver response to travel information must be determined and defined separately, requiring assumptions about individuals' behavior. Therefore, the inputs to the current framework include direct or indirect parameters that determine the type and level of driver response for the various ATIS devices and technologies to be evaluated.

8.1.2 Evaluation Methodology and Tool

As a complement to Figure 8.1, which provides a concise outline of the recommended framework, Figure 8.2 provides a more detailed sketch of the framework, include detail on the critical components of the evaluation tool. In simple terms, the evaluation methodology involves modeling of traffic operations under the various scenarios selected for analysis. Reasonable representation of the traffic conditions in turn requires sufficiently accurate modeling of the user decisions in response to dynamic traffic conditions and scenario dependent traveler information and the path assignments that flow from these user decisions.

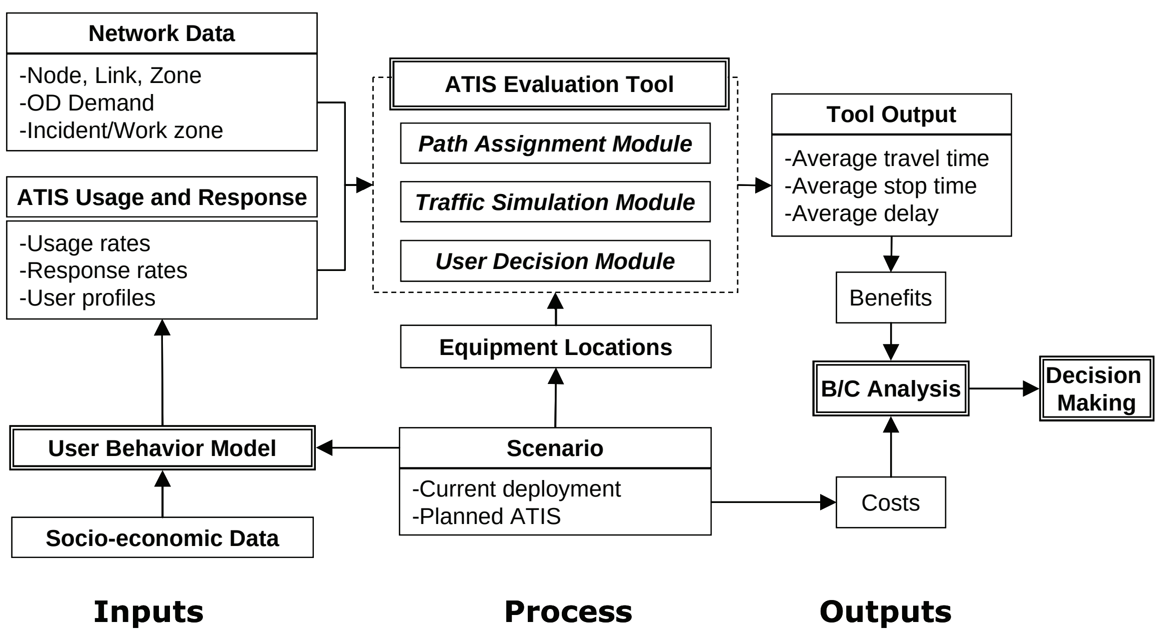


Figure 8.2 Detailed Evaluation Framework

Therefore, the ideal evaluation tool must include robust modules for traffic simulation, user decisions, and path assignment. As mentioned above, the current status of driver response models and related tool implementation necessitates that the embedded user decision module provides simple application of ATIS usage and response formulated outside the tool (as represented in the "Inputs" section of Figure 8.2). As the science and application of driver behavior advances, key elements of user behavior modeling will likely move from the "Inputs" to "Process" and be incorporated into the evaluation tool. It should be note that the application of FREEVAL to ATIS evaluation further requires that path choice be separated out as an input. This is because FREEVAL does not have the capability to model path changes, instead providing macroscopic simulation of given traffic conditions only. Although FREEVAL represents a simple and relatively straightforward way to assess ATIS impacts, DYNASMART-P provides greater capabilities as an integrating tool for implementing the ATIS framework.

8.1.3 Framework Outputs

The primary evaluation tool outputs will be network measures of effectiveness under the various operational scenarios defined for comparative analysis. These measures of effectiveness, such as average travel time and vehicle delay, will provide direct support to ATIS deployment decisions (both new deployments and system enhancements) and can also be incorporated into comparative analyses of benefits and costs. The framework also envisions the establishment of an ongoing program for evaluating the effectiveness of deployed ATIS systems. This ongoing evaluation will help refine the NCDOT's understanding of the relative value of ATIS investments, which in turn will improve future deployment planning and project decisions.

8.2 Recommended Integration Tool

As mentioned above, the project research team recommends that the NCDOT strongly consider using the DYNASMART-P program as the integration tool for an institutional ATIS evaluation framework. The key characteristics and capabilities of DYNASMART-P were presented in Chapter 3. The initial rating of DYNASMART-P as one of the most appropriate evaluation tools was born out through the case study analyses. Chief among its pivotal features is DYNASMART-P's ability to model driver response to various ATIS devices and deployments. Other important features include the relative ease of incorporating network and origin-destination data from regional travel demand models and dynamic traffic assignment. In summary, DYNASMART-P is well suited to serve as the key integrating tool in the proposed ATIS evaluation framework.

8.3 Supplemental Modeling Tools

Although DYNASMART-P is recommended as the system-level integration tool for the ATIS evaluation framework, there is a clear role in detailed corridor-level, project-specific evaluation for a simpler, macroscopic modeling tool such as FREEVAL. As the case study results revealed, when DYNASMART-P and FREEVAL are given the same flow parameters and ATIS impacts, their inherently disparate modeling approaches yield very similar results. Given the ease and flexibility of conducting FREEVAL analyses, a tool such as FREEVAL could be used to evaluate a series of detailed ATIS deployment alternatives with much lower cost in terms of analyst effort and computational burden.

CHAPTER 9. FINDINGS AND CONCLUSIONS

Findings and conclusions arising from the project research activities are organized as follows. Section 9.1 presents key findings and conclusions from the Phase 1 tasks, and section 9.2 presents the key findings and conclusions from the Phase 2 tasks. Recommendations arising from the project findings are presented in Chapter 10.

9.1 Phase 1 Findings and Conclusions

Chapter 2 through Chapter 6 presents comprehensive findings on all the Phase 1 research tasks. The sections below highlight key findings and conclusions regarding the evaluation tool assessment task and the general ATIS evaluation.

9.1.1 Evaluation Tool Assessment

The tool evaluation presented in Chapter 3 revealed that DYNASMART-P and a hypothetical extension of the FREEVAL-based IMAP tool were the most promising tools when judged relative to the objective criteria established by the project team (see Table 3-1). These subjective assessments were affirmed by the preliminary case study (see section 3.2).

The results of the completed evaluation tool assessment task led the conclusion that IDAS, although useful in the context of broad programmatic sketch planning, was not effective in supporting project specific decisions. This is primarily a result of the inability of IDAS to estimate and consider driver response to ATIS devices. Rather IDAS uses simple multiplicative factors to estimate the benefits of various ATIS device option.

Although DYNASMART-P does not provide full functionality vis-à-vis all the ideal tool criteria, it did emerge as the most fully featured of the candidate tools. Through the preliminary case study, DYNASMART-P demonstrated the capability to provide reasonable dynamic assignment based modeling of the network impacts resulting from driver decisions in the presence of traveler information.

What was originally termed as an investigation of a possible extension to the IMAP planning tool was in essence an evaluation of the ATIS evaluation functionality of the FREEVAL freeway facilities tool. The underlying traffic flow models in the IMAP tool were derived from FREEVAL analyses. The tool evaluation task confirmed that FREEVAL can provide reasonable evaluation results. However, it should not and cannot be compared directly with DYNASMART-P. Unlike DYNASMART-P, FREEVAL does not directly model driver behavior. Driver behavior such as diversion percentages must be determined separately and submitted to FREEVAL as inputs. Furthermore, FREEVAL cannot model mixed freeway and surface street networks. Nevertheless, FREEVAL did demonstrate effectiveness in corridor level freeway ATIS evaluation. Therefore, it should be considered a complementary tool that can provide simple evaluations of freeway sub-networks.

The original idea was that if FREEVAL could provide adequate modeling of ATIS investments, a similar user friendly graphical user interface could be developed. However, for the purpose of freeway ATIS evaluation the FREEVAL tool is sufficiently easy to use. This fact, coupled with the limitations discussed in the previous paragraphs, does not motivate a need for investing in development of a front end user interface for the application of FREEVAL to ATIS evaluation.

9.1.2 General ATIS Evaluation

The general ATIS evaluation was based on a series of special questions added to the Triangle Travel Survey (see section Chapter 6). In addition to providing useful information regarding percentages of traveler information users among Triangle region drivers and their propensity for route changes, the survey findings also provided several important findings. Some were not surprising, such as the correlation of higher level information sources, such as the Internet, with a higher incidence of travel change decisions. The top level finding was that roughly half of survey respondents use traveler information sources. Although this could be considered a discouraging finding, it should be viewed in the light of the related finding that the majority of travelers who use traveler information sources consult them frequently, essentially daily.

9.2 Phase 2 Findings and Conclusions

The key Phase 2 tasks were the case study based ATIS evaluation using the evaluation tools selected in Phase 1 (see Chapter 7) and the development of an evaluation framework (Chapter 8). The key findings and conclusions from these tasks are summarized below.

9.2.1 Case Study Based ATIS Evaluation

9.2.1.1 DYNASMART-P

Overall, DYNASMART-P performed well in evaluation various levels of ATIS deployment in the work zone and incident case studies (see section 7.2). The case studies did however reveal several areas for improvement. As a result of the project team working closely with FHWA's DYNASMART-P support team, some of these shortcomings were addressed with modifications to the software during the course of the project. The modifications included the additions of two functions, one to increase centroid connector capacity and one to support demand level calibration by generating goodness of fit statistics between expected and actual link demands. The modifications also included the development of two new tools that greatly enhanced the ATIS evaluation and enabled more directly comparison between the DYNASMART-P and FREEVAL results. The new tools are a tool to isolate measures of effectiveness for impacted vehicles (defined as vehicles whose original route was effected by a work zone or incident) and a tool to calculate link based measures of effectiveness.

Even with these enhancements, two key weaknesses remain. First, in the absence of any specifically defined traveler information source, none of the simulated DYNASMART-P drivers will deviate from their original route even in the presence of extreme congestion. This behavior is unrealistic, because drivers will make re-routing decision based on visual clues. Second, while DYNASMART-P models queue propagation and any resulting spillback blockage, the simulation logic grows all queues at jam density. Therefore, queues grow more slowly in the DYNASMART-P simulation and are not as long as they would be in real life under similar conditions.

9.2.1.2 FREEVAL

The FREEVAL tool also provided reasonable case study results. As mentioned above, vehicle flow diversion from the base case routing must be estimated outside of FREEVAL and the freeway mainline and ramp flows must be adjusted accordingly.

9.2.1.3 Tool Comparison

Initially there were some significant discrepancies between the DYNASMART-P results and the FREEVAL results for some of the scenarios. However, the primary reason for the differences flowed directly from the decision to test each tool as realistically as possible relative to how they would be used independently to analyze the selected network. This resulted in completely different demand estimates. The DYNASMART-P demand levels were based on the OD demands taken from the Triangle regional travel demand model. FREEVAL on the other hand was run using demand flow derived from reported AADT values with a directional split derived from a single permanent count station.

In order to provide a more clear direct comparison, the project team decided to rerun the FREEVAL tool using the demand levels from the DYNASMART-P model. When the demand levels were thus synchronized, the results of the two projects were very similar. Therefore, the project team concluded that both tools are valid for ATIS evaluation when given appropriate inputs.

9.2.1.4 Speed Validation

As discussed in section 7.4.2, speed data was acquired for a time period for the I-40 resurfacing work zone during which the extents of the work zone were known. The specific work zone condition was model in both DYNASMART-P and FREEVAL. Both tools gave reasonable speed results. Although this did not represent a rigorous validation, it provided further support for the conclusion that both tools were providing reasonable results.

9.2.1.5 Benefit Cost Analysis

The example benefit cost analysis presented in section 7.4.3 illustrates that high benefit to cost ratios can be derived for effective traveler information (higher than 20:1 for the case study evaluations). However, it must be stressed that this is in essence based on benefits of traveler information and not necessarily the modeled ATIS investments. It continues to difficult to isolate the marginal effect of individual ATIS technology investments. Therefore, the ability to perform more and more precise benefit cost analyses will come with improved understanding of the impact of specific ATIS technologies on driver behavior and improved data collection and analysis procedures.

9.2.2 Evaluation Framework

In the course of reflecting on the project tasks and developing the recommended framework under task 10, three guiding principles were identified –

1. The evaluation of ATIS alternatives should be conducted at a system level. This will avoid unnecessarily sending the problem downstream or creating a more serious problem through unintended network effects.
2. The integrating tool should be able to easily extract network and demand information from existing travel demand models.
3. The integrating tool should be able to model driver response and include dynamic assignment functionality.

These guiding principles were considered in the development of the framework presented in Chapter 8.

CHAPTER 10. RECOMMENDATIONS

The project findings and conclusions give rise to concrete recommendations. The project team's recommendations are concisely presented in this chapter beginning with recommendations for the NCDOT followed by recommendations for future research.

10.1 Recommendations for the NCDOT

The bottom line general recommendation is that NCDOT continue its focus on seeking to make wise investments in systems that provide travelers with ever more accurate, timely, and valuable information both pre-trip and en-route. Another high level recommendation is that the NCDOT continue to seek opportunities and develop strategies for continually increasing the general awareness of traveler information. The ATIS survey questions reveal that most information users are regular information users. Although the questions did not include one on whether or not the respondents were familiar with traveler information sources, there is a strong implication that once travelers are aware of the information sources, they find it to be valuable.

The remaining recommendations are presented under the headings of evaluation framework and ATIS data collection.

10.1.1 Evaluation Framework

The recommended evaluation framework is presented in Chapter 8. Implementation of this framework will provide the NCDOT a rational and systematic methodology for evaluation ATIS investment alternatives and evaluating the effectiveness of existing systems and devices. As discussed in Chapter 8, DYNASMART-P is recommended as the integrating evaluation tool.

10.1.2 Ongoing ATIS Data Collection

The project research revealed an important need for richer and more extensive data collection to support ATIS planning and evaluation. The needed data are both from the operation, traffic stream environment and from the traveling public in terms of data to increase our understanding of driver behavior, especially with regard to travel changes in the presence of advanced traveler information.

While there will always be practical and fiscal limits on the level of traffic data collection that is feasible at any given point in time, it is true the more, the better in terms of remotely sensed traffic stream data. Also, the data collection needed to properly support the evaluation of ATIS will also support the increased accuracy and availability of accurate real time data. The Traffic.com data that will be coming online in the near future will help. However, the NCDOT should be continually looking for cost effective ways to implement more data collection. Third-party data sources, including travel time data from for profit transportation services companies, are also likely to be key in the future.

No matter how extensive the traffic stream data collection is, it will always be difficult to isolate the impact of traveler information from the panoply of factors that affect driver behavior and resulting system performance. Therefore it will also be critical going forward for the NCDOT to seek ways to strategically gather data to increase understanding of driver behavior and to assist in isolating the marginal impact of traveler information investments.

10.2 Future Research

All research efforts in the ATIS domain will provide additional motivation for basic research to increase our understanding driver behavior and decision making and applied research in network modeling including the representation of driver decisions and dynamic traffic assignments. In addition to these general calls for further research, the project team recommends specific research efforts aimed at –

1. Developing a realistic model of driver response to visual recognition of downstream congestion. (Ideally with testing and implementation within DYNASMART-P.)
2. Developing a realistic model of queue propagation that can be implemented in a mesoscopic model such as DYNASMART-P
3. Continued research to develop increasingly valid and accurate models of driver behavior.

CHAPTER 11. IMPLEMENTATION AND TECHNOLOGY TRANSFER PLAN

The primary research product for this project is the project final report. The key implementation element of the report is the recommended ATIS framework. This report and the framework should be used by the Intelligent Transportation Systems Operations Unit, the Intelligent Transportation Systems Section and other NCDOT units involved in the planning and operation of the Advanced Traveler Information Systems in the state of North Carolina. The report will also provide valuable information for North Carolina MPOs in their ATIS project evaluation efforts.

This research project also involved the development of DYNASMART-P and FREEVAL models for a variety of scenarios based around the I-40/I-85/NC-147 freeway network in western Wake and Durham Counties. The computer files necessary to run these models will be provided to the NCDOT on CDROM media. These models may be useful in continue evaluation of the subject freeway network as well as providing a valuable case study example to aid the NCDOT in applying the recommended evaluation framework in other areas.ill be provided to the ITS Unit. However, as explained in the report, none of the currently available simulation tools are ideal for analysis of extensive evacuation networks. Furthermore, there are scalability and output processing issues that render it impractical for the NCDOT to consider these models to be readily accessible and useful in the current state of the practice.

CITED REFERENCES

Abdel-Aty, M. "Design and Development of a Computer Simulation Experiment to Support Mode/Route Choice Modeling in the Presence of ATIS", Transportation Research, Part B 37, 2003, pp.793–814.

Abdel-Aty, M., and M. F. Abdalla. "Modeling Repeated Multinomial Route Choices Under Advanced Traveler Information System: Generalized Estimating Equations With Polytomous Logit Function", Transportation Research Records 1882, 2004.

Ben-Akiva and Moshe, "Dynamit, a Simulation-Based System for Traffic Prediction and Guidance Generation". Prepared for Massachusetts Institute of Technology. Intelligent Transportation Systems Program, 1998.

Bogers E., F. Viti, and S. Hoogendoorn, "Joint Modeling Of ATIS, Habit, And Learning Impacts On Route Choice By Laboratory Simulator Experiments", Transportation Research Records TBD, 2005.

Chen, P. S-T., K. K. Srinivasan, and H. S. Mahmassani. "Effect of Information Quality on Compliance Behavior of Commuters under Real-Time Traffic Information", Transportation Research Records 1676, 1999.

Cambridge Systematics, "IDAS, Intelligent Transportation Systems Deployment Analysis System", prepared for FHWA, 2000.

Ettema, D., A. Borgers, and H. Timmermans. "SMASH (Simulation Model Of Activity Scheduling Heuristics): Some Simulations", Transportation Research Records 1551, 1996.

Florian, D. G., "Simulation-Based Evaluation of Advanced Traveler Information Services (ATIS)", Master thesis at the Massachusetts Institute of Technology, 2004

Fox, J. E., and D. A. Boehm-Davis, "Effects of Age and Congestion Information Accuracy of Advanced Traveler Information Systems on User Trust and Compliance", Transportation Research Records 1621, 1998.

Gel, Y. E., H. M. Zhang, and W. H. K. Lam, "Network Reserve Capacity under Influence of Traveler Information", Journal Of Transportation Engineering vol. 129-3, June 2003.

Gordon, S., and J. Trombley. "Tracking the Deployment of the Integrated Metropolitan Intelligent Transportation Systems Infrastructure in the USE: FY2002 Results". Prepared for ITS Joint Program Office, FHWA by Oak Ridge National Laboratory, 2004.

Harder, K. A., J. R. Bloomfield, D. M. Levinson, and L. Zhang. "Route Preferences and the Value of Travel-Time Information for Motorists Driving Real-World Routes", prepared for Minnesota Department of Transportation, May 2005.

Henk, R. H., and B. T. Kuhn. “Assessing the Effectiveness of Advanced Traveler Information on Older Driver Travel Behavior and Mode Choice”, prepared for Texas Transportation Institute, August 2000.

Hobeika, A., R. Sivanandan, K.M. Jehanian, and M. D. Ameen. “Advanced Traveler Information System Users' Needs in I-95 Northeast Corridor”, Transportation Research Records 1537, 1996.

Horowitz, A J, Weisser, I, and Notbohm, T., “Diversion from a Rural Work Zone with Traffic-Responsive Variable Message Signage System”, Transportation Research Record No. 1824 , 2003.

ITS joint program office, USDOT. Cost database and benefit database. Benefits: http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ByLink/BenefitsHome, Costs: http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ByLink/CostHome, Accessed July, 2005.

Jeannotte, K., “Evaluation of the Advanced Regional Traffic Interactive Management and Information System (ARTIMIS)”. Presented at the 11th Annual ITS America Meeting, Miami, Florida, 2001.

Jensen, M., C. Cluett, K. Wunderlich, A. Deblasio, and R. Sanchez, “Metropolitan Model Deployment Initiative Seattle Evaluation Report: Final Draft”. Prepared for the USDOT by SAIC, FHWA-OP-00-020, 2000.

Jou, R-C., T-Y. Hu, and C-W. Lin. “Empirical Results From Taiwan and Their Implications for Advanced Traveler Pretrip Information Systems”, Transportation Research Records 1607, 1997.

Jung, S., J. Larkin, V. Shah, A. Toppen, M.Vasudevan, and K. Wunderlic, “On-Time Reliability Impacts of Advanced Traveler Information Services (ATIS), Volume II Extensions and Applications of the Simulated Yoked Study Concept”, Prepared for Federal Highway Administration, March 2002.

Jung, S., J. Larkin, V. Shah, A. Toppen, M. Vasudevan, and K. Wunderlich, “On-Time Reliability Impacts of ATIS, Volume III Implications for ATIS Investment Strategies”, prepared for Federal Highway Administration, May 2003.

Khattak AJ. “Driver response to unexpected travel conditions: effect of information and other factors [Ph.D. Dissertation]”. Evanston, Illinois: Northwestern University, 1991.

Khattak, A J; Al-Deek, H M; Hall, R W, “Concept of an Advanced Traveler Information System Tested for the Bay Area: Research Issues”, Journal: IVHS JOURNAL, Vol. 2 No. 1, 1994.

Khattak, A. J., Y. Yim, and L. Stalker. “Does Travel Information Influence Commuter and Noncommuter Behavior? Results from the San Francisco Bay Area TravInfo Project”, Transportation Research Record 1694, 1999.

Khattak, A., A. Polydoropoulou, and M. Ben-Akiva. "Modeling Revealed and Stated Pretrip Travel Response to Advanced Traveler Information Systems", Transportation Research Records 1537, 1996.

Khattak, A. J. and Asad J. Khattak. " Comparative Analysis of Spatial Knowledge and En Route Diversion Behavior in Chicago And San Francisco: Implications for Advanced Traveler Information Systems", Transportation Research Records 1621, 1998.

Khattak A and Rouphail N, "Incident Management Assistance Patrols: Assessment of Investment Benefits and Costs". Prepared for NCDOT. Report No.: FHWA/NC/2005-02, 2005.

Kim, K. S., and U. Vandebona. "User Requirements and Willingness to Pay for Traffic Information Systems: Case Study of Sydney", Australia, Transportation Research Records 1694, 1999.

Kim, L. H., Y. Chung, and W. Recker, "Evaluation of Effectiveness of Automated Workzone Information Systems", Transportation Research Records1911, 2005.

Lappin J., and J. Bottom. "Understanding and Predicting Traveler Response to Information: A Literature Review". U.S. Department of Transportation, Federal Highway Administration, Office of Metropolitan Planning and Programs, Washington, D.C., 2001.

Levinson, D. "The value of advanced traveler information systems for route choice", Transportation Research Part C vol. 11, 2003, pp. 75–87.

Levinson, D., D. Gillen, and E. Chang. "Assessing the Benefits and Costs of Intelligent Transportation Systems: The Value of Advanced Traveler Information systems", California PATH Research Report, July 1999.

Liu, Y-H., and H. S. Mahmassani, "Dynamic Aspects of Commuter Decisions under Advanced Traveler Information Systems: Modeling Framework and Experimental Results", Transportation Research Records 1645, 1998.

Lo, H. K., and W.Y. Szeto, "Modeling Advanced Traveler Information Services Static versus Dynamic Paradigms", Transportation Research Part B vol. 38, 2004, pp. 495–515.

London Transport. "Survey Finds London Transit Info Changes Behavior, Creates Revenue". Inside ITS, 1998, pp. 8.

Mahmassani, H. S. and Jayakrishnan, R., "System Performance and User Response Under Real-Time Information in a Congested Traffic Corridor", Transportation Research. Part A: Policy and Practice, Vol. 25A No. 5, 1991

Mahmassani, H. S. and Peeta, S., "Network Performance under System Optimal And User Equilibrium Dynamic Assignments: Implications For Advanced Traveler Information Systems", Transportation Research Record No. 1408,1993.

Mehndiratta, S. R., M. A. Kemp, J. E. Lappin, and E. Nierenberg. “Likely Users of Advanced Traveler Information Systems Evidence from the Seattle Region”, Transportation Research Record 1739, 2000.

Mehndiratta, S. R., M. A. Kemp, J. E. Lappin, and D. Brand. “What Advanced Traveler Information System Information Do Users Want? Evidence from In-Vehicle Navigation Device Users”, Transportation Research Records 1679, 1999.

Ng, L., W. Barfield, and F. Mannering. “Analysis Of Private Drivers' Commuting and Commercial Drivers' Work- Related Travel Behavior”, Transportation Research Records 1621, 1998.

North Carolina Department of Transportation (NCDOT), “North Carolina Statewide Intelligent Transportation Systems (ITS) Strategic Deployment plan”, http://www.ncdot.org/doh/operations/dp_chief_eng/its/strategic/plandocuments.html, Accessed August, 2007.

NuStats. “Greater Triangle Travel Study: Household Travel Survey Final Report”. 2006.

Pagan, Y. L. L., H. S. Mahmassani, and M. Kraan. “Trip Planning Behavior of Tourists San Antonio Case Study”. Prepared for Texas Transportation Institute, January 2000.

Peeta, S., J. L. Ramos, and R. “Pasupathy. Content of Variable Message Signs and On-Line Driver Behavior”, Transportation Research Record 1725, 2000.

Pesti, G, McCoy, P T, Meisinger, M D, and Kannan, V., “Evaluation of Work Zone Speed Advisory System”, Federal Highway Administration; Federal Motor Carrier Safety Administration , http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/14057.htm , 2004.

Pierce, S. and Lappin, J., “Evolving Awareness, Use, and Opinions of Seattle Region Commuters Concerning Traveler Information: Finding from the Puget Sound Transportation Panel Survey, 1997 and 2000”, Volpe National Transportation Systems Center, U.S. Department of Transportation. Washington DC, November 2002.

Polydoropoulou, A., D. A. Gopinath, and M. Ben-Akiva. “Willingness to Pay for Advanced Traveler Information Systems: Smartraveler Case Study”, Transportation Research Records 1588, 1997.

PTV, VISSIM. http://www.ptvamerica.com/vissim.html

Schiesel, R., and M. J. Demetsky, “Evaluation of Traveler Diversion Due to En-Route Information”, Department of Transportation, University Transportation Centers Program, May 2000.

Shah, V., K. Wunderlich, A. Toppen, and J. Larkin, “Potential of advanced traveler information system to reduce travel disutility”, Transportation Research Record: Journal of the Transportation Research Board, No. 1826, 2003.

Srinivasan, K. K. and Z. Guo. “Day-To-Day Evolution of Network Flows under Route Choice Dynamics in Commuter Decisions”, TRB annual meeting, 2004.

Sundaram, S., “Development of a Dynamic Traffic Assignment System for Short-Term Planning Applications”, Master thesis at the Massachusetts Institute of Technology, June 2002.

Tech Environmental, Inc., “Air Quality Benefit Study of the SmarTraveler Advanced Traveler Information Service”, Tech Environmental, Inc., 1993.

Toppen, A, K.Wunderlich, J. Lappin, M. Petrella, and S. Peirce (2003), “Corroborating Qualitative Benefits of Online ATIS with Modeling: Los Angeles Case Study”. Prepared for Volpe National Transportation Systems Center; Federal Highway Administration, 2003.

Toppen, A., S. Jung, V. Shah, and K. Wunderlich, “Toward a Strategy for Cost-Effective Deployment of Advanced Traveler Information Systems”, Transportation Research Records 1899, 2004.

Transportation Research Board, “Highway Capacity Manual - HCM 2000 (U.S. Customary Units)”, 2000.

Vasudevan, M., K. Wunderlich, A. Toppen, and J. Larkin, “Making the Most of Limited Data in the Evaluation of Advanced Traveler Information Services (ATIS) Through Experimental Resampling”, 83rd Annual Meeting of the Transportation Research Board, Washington, D.C., 2004.

Van Aerde, M., “Modeling of Traffic Flows, Assignment and Queuing in Integrated Freeway/Traffic Signal Networks”. PhD. Thesis, Department of Civil Engineering, University of Waterloo, Waterloo, Canada, 1985.

Van Aerde, M., and Yagar, S., “Dynamic Integrated Freeway/Traffic Signal Networks: A Routing-Based Modeling Approach”, Transportation Research A, Volume 22A, Number 6, 1988a, pp.445-453.

Van Aerde, M., and Yagar, S., “Dynamic Integrated Freeway/Traffic Signal Networks:Problems and Proposed Solutions”, Transportation Research A, Volume 22A, Number 6, 1988b, pp.435-443.

Van Aerde, M and Yagar, S., “Combining Traffic Management and Driver Information in Integrated Traffic Networks” , International Conference On Road Traffic Control, 1990

Van Aerde M. and Rakha H., “*TravTek Evaluation Modeling Study”*, FHWA-RD-95-090, 1995.

Viswanathan, K., K.G. Goulias, and P. P. Jovanis. “Use of Traveler Information in the Puget Sound Region: Preliminary Multivariate Analysis”, Transportation Research Records 1719, 2000.

Wells, K., and T. Horan. “ Toward A Consumer Demand-Driven Intelligent Transportation System Policy: Findings from Southern California”, Transportation Research Records 1679, 1999.

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

Yang, Q., H. N. Koutsopoulos, and M. E. Ben-Akiva, "Simulation Laboratory for Evaluating Dynamic Traffic Management Systems", Transportation Research Records 1710, 2000.

Yim, Y., and J-L. Ygnace, "Link Flow Evaluation Using Loop Detector Data: Traveler Response to Variable-Message Signs", Transportation Research Records 1550, 1996.

Yim, Y., and M. Miller, "Evaluation of TravInfo Field Operational Test", University of California at Berkeley. Institute of Transportation Studies, California PATH Program, 2000.

Yin, Y., and H. Yang, "Simultaneous Determination of the Equilibrium Market Penetration and Compliance Rate of Advanced Traveler Information Systems", Transportation Research Part A vol. 37, 2003, pp. 165–181.

Yim Y., "TravInfo Evaluation: Traveler Response Element Broad Area Study: Phase 2 Results Analysis of Wave-2 Survey", California PATH Working Paper, UCB-ITS-PWP-2001-4, California PATH Program, University of California at Berkeley, 2001.

Ziliaskopoulos, A. K., and S. T. Waller, "An Internet-Based Geographic Information System that Integrates Data, Models and Users for Transportation Applications", Transportation Research Part C, vol.8, 2000, pp. 427-444.

Zimmerman, C., J. Marks, J. Jenq, C. Cluett, A. DeBlasio, J. Lappin, H. Rakha, and K. Wunderlich. "Phoenix Metropolitan Model Deployment Initiative Evaluation Report". Prepared by Battelle for the USDOT FHWA, FHWA OP-00-015, 2000.

BIBLIOGRAPHY

511 Deployment Coalition, "Deployment Assistance Report #1 Business Models and Cost Considerations", January 2002.

Abdel-Aty, M., and M. F. Abdalla. "Modeling Drivers' Diversion from Normal Routes under ATIS Using Generalized Estimating Equations and Binomial Probit Link Function", Transportation 31, 2004, pp. 327–348.

Abdel-Aty, M., and M. F. Abdalla. "Modeling Repeated Multinomial Route Choices under ATIS Using Generalized Estimating Equations with Polytomous Logit Function". Presented at 83rd Annual Meeting of the Transportation Research Board, Washington D.C., 2004.

Abdel-Aty, M.A. " Using Ordered Probit Modeling to Study the Effect of ATIS on Transit Ridership", Transportation Research, Part C vol.9, 2001, pp. 265-277.

Ajay, K. R., and Oak Ridge National Laboratory, "Models For Assessing the Impacts and the Potential Benefits of Intelligent Transportation System". Prepared for IVHS Research Division Joint Program Office, August 15, 1995.

Ajisawa, S. "Impacts on Traffic Congestion by Switching Routes and Shifting Departure Time of Trips". Presented at 5th World Congress Conference on ITS, Seoul, Korea. 1998.

Atsush, A., M. Shimizu, and T. Daito. "Evaluation of Route Comparison Information Boards on Hanshin Expressway". Presented at 5th World Congress Conference on ITS, Seoul, Korea. 1998.

Balakrishna, R., H. N. Koutsopoulos, and M. E. Ben-Akiva. "Fernandez Ruiz BM and Mehta M, Simulation-Based Evaluation of Advanced Traveler Information Systems", Transportation Research Records TBD, 2005.

Baum, H. " Evaluation of Stadtinfo Cologne: Methodological and Empirical Approach for an Overall Economic Assessment of Traffic Information Services". Presented at 6th World Congress Conference on ITS, Toronto, Canada. 1999.

Cambridge Systematics and SAIC. Final Report. "Prepared for the I-95 Corridor Coalition by Cambridge Systematics and SAIC", U.S. DOT ITS Program Assessment Support Contract. 2000.

Carter, M., C. Cluett, A. DeBlasio, F. Dion, B. Hicks, J. Lappin, D. Novak, H. Rakha, J. Riley, C. St-Onge, and M. Van Aerde. "Metropolitan Model Deployment Initiative San Antonio Evaluation Report". Prepared for the USDOT, May 2000.

Cheng, Y., and M. Demetsky. "Application of US DOT ITS Evaluation Guidelines". Prepared by the Center for ITS Implementation Research, U.S. DOT University Transportation Center, 2001.

Clemons, J., L. Aultman-Hall, and S. Bowling. "ARTIMIS Telephone Travel Information Service: Current Use Patterns and User Satisfaction". Kentucky Transportation Center, University of Kentucky, 1999.

Cluett, C., et al. **"**Evaluation of Rural ITS Information Systems along U.S. 395". Prepared for the USDOT by Battelle Memorial Institute, January 2004.

Collura, J., J. Chang, and M. Carter. "Seattle Intelligent Transportation System Information Backbone". Transportation Research Records 1753, 2001.

Cordis Transport Sector of Telematics Applications Programme, 4th Framework Programme. RTD&D 1994-1998. http://www.cordis.lu/telematics/tap_transport/research/10.html. Accessed June 15, 2005.

Cutler, M. R., S. Cahill, K. E. Proussaloglou, and K. L. Jeannotte. "An Evaluation of the Deployment of Advanced Traveler Information Systems (ATIS) in the Minneapolis/St. Paul Metropolitan Region". Presented at 80th Annual Meeting of the Transportation Research Board, Washington, D.C., 2001.

Daigle, J., and C. Zimmerman. "Acadia National Park Field Operational Test: Visitor Survey". Prepared for the USDOT by Battelle Memorial Institute, 2003.

Englisher, L. S., R. D. Juster, S. Bregman, D.G. Koses, and A. P. Wilson. "User Perceptions of Smartraveler Advanced Traveler Information System: Findings from Second-Year Evaluation", Transportation Research Records 1537, 1996.

Englisher, L., J. Marks, and J. Schwenk. "Houston Smart Commuter". Prepared for the USDOT by Volpe and Multisystems, Inc. Final Report 1996-1998, Report No. DOT-VNTSC-FTA-02-07. 2002.

ERTICO News, 1998.

Fekpe, E., and S. Collins. "Evaluation of Intelligent Transportation Infrastructure Program (ITIP) in Pittsburgh and Philadelphia, Pennsylvania". Prepared for the USDOT by Battelle, 2002.

Giuliano, G., and J. Golub. "Los Angeles Smart Traveler Information Kiosks: A Preliminary Report. Presented at the 74th Transportation Research Board Annual Meeting", Washington, D.C., 1995.

Glassco, R. A., A. T. Proper, V. P. Shah, and K. E.Wunderlich. "Studies of Potential Intelligent Transportation Systems Benefits Using Traffic Simulation Modeling-Volume2". Prepared for the USDOT FHWA by Mitretek Systems, Inc., 1997.

Glazer, L. J., and R. Cruz. "Intelligent Transportation Systems at the 2002 Salt Lake City Winter Olympic Games". Prepared for the Utah DOT, Apr. 2003.

Golob, T. F., and A. C. Regan. "Trucking Industry Preferences for Driver Traveler Information Using Wireless Internet-enabled Devices, Transport Direct Programme". Presented at the 82nd Transportation Research Board Annual Meeting, Washington, D.C., 2003.

Hallinan, M., M. Patten, and K. Goulias. "Survey of Travel Information Use in Southeast Pennsylvania". Prepared for the ITS America 13th Annual Meeting and Exposition, Minneapolis, 2003.

Hardy, M., J. Larkin, and K. Wunderlich. "Analyzing the Effects of Web-based Traffic Information and Weather Events in the Seattle Puget Sound Region: Draft Report". Prepared for the USDOT by Mitretek Systems, 2000.

Inman, V., R. Fleischman, R. Sanchez, C. Porter, L. Thelan, and G. Golembiewski. "TravTek Evaluation: Rental and Local User Study". Performed for the Federal Highway Administration by SAIC, FHWA-RD-96-028, 1996.

Inman, V., R. Sanchez, C. Porter, and L. Bernstein. "TravTek Evaluation: Yoked Driver Study. FHWA, U.S. Department of Transportation". Washington DC, October 1995.

ITERIS. Evaluation of a funded FY00 ITS Integration Component of the ITS Deployment Program "Traveler Information Integration Project within the East Bay SMART Corridors Project". Prepared for Alameda County Congestion Management Agency, December, 2004.

Kato, T. "Study on the ITS-based Traffic Operation Strategy in Poor Visibility Environment on Inter-Urban Expressways in Japan". Presented at 7th World Congress Conference on ITS, Turin, Italy, 2000.

Kraan, M., H. S. Mahmassani and N. Huynh. "Interactive Survey Approach to Study Traveler Responses to ATIS For Shopping Trips". Presented at the 79th Transportation Research Board Annual Meeting, Washington, D.C., 2000.

Kraan, M., H. S. Mahmassani, and N. Huynh. "Traveler Responses to Advanced Traveler Information Systems for Shopping Trips: Interactive Survey Approach", Transportation Research Records 1725, 2000.

Kristof, T., M. Lowry, and G. S. Rutherford. "Assessing the Benefits of Traveler and Transportation Information Systems". Prepared for Washington State DOT and TransNow, March 2005.

Lee, D. B. Jr. "Benefit-Cost Evaluation of Traveler Information Seattle's Washington State Department of Transportation Website", Transportation Research Record 1739, 2000.

Look H., and B. Abdulhai. "Accident Risk Assessment Using Microsimulation for Dynamic Route Guidance". Presented at 80th Annual Meeting of the Transportation Research Board, Washington, D.C., 2001.

McCoy, P. and G. Pesti. "Chapter 5: Nebraska from Midwest States Smart Work Zone Deployment Initiative: Technology Evaluations Year One 2000", 2000.

Noonan, J., and O. Shearer. "Advanced Traveler Information Systems". Prepared for the FHWA, Sep. 1998.

Orban, J., B. Pierce, M. Burt, H. Clark, and D. Burkom. "Advanced Traveler Information Services in Rural Tourism Areas: Branson Travel and Recreational Information Program (Missouri) and Interstate 40 Traveler and Tourist Information System (Arizona)". Prepared for the USDOT by Battelle, BRW, and CJI Research, 2000.

Perez, W., and B. Wetherby. "Seattle Wide-area Information for Travelers (SWIFT): Evaluation Summary". Prepared for Washington State Department of Transportation by Science Application International Corporation, WSDOT Y-5908, 1995.

Pierce, S. and Lappin, J. "Evolving Awareness, Use, and Opinions of Seattle Region Commuters Concerning Traveler Information: Finding from the Puget Sound Transportation Panel Survey, 1997 and 2000". Volpe National Transportation Systems Center, U.S. Department of Transportation. Washington DC, November 2002.

Prevedouros, P. "Incident Management Simulation on a Freeway Corridor in Honolulu". Paper presented at the 6th World Congress Conference on ITS, Toronto, Canada. 1999.

Puget Sound Regional Council (PSRC). "Puget Sound Gets More Connected – Use of Travel Information Services on the Rise". Trends No. T23, PSRC, April 2004.

Reed, T. "Commuter Perception of Commercial Radio Traffic Information". University of Michigan Report, 2000.

Remer, M., J. Wright, and F. Robinson. "ITS Benefits, Evaluation and Costs: Results and Lessons from the Minnesota Guidestar Travlink Operational Test". Minnesota TravLink Operational Test - Draft, 1995.

Sanchez, R., R. Hass, and C. Mitchell. "Final Evaluation Report for the Greater Yellowstone Regional Traveler and Weather Information System (GYRTWIS)". Report prepared for the USDOT by SAIC, Task 9826, 2003.

Shah, V., and K. Wunderlich. "Detroit Freeway Corridor ITS Evaluation". Prepared for the FHWA USDOT by Mitretek Systems, DTFH61-00-C-0001, 2001.

Soolman, J., and S. Radin. "Features of Traffic and Transit Internet Sites". Prepared for the U.S. Department of Transportation by the Economic Analysis Division, John A. Volpe National Transportation Systems Center, 2000.

Srinivasan, K. K. and H. S. Mahmassani. "Modeling Inertia and Compliance Mechanisms in Route Choice Behavior under Real-Time Information", Transportation Research Record 1725, 2000.

Srinivasan, K. K. and Z. Guo. " Day-To-Day Evolution of Network Flows under Route Choice Dynamics in Commuter Decisions", TRB annual meeting 2004.

Srinivasan, K. K., and H. S. Mahamassani. “Dynamic Decision and Adjustment Processes in Commuter Behavior under Real-Time Information”. Prepared for Texas Transportation Institute, February 2002.

Srinivasan, K. K., and H. S. Mahmassani. “Analyzing heterogeneity and unobserved structural effects in route-switching behavior under ATIS a dynamic kernel logit formulation”, Transportation Research Part B vol. 37, 2003, pp. 793–814.

Srinivasan, K. K., and H. S. Mahmassani. “Trip time Perception and Judgment Processes in Tripmaker Decisions under Real-time Traffic Information”. Presented at 81st Annual Meeting of the Transportation Research Board, Washington, D.C., July 2001.

Srinivasan, K. K., and Z. Guo. “Day-To-Day Evolution of Network Flows under Route-Choice Dynamics in Commuter Decisions”, Transportation Research Records 1894, 2004.

Swan, N., S. Baker, R. Hintz, and T. Trimble. “511 Virginia Evaluation”. Prepared for Virginia DOT, 2004.

TEA-21 ITS evaluation guidelines. http//www.its.dot.gov/evaluation/eguide_tea21.htm. Accessed July, 2005.

Toppen, A., V. Shah, J. Larkin, and K. Wunderlich. “Time Management Benefits of ATIS for Unfamiliar Urban Drivers”. Presented at 9th World Congress Conference, Chicago, IL, 2002.

Trombly, J. and B. Wetherby. “Seattle Wide-area Information for Travelers (SWIFT): Consumer Acceptance Study”. Prepared for Washington State Department of Transportation by Science Application International Corporation, January 1998.

Vasudevan, M., K. Wunderlich, J. Larkin, and A. Toppen. “A comparison of mobility impacts on urban commuting between broadcast advisories and advanced traveler information services”. FHWA, ITS JPO, 2004.

Vasudevan, M., K. Wunderlich, V. Shah, and J. Larkin. “Effectiveness of advanced traveler information systems (ATIS) under extreme congestion”. Presented at 14th Annual Meeting of ITS America, 2004.

VISTA Overview, Software Walkthrough, Tutorial, and Data Model. http//vista.civil.northwestern.edu/. Accessed September 2005.

Wetherby, B. “ System Effectiveness Test”. Draft Genesis FOT, 1997.

Wunderlich, K., and J. Larkin. “Impacts of Supplementing Web-Based Urban Freeway ATIS With Parallel Arterial Travel-Time Data”. Presented at 7th World Congress Conference on ITS, Turin, Italy, 2000.

Wunderlich, K., J. Bunch, and J. Larkin. “ITS Impacts Assessment for Seattle MMDI Evaluation: Modeling Methodology and Results”. Prepared for the USDOT FHWA by Mitretek Systems, Inc., 1999.

Wunderlich, K., J. Bunch, and J. Larkin. "Seattle Metropolitan Model Deployment Initiative Evaluation: Results and Key Findings from Modeling". Transportation Research Records 1739, 2000.

Wunderlich, K., M. Hardy, J. Larkin, and V. Shah. "On-Time Reliability Impacts of Advanced Traveler Information Services (ATIS)". Prepared for the USDOT FHWA by Mitretek Systems, Inc., 2001.

Yang, C. Y. D., J. D. Fricker, and T. Kuczek. "Designing Advanced Traveler Information Systems from a Driver's Perspective Results of a Driving Simulation Study", Transportation research records 1621, 1998.

Ygnace, J. "User Response to the Telephone Assisted Traveler Information System in the San Francisco Bay Area (TATS)". Presented at 5th World Congress Conference on ITS, Seoul, Korea, 1998.

Yun, I., and B. B. Park. "Feasibility Assessment of ITS Deployment Analysis System (IDAS) for ITS Evaluation", December 2003.

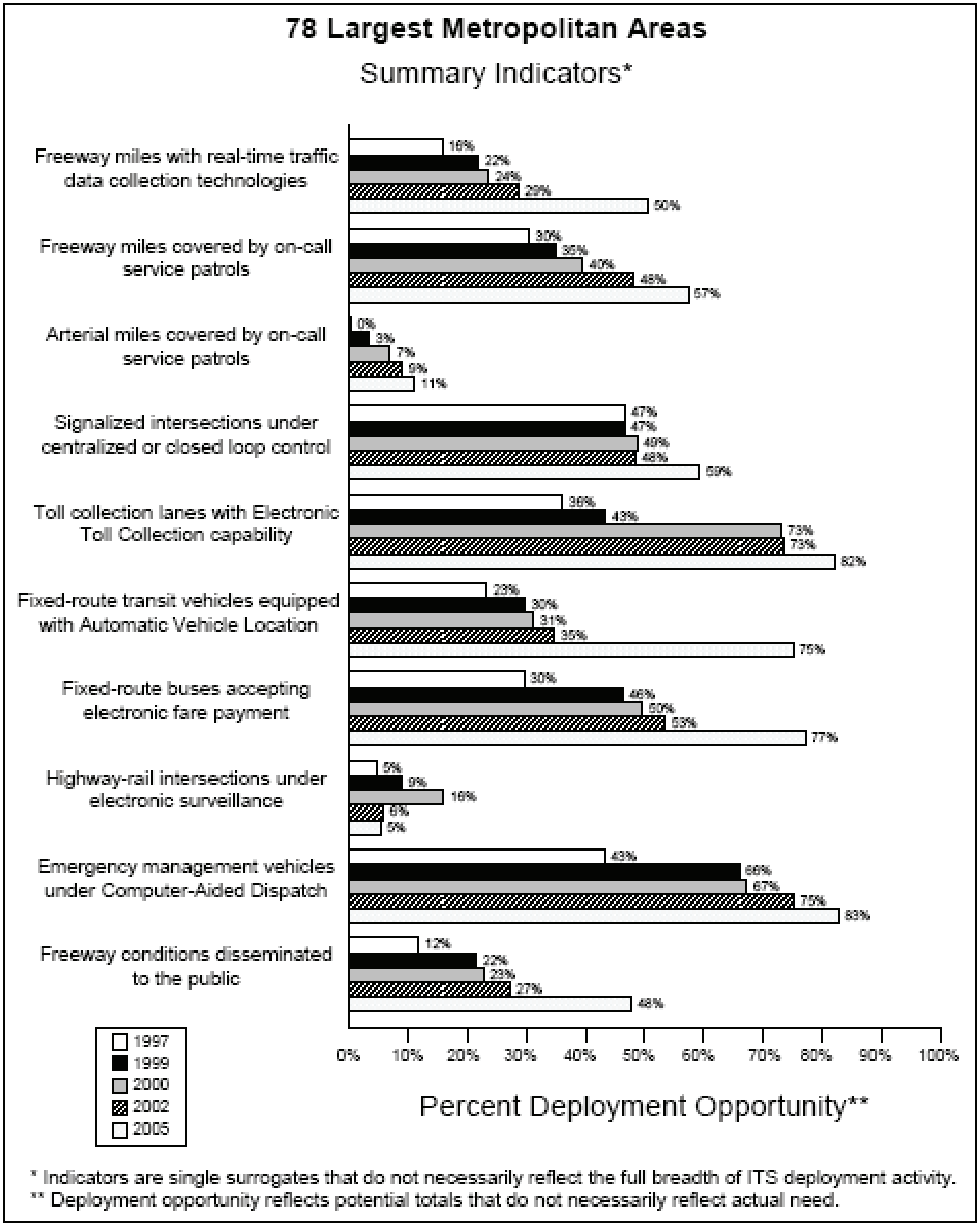
Appendices

APPENDIX A. ITS USER SERVICES

User Service Bundle	User Service
Travel and Traffic Management	1.1 Pre-trip Travel Information 1.2 En-route Driver Information 1.3 Route Guidance 1.4 Ride Matching And Reservation 1.5 Traveler Services Information 1.6 Traffic Control 1.7 Incident Management 1.8 Travel Demand Management 1.9 Emissions Testing And Mitigation 1.10 Highway Rail Intersection
Public Transportation Management	2.1 Public Transportation Management 2.2 En-route Transit Information 2.3 Personalized Public Transit 2.4 Public Travel Security
Electronic Payment Services	3.1 Electronic Payment Services
Commercial Vehicle Operations	4.1 Commercial Vehicle Electronic Clearance 4.2 Automated Roadside Safety Inspection 4.3 On-board Safety And Security Monitoring 4.4 Commercial Vehicle Administrative Processes 4.5 Hazardous Materials Security & Incident Response 4.6 Freight Mobility
Emergency Management	5.1 Emergency Notification And Personal Security 5.2 Emergency Vehicle Management 5.3 Disaster Response And Evacuation
Advanced Vehicle Safety Systems	6.1 Longitudinal Collision Avoidance 6.2 Lateral Collision Avoidance 6.3 Intersection Collision Avoidance 6.4 Vision Enhancement For Crash Avoidance 6.5 Safety Readiness 6.6 Pre-crash Restraint Deployment 6.7 Automated Vehicle Operation
Information Management	7.1 Archived Data
Maintenance and Construction Management	8.1 Maintenance And Construction Operations

Source: http://itsarch.iteris.com/itsarch/html/user/userserv.htm Accessed October 15, 2005.

APPENDIX B. ITS DEPLOYMENT IN 78 LARGEST METRO AREAS IN THE US



Source: Gordon & Trombley (2004), p. 3

APPENDIX C. BENEFITS OF ADVANCED TRAVELER INFORMATION SYSTEM BY MEASURES

Source	ITS category	Location	Study subject	Methodology	Benefits	Benefit *	Comments
Benefits in Capacity/Throughput							
Hardy et al, 2000	Advanced Traveler Information System	Seattle, Washington	Freeway and Arterial	Simulated (no field data)	Number of Stops: -6.39%, Travel Time -0.74%	Moderately positive	Vehicle Kilometers of Travel increased by 0.15 percent
Wunderlich & Larkin, 2000	Advanced Traveler Information System	Seattle, Washington	Freeway and arterial	Simulated (no field data)	0.1% increase in throughput	Mixed	Reduction in delay and number of stops
Van Aerde & Rakha, 1996	Dynamic route guidance	Orlando, Florida,	Urban transportation network	Predicted	10% increase	Highly positive	Market penetration rate of 30% and constant average trip duration
Shah & Wunderlich, 2001	Internet-based pre-trip ATIS, highway advisory radio, ramp metering, variable message signs	Detroit, Michigan	Freeway	Simulated (without field data)	Beneficial to corridor capacity		Speed:+5.4 mph Trip time:-4.6 mins Delay: -22%
Jensen et al., 2000	Advanced Traveler Information System	Seattle, Washington	Freeway	Simulated (no field data)	Slight increase in vehicle throughput	Mixed	Delay: -1.8%; Stops: -5.6% Emissions: -2%
Look and Abdulhai, 2001	Dynamic Route Guidance Systems	Toronto, Canada	Urban transportation networks	Simulated (no field data)	Reduced travel times, and increased network throughput	Mixed	A maximum 15.5 % increase in accidents was observed at a market penetration of 60%
Wunderlich et al., 1999	Integrated ATIS and ATMS	Seattle, Washington	Freeway and arterial	Simulated (with field data)	Higher vehicle throughput	Mixed benefit	More sub-area travel, fewer stops resulted in mixed bag of energy and emissions impacts
Benefits in Cost/Saving							
London Transport, 1998	Travel enquiry system	London, United Kingdom	Public Transit	Behavioral survey & measured	13% increase in ridership generates benefits: Operators: 3.5 million Societal benefits: 11 million	Highly positive	Benefit units: pounds sterling Route changes: 38%
Kato, 2000	Vehicle-guidance system designed for heavy fog	Kanetsu, Oita, Japan	Inter-Urban Expressways	Predicted	B/C: 1.7 to 2.1 (Kanetsu Expressway); 1.8 to 2.2 (Oita Expressway)		Benefits: measured by estimating 75% drop in costs generated by road closures.

Source	ITS category	Location	Study subject	Methodology	Benefits	Benefit *	Comments
Cambridge Systematics, and Science Applications International Corp., 2000	Carrier Operations & Fleet Management, Traveler Information	General USA Data	Freeway	Measured (Survey)	Motor carrier operational efficiencies not significantly impacted as far as on-time delivery, estimated arrival times, delivery penalties, fuel consumption, etc	Mixed	
Shah et al., 2003	Personalized pre-trip notification service	Wash. D.C., Maryland, Virginia	Urban transportation networks	Simulated (with field data)	40% of all ATIS users achieved individual net positive benefit $\geq$\$60/year		Significant benefit: reduced frequency of early and late arrivals (56% and 52% ,resp)
Benefits in customer satisfaction							
Wetherby, 1997	Incident information delivery via alphanumeric pagers	Minneapolis, Minnesota	Urban transportation networks	Measured-field operational test	Only 2% dropped out of project due to dissatisfaction with the service	Highly positive	65% Genesis users reported using the service daily; 88% once or more per week
Yim & Miller, 2000	TravInfo regional traveler information system	San Francisco, California	Urban transportation networks	Measured (Survey)	Only 9 percent of households were aware of TravInfo	Mixed	TravInfo effective in changing behavior, but insignificantly impacted transport system
Cordis Transport Sector, 2000	Traveler information	Europe	Urban transportation networks	Measured (Survey)	79-95% of users finding the systems easy to use	Highly positive	1/3 third users reported changing mode, 1/2 changed route.
Reed, 2000	Commercial radio traffic information	Detroit, Michigan	Freeway	Measured (field test & survey)	89% drivers use commercial radio for traffic info; 62% rate route-specific traffic reports "extremely useful"	Highly positive	Commercial radio information was perceived as "more reliable" than television or CMS information
Clemons et al., 1999	Advanced Regional Traffic Interactive Management and Information System	Kentucky, Ohio	Urban transportation networks	Measured (survey)	> 99% respondents avoided traffic, saved time, reduced frustration, arrived on time; 81% recommended the service to others	Highly positive	Users rated service very high in accuracy, ease of use; 65% willing to pay for service (free during survey); most common suggestion: expand service
Perez & Wetherby, 1995	Advanced Traveler Information System	Seattle, Washington	Urban transportation networks	Measured (survey)	Generally users found infor-mation useful for making travel decisions reduction in stress and travel time	Slightly positive	This system includes a wristwatch, an in-vehicle navigation system, and a PC based system.

Source	ITS category	Location	Study subject	Methodology	Benefits	Benefit *	Comments
Baum, 1999	Traveler information services	Cologne, Germany	Urban transportation networks	Measured (customer questionnaires)	Average Willingness-to-Pay: 7.17 to 12.90 Euro/month		
Giuliano & Golub, 1995	Smart Traveler Information Kiosks	Los Angeles, California	Urban transportation networks	Measured	The number of daily accesses ranges from 20 to 100 in a 20-hour day.		Most frequent request (83% users): freeway map
Jensen et al., 2000	Transit information dissemination	Seattle, Washington	Public Transit	Measured (focus group, questionnaire)	High rate but low usage	Mixed	
Inman et al., 1996	Navigational information	Orlando, Florida	Urban transportation networks	Measured	38% of rental car users and 63% of local drivers found the device helpful	Slightly positive	Navigational information may reduce travel stress for drivers in unfamiliar areas.
Soolman & Radin, 2000	Public and private Internet web sites with traffic and transit information	General USA Data	Urban transportation networks	Measured (Survey)	The most sought-after traffic information is not available in most metro areas of the country.	Mixed	Private web sites have more features related to traffic; public sites have more features related to transit
Ygnace, 1998	Telephone Assisted Traveler Information System	San Francisco, California	Urban transportation networks	Measured (Survey)	Average scores: Convenience: 4.2 out of 5; Ease of comprehension: 4.3 out of 5	Highly positive	Better than television or radio traffic information reports, but users were not willing to pay much for the information.
ERTICO News, 1998	Vehicle Information and Communication System (VICS)	Tokyo, Aichi, Osaka, Kyoto	Urban transportation networks	Measured (Survey)	▪ VICS advice = less stress ▪ valuable information on traffic jams ▪ want expanded service area	Highly positive	The system provides drivers with upcoming road conditions and alternative routes to avoid congestion.
Zimmerman et al., 2000	Traveler Information Service	Phoenix, Arizona	Urban transportation networks	Measured (Survey)	77% respondents rate service "useful" for radio broadcasts, 60% for finding congestion first-hand	Highly positive	pre-trip information in general may be less useful than en-route information
Orban et al., 2000	Traveler and Tourist Information System (TTIS)	Arizona, Missouri	Urban transportation networks	Measured (Survey)	>50% of tourists inter-viewed in Arizona agreed or strongly agreed that the info saved them time.	Moderately positive	78% aware of at least one deployed ATIS component, and 45% of travelers surveyed used the system.

Source	ITS category	Location	Study subject	Methodology	Benefits	Benefit *	Comments
Remer et al., 1995	Transit route and schedule information	Minneapolis Minnesota	Public transit	Measured (Survey)	33% of visitors accessing the system requested bus schedule adherence; 31% sought bus schedules	Moderately positive	Averaged slightly more than one access per participant per week.
Englisher et al., 2002	Real-time traffic information	Houston, Texas	Urban transportation networks	Measured (user surveys, diaries, participant use statistics)	▪ rated the handheld portable computer system good or very good ▪ 40% dwilling to pay for travel information.	Moderately positive	▪ preferred radio, Internet, or television over handheld portable computers or phones ▪ preferred traffic over mode-choice info
Fekpe, & Collins, 2002	Web-based traveler information services	Pittsburgh & Philadelphia, Pennsyl-vania	Urban transportation networks	Measured (website surveys)	18% of Internet respondents in Pittsburgh and 47% in Philadelphia: Traffic.com shortened commute	Slightly positive	68% of users in Pittsburgh and 86% of users in Philadelphia changed their original route
Daigle & Zimmerman, 2003	Traveler information systems	Bar Harbor, Mount Desert Island, Maine	Urban transportation networks	Measured (mail-back questionnaire)	Useful technologies: visitors who used real-time transit departure (90%), automated on-board next-stop announcements (84%), real-time parking info (74%)	Highly positive	Most visitors who experienced ITS at Acadia indicated the information they received was accurate, clearly understandable, and easy to use.
Sanchez et al., 2003	The Greater Yellowstone Weather and Traveler Information System	Montana	Urban transportation networks	Measured (Survey)	Overall customer satisfaction increased from 71% to 81% after the new 511 service was deployed	Moderately positive	Caution: The before survey measured respondents' *perception* of system; after survey measured *satisfaction*
Swan et al., 2004	Virginia's 511 phone and website service	Virginia	Urban transportation networks	Measured (focus group, phone and web surveys)	The majority of those who utilized Virginia 511 were satisfied to very satisfied with the service	Moderately positive	Awareness of the Virginia 511 service was higher than the national average of 511awareness
Hallinan et al., 2003	Travel information services	Philadelphia Pennsyl-vania	Urban transportation networks	Measured (Mail survey)	Commercial radio rated most useful travel info sources; TV and variable message sign also useful	Moderately positive	The response rate was 31.3% (a total of 1,124 responses).

Source	ITS category	Location	Study subject	Methodology	Benefits	Benefit *	Comments
Glazer et al., 2003	CommuterLink Website (CLW) 511 Telephone Service (511) Variable Message Signs (VMS) Highway Advisory Radio (HAR)	Salt lake city, Utah	Freeway	Survey	Visitors and residents answered the ATIS systems worked well.	Highly positive	
Cutler et al, 2001	Telephone based service and web site	Minnesota	Freeway	Survey (before/after)	between 45 and 48 percent of respondents said that the quality of the service was improved		
PSRC 2004	HAR, TV, telephone, and Internet	Seattle, Washington	Freeway and arterial	Survey	75% of respondents use Radio for traffic information Telephone: 12% of respondents use telephone for traffic information		
Cluett, 2004	HAR, Web and telephone	Spokane, Washington	-	Survey	56% of CVO respondents use HAR, 46% of post-deployment operators for CVOs use the Internet Respondents answered HAR and Web information is useful.		
McCoy and Pesti, 2000	VMS	Greenwood, Nebraska	-	Field observations and survey	57% of passing vehicles saw the sign		4% increased in traffic diversion
Pierce and Lappin, 2002	Web, Radio, and TV	Seattle, Washington	-	Survey	3.2% of respondents consult traveler information Radio 56%, pre-trip radio 22%, TV news 13%, traffic website 6%, transit website 6%		37% change in travel behavior (1.1% of total trips)-13% change departure time, 11% make small route change, 9% took whole different route, 2% added, delayed, or cancelled trip, 1% change mode

Source	ITS category	Location	Study subject	Methodology	Benefits	Benefit *	Comments
ITERIS, 2004	Web	East bay smart corridors, Alameda county	-	Survey	43.8% of respondents visit website		
Benefits in delay/time							
Wunderlich & Larkin, 2000	Web-Based Urban Freeway ATIS	Seattle, Washington	Freeway and arterial	Simulated (without field data)	▪ Vehicle-Hours of Delay: -3.4% ▪ Total Number of Stops: -5.5%	Moderately positive	Vehicle Throughput: +0.1%
Atsush et al., 1998	Traffic control system equipped with Dynamic Message Signs	Osaka-Kobe, Japan	Freeway	Predicted	▪ Saved 9.8 min/vehicle in periods of congestion ▪ Saved up to 38 min/vehicle during incident congestion		The average divergence rate increased 3.7% during periods of congestion.
Ajisawa, 1998	Pre-trip Information	Tokyo, Japan	Urban transportation networks	Simulated (no field data)	40%-80% decrease in time loss	Highly positive	
Wunderlich et al., 2001	Advanced Traveler Information Services (ATIS)	Washington DC	Urban transportation networks	Simulated (with field data)	ATIS users' on-time reliability (97%) more than Conservative Non-User 92%	Slightly positive	ATIS users demonstrated better performance than conservative non-users
Jeannotte, 2001	Advanced Regional Traffic Interactive Management and Information System	Cincinnati, Ohio	Freeway	Simulated (without field data)	Travel time delay reduced by 12,000 hours per A.M. peak period and 6,940 hours of unexpected delay per P.M. peak period		
Hardy et al., 2000	Web-based Traffic Information and Weather Events	Seattle, Washington	Urban transportation networks	Simulated (without field data)	▪ # stops decreased by 6.39% ▪ Adjusted Travel Time decreased by 0.74 % ▪ VKT increase by 0.15%	Slightly positive	VKT: Vehicle Kilometers Treveled
Shah et al., 2003	Pre-trip Advanced Traveler Information Service	Washington DC	Urban transportation networks	Simulated (with field data)	Reducing the frequency of early and late arrivals by 56% and 52% respectively	Highly positive	ATIS users were early 12% and late 2% of all trips, and ATIS non-users were early 28% and late 4% of all trips.

Source	ITS category	Location	Study subject	Methodology	Benefits	Benefit *	Comments
Toppen et al., 2002	ATIS	Washington DC	Urban transportation networks	Simulated (with field data)	Significantly reduced the amount of time spent on early arrivals		Using ATIS, unfamiliar drivers arrived at destination within 15 minutes of target arrival time 79% of time. Without ATIS--42% of time.
Carter et al, 2000	Variable Message Signs, Kiosk, Internet-based ATIS, In-Vehicle Device	San Antonio, Texas	Freeway and arterial	Simulated (with field data)	VMS: 5.7% decrease in delay Web: 5.4% reduction in delay In-Vehicle device: 8.1% reduction in delay		Kiosk had a function problem.
Glassco, R., et al.,1997	Advanced Traveler Information System ATMS, CVO	Detroit CBD	Urban transportation networks	Simulated (without field data)	25%~ 41% under non-incident conditions		
Noonan and Shearer, 1998	Various pre-trip and en-route information systems technologies	Several region	-	Field operation test	TravTek: 12% reduction in travel time and 32% reduction in vehicle stops ADVANCE: 4 % reduction in travel time		The impact are generally positive with a few exceptions
Prevedouros, 1999	HAR, VMS	Honolulu, Hawaii	-	Simulation	40% reduction in delay		Traffic diversion increased by 25%
Trombley and Wetherby, 1998	In-vehicle system	Seattle, Washington	-	Survey			With traveler information: 80% changed route, 50% changed departure time, 10% change mode With route guidance: 63% changed route, 12% changed departure time
Inman et al., 1995	In-vehicle system	Orlando, Florida	-	Field observation	80% time savings in trip planning		No observed benefit for real time traffic information
Benefits in Energy & Environment							
Tech Environmental, Inc., 1993	SmarTraveler Advanced Traveler Information Service	Boston, Mass.; Seattle, Washington	Urban transportation networks	Simulated (without field data)	▪ Reduced VOC by 498 kilograms (25%) per day, ▪ Reduced NOx by 25 kilograms (1.5%) per day ▪ Reduced CO by 5,032 kilograms (33%) per day	Moderately positive	50% of travelers changed their travel route and 45% changed their departure time as a result of better traveler information

Source	ITS category	Location	Study subject	Methodology	Benefits	Benefit *	Comments
Jensen et al., 2000	Advanced Traveler Information System	Seattle, Washington	Freeway	Simulated (without field data)	2% reduction in vehicle emissions	Slightly positive	• 1.8% reduction in delay • 5.6% reduction in the number of stops
Jeannotte, 2001	Advanced Regional Traffic Interactive Management and Information System	Cincinnati, Ohio	Freeway	Simulated (without field data)	▪ Hydrocarbon: -3.6% -3.8%. ▪ CO: -3.6% -3.8%. ▪ NOx: -4.5% -4.7%.	Moderately positive	
Zimmerman et al., 2000	Advanced Traveler Information Systems (ATIS)	Phoenix, Arizona	Urban transportation system	Simulated (with field data)	▪ 1.6% reduction in fuel consumption ▪ 1.2% increase in CO ▪ no significant change in HC or NOx emissions	Mixed	▪ 6.2% increase in vehicle speeds ▪ a reduction in the crash risk along the mainline of 6.7%
Noonan and Shearer, 1998	Various pre-trip and en-route information systems technologies	Several region	-	Field operation test	TravTek: 11% reduction in fuel consumption and 6% reduction in emission		The impact are generally positive with a few exceptions
Carter et al, 2000	Variable Message Signs, Kiosk, Internet-based ATIS, In-Vehicle Device	San Antonio, Texas	Freeway and arterial	Simulated (with field data)	VMS: 1.2% decrease in fuel consumption Web: 1.8% reduction in fuel consumption In-Vehicle device:3% reduction in fuel consumption		
Benefits in safety							
Jeannotte, 2001	Advanced Regional Traffic Interactive Management and Information System	Cincinnati Ohio	Freeway	Simulated (without field data)	Fatalities were reduced by 3.2 %		Travel time delay reduced by 12,000 hours per AM peak period; 6,940 h unexpected delay per PM peak
Carter et al, 2000	Variable Message Signs, Kiosk, Internet-based ATIS, In-Vehicle Device	San Antonio, Texas	Freeway and arterial	Simulated (with field data)	VMS: 2.8% decrease in crashes Web: : 0.5% reduction in crashes In-Vehicle device: 4.6% reduction in crashes		

Note: * "mixed" <1% improvement; "slightly positive" 1% to 5% improvement; "moderately positive" 6%-10%; and "highly positive" >10%.

APPENDIX D. ADJUSTED COST DATABASE FROM ITS JOINT PROGRAM OFFICE

Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date
				Low	High		Low	High	
	Roadside Telecommunications (RS-TC)								
1	DS0 Communication Line	TC001	20	0.5	0.9	1995	0.6	1.2	2003
1	DS1 Communication Line	TC002	20	0.5	0.9	1995	4.6	8.1	2002
1	DS3 Communication Line	TC003	20	2.8	4.6	1995	23	68	2001
1	ISP Service Fee	TC007					0.17	0.6	2002
1	Conduit Design and Installation - Corridor		20	50	75	2004	0.02		1999
1	Twisted Pair Installation		20	11	15.8	2004	0.02		1999
1	Fiber Optic Cable Installation		20	20	52	2004	1	2.5	2004
1	900 MHz Spread Spectrum Radio		10	8.2		1999	0.1	0.4	2004
1	Terrestrial Microwave		10	9.6	19.2	2002	0.5	1	2002
1	Wireless Communications, Low Usage	TC004					0.12	0.2	2003
1	Wireless Communications, Medium Usage	TC005					0.6	0.6	1995
1	Wireless Communications, High Usage	TC006	20	0.5	0.9	1995	1.2	1.7	2002
1	Call Box		10	4	6.8	2004	0.25	0.58	2004
	Roadside Detection (RS-D)								
2	Inductive Loop Surveillance on Corridor		5	3	8	2001	0.4	0.6	1995
2	Inductive Loop Surveillance at Intersection		5	8.8	15.6	2003	0.9	1.4	1999
2	Machine Vision Sensor on Corridor		10	21.2	28	2003	0.2	0.4	2003
2	Machine Vision Sensor at Intersection		10	20	25.5	2004	0.2	0.5	2004
2	Passive Acoustic Sensor on Corridor			3.6	7.7	2002	0.2	0.4	1998
2	Passive Acoustic Sensor at Intersection			5	14	2001	0.2	0.4	2002
2	Remote Traffic Microwave Sensor on Corridor		10	9	13	2004	0.1	0.58	2004
2	Remote Traffic Microwave Sensor at		10	17		2001	0.1		2001

Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date
				Low	High		Low	High	
	Intersection								
2	Infrared Sensor Active			5.5	7	2000			
2	Infrared Sensor Passive			0.7	1.2	2002			
2	CCTV Video Camera	RS007	10	9	19	2004	1	2.3	2004
	CCTV Video Camera Tower	RS008	20	4	12	2004			
2	Pedestrian Detection Microwave			0.6		2001			
2	Pedestrian Detection Infrared			0.3	0.5	2002			
2	Environmental Sensing Station (Weather Station)		25	29	49	2003	1.9	4	2003
2	Traffic Camera for Red Light Running Enforcement			71	129	2001	57		2001
2	Portable Speed Monitoring System		15	4.8	14.4	2002			
2	Portable Traffic Management System			78	98	2003			
	Roadside Control (RS-C)								
2	Linked Signal System LAN	RS002	20	31	55	1995	0.3	0.6	1995
2	Signal Controller Upgrade for Signal Control	RS003	20	2.4	6	2003	0.2	0.4	1995
2	Signal Controller and Cabinet			8	15	2003	0.2	0.5	2001
2	Traffic Signal			90	109	2001	2.2	2.7	1999
2	Signal Preemption Receiver	RS004	5	2	6	1995	0.04	0.2	1995
2	Signal Controller Upgrade for Signal Preemption	RS005	10	2	4	1995			
2	Roadside Signal Preemption/Priority		10	5.6	6	2004	0.07	0.1	2004
2	Ramp Meter	RS006	5	24	49	2003	1.2	2.7	2003
3	Software for Lane Control	RS011	20	24	48	1995	2	5	1995
2	Lane Control Gates	RS012	20	78	117	1995	1.6	2	1995
2	Fixed Lane Signal	RS009	20	5	6	1995	0.5	0.6	1995
2	Automatic Anti-icing System Short span		12	22		1998	1.8		1998

Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date
				Low	High		Low	High	
2	Automatic Anti-icing System Long Span		12	45	448	1999	1.4	26.7	1999
	Roadside Information (RS-I)								
2	Roadside Message Sign	RS010	20	39	59	1995	2	3	1995
1	Wireline to Roadside Message Sign	RS013	20	6	8	1995			
2	Variable Message Sign	RS015	10	47	117	2004	2.3	6	2004
	Variable Message Sign Tower	RS016	20	25	120	2004			
2	Variable Message Sign - Portable		14	21	25	2002	1.1	1.8	2000
1	Highway Advisory Radio	RS017	20	15	30	2001	0.6	1	2001
2	Highway Advisory Radio Sign		10	5	9	2003	0.24		2003
2	Roadside Probe Beacon	RS020	5	5	8	2001	0.5	0.8	2001
2	LED Count-down Signal		10	0.307	0.426	2001			
2	Pedestrian Crossing Illumination System		5	26.9	41	2003	2.6	4	2001
2	Variable Speed Display Sign			3.5	4.7	2001			
	Roadside Rail Crossing (R-RC)								
2	Rail Crossing 4-Quad Gate, Signals	RS021	20	90	102	1995	3.3	3.8	1995
2	Rail Crossing Train Detector	RS022	20	13	17	1995	0.6	0.81	1995
2	Rail Crossing Controller	RS023	10	6	8	1995	0.3	0.4	1995
2	Rail Crossing Pedestrian Warning Signal, Gates	RS024	20	8	12	1995	0.2	0.2	1995
2	Rail Crossing Trapped Vehicle Detector	RS025	10	20	23	1995	1	1.2	1995
	Parking Management (PM)								
2	Entrance/Exit Ramp Meters		10	2	4	1995	0.2	0.4	1995
2	Tag Readers		10	2	4	1995	0.2	0.4	1995
3	Database and Software for Billing & Pricing		10	10	14	1995	1	2	1995
2	Parking Monitoring System		10	19	41	1998			

Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date
				Low	High		Low	High	
	Toll Plaza (TP)								
2	Electronic Toll Reader	TP001	10	2	5	2001	0.2	0.5	2001
2	High-Speed Camera	TP002	10	7	10	2003	0.4	0.8	1995
3	Electronic Toll Collection Software	TP003	10	5	10	1995			
4	Electronic Toll Collection Structure	TP004	20	12	18	1995			
	Remote Location (RM)								
2	CCTV Camera	RM001	7	2.1	5	2003	0.1	0.24	2004
3	Integration of Camera with Existing Systems	RM002	10	2	2.4	1995			
2	Informational Kiosk	RM003	7	11	24	2001	1.1	4.4	1998
3	Integration of Kiosk with Existing Systems	RM004	7	2.1	26.3	1995			
3	Kiosk Upgrade for Interactive Usage	RM005	5	5	8	1995	0.5	0.8	1995
3	Kiosk Software Upgrade for Interactive Usage	RM006	5	10	12	1995			
2	Transit Status Information Sign		10	4	8	2002			
2	Smart Card Vending Machine	RM007	5	29	31	1995	1.4	1.6	1995
3	Software, Integration for Smart Card Vending	RM008	20	3	5	1995			
	Emergency Response Center (ER)								
4	Basic Facilities, Comm for Large Area	EM006		4704		1995	470	706	1995
4	Basic Facilities, Comm for Medium Area	EM007		3763		1995	470	565	1995
4	Basic Facilities, Comm for Small Area	EM008		3293		1995	470	494	1995
5	Emergency Response Hardware	EM001	5	9	12	2004	0.18	0.24	2004
3	Emergency Response Software	EM002	10	67	144	1995	0.5	3.4	1995
6	Emergency Response Labor	EM003					68	225	1995
3	Emergency Management Communications Software	EM004	20	5	10	1995	2.4	5	1995
3	Hardware, Software Upgrade for E-911 and Mayday	EM005	10	101	173	1995	1.6	2.4	1995

Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date
				Low	High		Low	High	
1	800 MHz. 2-way Radio		5	0.8	1.6	2001	0.08	0.11	2001
	Emergency Vehicle On-Board (EV)								
1	Communications Interface	EV001	10	0.3	2	1995	0.02		1995
2	Signal Preemption/Priority Emitter		10	0.5	2.1	2004			
	Information Service Provider (ISP)								
4	Basic Facilities, Comm for Large Area	IS019		4704		1995	470	706	1995
4	Basic Facilities, Comm for Medium Area	IS020		3763		1995	470	565	1995
4	Basic Facilities, Comm for Small Area	IS021		3293		1995	470	494	1995
5	Information Service Provider Hardware	IS001	5	27	40	2004	0.54	0.8	2004
3	Systems Integration	IS017	20	85	104	1998			
3	Information Service Provider Software	IS002	20	264	528	1995	13.2	26.4	1995
3	Map Database Software	IS003	2	14	29	2003			
6	Information Service Provider Labor	IS004					239	341	1995
1	FM Subcarrier Lease	IS005					111	221	1995
5	Hardware Upgrade for Interactive Information	IS006	5	12	18	2004	0.24	0.36	2004
3	Software Upgrade for Interactive Information	IS007	20	240	480	1995	12	24	1995
6	Added Labor for Interactive Information	IS008					136	205	1995
3	Software Upgrade for Route Guidance	IS009	20	240	480	1995	12	24	1995
3	Map Database Upgrade for Route Guidance	IS010	2	96	192	1995			
5	Hardware Upgrade for Emergency Route Planning	IS011	5	6	10	2004	0.12	0.2	2004
3	Software Upgrade for Emergency Route Planning	IS012	20	48	96	1995	2.4	5	1995
5	Hardware Upgrade for Dynamic Ridesharing	IS013	5	6	8	2004	0.12	0.16	2004
3	Software Upgrade for Dynamic Ridesharing	IS014	20	95	189	1998	5	10	1995
6	Added Labor for Dynamic Ridesharing	IS015					136	205	1995

Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date
				Low	High		Low	High	
7	Liability Insurance for Dynamic Ridesharing	IS016					62	124	1995
3	Software Upgrade for Probe Information Collection	IS018	20	240	480	1995	12	24	1995
	Transportation Management Center (TM)								
4	Basic Facilities, Comm for Large Area	TM040		3772	8622	2003	377	1293	2003
4	Basic Facilities, Comm for Medium Area	TM041		3763		1995	470	565	1995
4	Basic Facilities, Comm for Small Area	TM042		3293		1995	470	494	1995
5	Hardware for Signal Control	TM001	5	21	30	2004	8	9.7	2003
3	Software, Integration for Signal Control	TM006	5	101	144	2003	144		2003
6	Labor for Signal Control	TM002					544	665	2001
3	Hardware, Software for Traffic Surveillance	TM003	20	130	159	1995	6.5	7.9	1995
3	Integration for Traffic Surveillance	TM032	20	216	264	1995	10.8	13.2	1995
5	Hardware for Freeway Control	TM004	5	9	12	2004	0.45	0.6	2004
3	Software, Integration for Freeway Control	TM007	5	164	201	2002			
6	Labor for Freeway Control	TM005					252	308	2001
5	Hardware for Lane Control	TM008	5	3	4	2004	0.15	0.2	2004
3	Software, Integration for Lane Control	TM009	10	216	264	1995	11	13	1995
6	Labor for Lane Control	TM010					101	123	2001
3	Software, Integration for Regional Control	TM011	10	284	378	1998			
3	Real-time, Traffic Adaptive Signal Control System		10	108	135	2001	18		2001
6	Labor for Regional Control	TM012					202	246	2001
5	Video Monitors, Wall for Incident Detection	TM013	10	52	95	2003	3	5	2003
5	Hardware for Incident Detection	TM014	5	39.8	61.6	2004	2	3	2004
3	Integration for Incident Detection	TM025	20	86	106	1995	4.3	5.3	1995
3	Software for Incident Detection	TM015	5	82	100	2002	4.1	5	2002

Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date
				Low	High		Low	High	
6	Labor for Incident Detection	TM016					706	862	2001
5	Hardware for Incident Response	TM018	5	3	4	2004	0.15	0.2	2004
3	Integration for Incident Response	TM026	20	173	211	1995			
3	Software for Incident Response	TM019	2	13	16	1995	0.648	0.793	1995
6	Labor for Incident Response	TM020					101	123	2001
2	Automated Incident Investigation System		5	14.2		2001			
5	Hardware for Traffic Information Dissemination	TM021	5	3	4	2004	0.15	0.2	2004
3	Software for Traffic Information Dissemination	TM022	5	17	21	1995	0.9	1.1	1995
3	Integration for Traffic Information Dissemination	TM023	20	82	100	2000	4.3	5.3	1995
6	Labor for Traffic Information Dissemination	TM024					101	123	2001
3	Software for Dynamic Electronic Tolls	TM027	5	22	26	1995	1.1	1.3	1995
3	Integration for Dynamic Electronic Tolls	TM028	20	86	106	1995	4.3	5.3	1995
5	Hardware for Probe Information Collection	TM033	3	3	4	2004	0.15	0.2	2004
3	Software for Probe Information Collection	TM034	5	17	21	1995	1.7	2.1	1995
3	Integration for Probe Information Collection	TM035	20	130	159	1995	13	16	1995
6	Labor for Probe Information Collection	TM036					50	62	2001
3	Software for Rail Crossing Monitor	TM037	5	17	21	1995	1.7	2.1	1995
3	Integration for Rail Crossing Monitor	TM038	20	86	106	1995			
6	Labor for Rail Crossing Monitor	TM039					50	62	2001
5	Road Weather Information System (RWIS)		25	13		1998	0.3	2	2001
	Transit Management Center (TR)								
4	Basic Facilities, Comm for Large Area	TR014		4704		1995	470	706	1995
4	Basic Facilities, Comm for Medium Area	TR015		3763		1995	470	565	1995
4	Basic Facilities, Comm for Small Area	TR016		3293		1995	470	494	1995

Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date
				Low	High		Low	High	
5	Transit Center Hardware	TR001	5	9	12	2004	0.18	0.24	2004
3	Transit Center Software, Integration	TR002	20	783	1652	1995	6	12	1995
4	Transit Center Additional Building Space	TR003					7	11	1995
6	Transit Center Labor	TR004					68	341	1995
3	Upgrade for Auto. Scheduling, Run Cutting, or Fare Payment	TR005	20	19	38	1995	0.4	0.8	1995
3	Integration for Auto. Scheduling, Run Cutting, or Fare Payment	TR012	20	216	480	1995			
3	Further Software Upgrade for E-Fare Payment	TR013	20	38	58	1995	0.8	1.2	1995
3	Vehicle Location Interface	TR007	20	10	14	1995			
5	Video Monitors for Security System	TR008	5	3	6	2003	0.06	0.13	2003
5	Hardware for Security System	TR009	5	15	22	2004	0.3	0.44	2004
3	Integration of Security System with Existing Systems	TR010	20	240	480	1995			
6	Labor for Security System	TR011					276	337	1995
	Toll Administration (TA)								
5	Toll Administration Hardware	TA001	5	6.4	9.6	2004	0.32	0.48	2004
3	Toll Administration Software	TA002	10	38	77	1995	3.8	7.7	1995
	Transit Vehicle On-Board (TV)								
2	Driver Interface and Schedule Processor	TV001	10	0.2	0.4	1995	0.005	0.01	1995
1	Cell Based Communication Equipment	TV002	10	0.14	0.23	1995	0.007	0.012	1995
2	GPS/DGPS for Vehicle Location	TV003	10	0.5	2	2002	0.01	0.038	2002
2	Signal Preemption Processor	TV004	10	0.2	0.5	1995	0.005	0.008	1995
2	Signal Preemption/Priority Emitter		10	0.5	2.1	2004	0.1		2004
2	Preemption/Priority Transponder			0.07		2000			
2	Trip Computer and Processor	TV005	10	0.1	0.12	1995	0.002	0.002	1995

Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date
				Low	High		Low	High	
2	Security Package	TV006	10	3.3	5	1995	0.16	0.21	1995
2	Electronic Farebox	TV007	10	0.6	1.2	1995	0.03	0.06	1995
2	Automatic Passenger Counting System		10	0.98	9.8	2003			
	Commercial Vehicle Administration (CA)								
5	Commercial Vehicle Admin Hardware	CA001	5	9	12	2004	0.18	0.24	2004
3	Commercial Vehicle Admin Software, Integration	CA002	20	192	211	1995	4	4.2	1995
6	Commercial Vehicle Admin Labor	CA003					280	342	2003
3	Software Upgrade for Electronic Credential Purchasing	CA004	20	58	134	1995	1.2	2.7	1995
3	Software Upgrade for Inter-Agency Information Exchange	CA005	20	19	38	1995	0.4	0.8	1995
6	Added Labor for Inter-Agency Info Exchange	CA006					91	112	1995
3	Software Upgrade for Safety Administration	CA007	20	38	77	1995	0.8	1.5	1995
	Commercial Vehicle Check Station (CC)								
4	Check Station Structure	CC001	20	59	88	1995			
2	Signal Board	CC002	10	8	12	1995	0.8	1.2	1995
2	Signal Indicator	CC003	20	4	8	1995	0.2	0.4	1995
2	Roadside Beacon	CC004	10	4	6	1995	0.4	0.6	1995
1	Wireline to Roadside Beacon	CC005	20	9	18	1995			
3	Check Station Software, Integration	CC006	20	173	207	1995			
5	Check Station Hardware	CC007	5	3	4	2004	0.06	0.08	2004
5	Safety and Fitness Electronic Records (SAFER) Data Mailbox			4.5	5.6	1999	0.27	0.4	1999
1	Detection System	CC008	10	46	69	1995	2.3	3.5	1995
3	Software Upgrade for Safety Inspection	CC009	20	38	77	1995	0.8	1.5	1995
2	Handheld Safety Devices	CC010	5	2	4	1995	0.2	0.4	1995

Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date
				Low	High		Low	High	
3	Software Upgrade for Citation and Accident Recording	CC011	20	19	38	1995	1	2	1995
3	Weigh-In-Motion Facility	CC012	10	13	20	1995	1.3	2	1995
1	Wireline to Weigh-In-Motion Facility	CC013	10	1	2	1995	0.1	0.2	1995
	Commercial Vehicle On-Board (CV)								
2	Electronic ID Tag	CV001	10	0.51	0.9	1995	0.01	0.017	1995
1	Communication Equipment	CV002	10	1.1	2.1	1995	0.007	0.012	1995
2	Central Processor and Storage	CV003	10	0.2	0.4	1995	0.005	0.01	1995
2	GPS/DGPS	CV004	10	0.5	1.7	2002	0.01	0.035	2002
2	Driver and Vehicle Safety Sensors, Software	CV005	10	0.9	1.7	1995	0.03	0.06	1995
2	Cargo Monitoring Sensors and Gauges	CV006	10	0.13	0.27	1995	0.013	0.027	1995
2	Electronic Cargo Seal Disposable			0.01	0.024	2003			
2	Electronic Cargo Seal Reusable			0.034	0.42	2002			
2	Autonomous Tracking Unit			0.34	0.8	2003	0.141	0.41	2003
	Fleet Management Center (FM)								
5	Fleet Center Hardware	FM001	5	9	12	2004	0.18	0.24	2004
3	Fleet Center Software, Integration	FM002	20	207	480	1995			
6	Fleet Center Labor	FM003					460	562	1995
3	Software for Electronic Credentialing, Clearance	FM004	20	77	173	1995			
3	Software for Tracking and Scheduling	FM005	20	38	96	1995	4	10	1995
3	Vehicle Location Interface	FM006	20	10	14	1995			
3	Software Upgrade for Fleet Maintenance	FM007	20	19	38	1995	0.4	0.8	1995
3	Integration for Fleet Maintenance	FM008	20	96	192	1995	2	4	1995
3	Software Upgrade for HAZMAT Management	FM009	20	19	38	1995	0.4	0.8	1995
5	Hardware Upgrade for HAZMAT Management	FM010	5	3	4	2004	0.06	0.08	2004

Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date
				Low	High		Low	High	
2	Electronic Cargo Seal Reader			0.3	1.4	2002			
	Vehicle On-Board (VS)								
1	Communication Equipment	VS001	7	0.2	0.4	1995	0.004	0.007	1995
2	In-Vehicle Display	VS002	7	0.04	0.1	1995	0.001	0.002	1995
2	In-Vehicle Signing System	VS003	7	0.13	0.31	1995	0.002	0.006	1995
2	GPS/DGPS	VS004	7	0.2	0.4	1995	0.004	0.01	1995
3	GIS Software	VS005	7	0.2	0.3	1995			
2	Route Guidance Processor	VS006	7	0.08	0.12	1995	0.002	0.002	1995
2	Sensors for Lateral Control	VS007	7	0.6	0.9	1995	0.013	0.017	1995
2	Electronic Toll Equipment	VS008	7	0.03	0.1	1995			
2	Mayday Sensor and Processor	VS009	7	0.12	0.5	1995	0.002	0.01	1995
2	Sensors for Longitudinal Control	VS010	7	0.2	0.4	1995	0.005	0.01	1995
2	Advanced Steering Control	VS011	7	0.4	0.5	1995	0.008	0.01	1995
2	Advanced Cruise Control	VS012	7	0.12	0.23	1995	0.002	0.005	1995
2	Intersection Collision Avoidance Processor, Software	VS013	7	0.22	0.43	1995	0.005	0.009	1995
2	Vision Enhancement System	VS014	7	2	2.4	2003	0.1	0.122	2003
2	Driver and Vehicle Safety Monitoring System	VS015	7	0.52	1	1995	0.026	0.05	1995
2	Pre-Crash Safety System	VS016	7	0.9	1.7	1995	0.03	0.05	1995
3	Software, Processor for Probe Vehicle	VS020	7	0.05	0.14	1995	0.001	0.003	1995
2	Toll Tag/Transponder		5	0.025		2004			
2	In-Vehicle Navigation System		7	2.5		1998			
	Personal Devices (PD)								
2	Basic PDA	PD001	7	0.1	0.3	2004			
2	Advanced PDA for Route Guidance, Interactive Information	PD002	7	0.4	0.6	2004			

Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date
				Low	High		Low	High	
2	Modem Interface, Antenna for PDA	PD003	7	0.14	0.2	1995	0.003	0.004	1995
2	PDA with Wireless Modem		2	0.2	0.6	2003	0.11	0.3	2001
2	GPS/DGPS	PD005	7	0.14	0.17	2001	0.003	0.004	2001
3	GIS Software	PD006	7	0.1	0.14	1995	0.005	0.008	1995

* Not available for all unit cost elements

Notes

ITS unit costs data is available in two formats: unadjusted and adjusted. Please read the information below. Comments and feedback are encouraged. Send correspondence to Barbara Staples at bstaples@mitretek.org.
--Equipment List Not Adjusted - this is the cost data with the dollar year for capital and O&M cost identified. The header on this worksheet is "ITS Unit Costs Database (as of July 31, 2005)." This page is formatted to print a total of 7 pages.
--Indexes - this sheet contains the index series and ratio values used to adjust the cost data. Also, the year-by-year index for 1995 to 2004 for each series is provided. Users are advised that they can select other indexes they think may be more appropriate. The formulas are setup such that users can enter another index ratio and the calculations will be automatic.This page is formatted to print a total of 8 pages.
--Equipment List Adjusted 2004 - this is the adjusted cost data. The header for this worksheet is "ITS Unit Costs Database (in 2004 dollars) As of July 31, 2005." This page is formatted to print a total of 7 pages. The far left column "Index" contains a number. The number corresponds to the index on the Indexes worksheet and is the index used to adjust the capital and/or O&M cost values to 2004 dollars. The index is representative of the ITS element. For example, the eighth element in Roadside Telecommunications, 900 Mhz Spread Spectrum Radio, is tagged with Index 1. Index 1 is WPU1176 and is applied to communications and related equipment. The capital cost range is an adjusted value and was adjusted from 1999 (see column labeled "Adjusted From Date"). The O&M costs are 2004 values obtained in Mitretek's analysis (as such, no adjustment needed).

APPENDIX E. EXISTING AND PLANNED ATIS DEPLOYMENTS FOR NORTH CAROLINA

The North Carolina ITS Strategic Deployment Plan deals with all ITS options. The information about the existing and planned ATIS deployments for each ITS region is included in the each regional report. Most contents of this section are captured and quoted directly from those nine regional ITS reports.

E.1 Asheville

E.1.1. Regional overview and existing ATIS deployments

The Asheville Region encompasses Buncombe, Henderson, Madison, Yancey, Mitchell, McDowell, Polk, Rutherford and Cleveland Counties. It has a population of greater than 250,000 people, and includes the area surrounding the cities of Asheville, and Hendersonville. Other cities in the Asheville Region include: Black Mountain, Fairview, Weaverville, and Woodfin.

The deployed ATIS facility in Asheville is not found in the Asheville regional ITS reports.

E.1.2. Recommended Project and Technologies

Transportation needs

Four key program areas for the Asheville Region were identified:

- Tourist Information
- Traveler Information
- Weather Information
- Road Condition/Construction Information

Also, the key transportation issues were identified based on the discussions of the various groups in the break-out session in the regional Summit. For the Traveler Information:

- Lack of pre-trip tourist information
- Highway Advisory Radio (HAR) is not as effective as it could/should be
- Lack of real time traffic information
- Lack of traveler information – via message signs
- No IMAP unit
- Need IMAP Coordinator
- Need up-to-date HAZMAT information
- Real-time weather information, fog detection, and early warning of reduced visibility
- Information on construction, weather, road conditions, rock slides
- Traveler Information Kiosks (@ Rest areas, hotels, Super K, malls, other locations)
- FCC *211 – cellular telephone – information

Following describes the recommended ATIS projects for Ashville. Table E.1 shows items and costs for these recommended projects.

Short-Term (2000 - 2006) Technologies

1. DMS. There is a need for motorists on major highways and arterials to have frequently updated information regarding road construction, incidents, and road conditions. In a mountainous region such as Asheville, signs also can be employed to display weather-related information such as fog advisories, and warnings to truckers about steep mountain grades.

Signs will be installed at 2 sites in the Asheville Region. The anticipated cost for these improvements is $400,000.

2. Additional HAR sites. NCDOT will expand the existing HAR system by adding additional HAR sites on both AM and FM radio. These sites will permit a focused response to traffic incidents and issues by alerting motorists to their existence and detailing the appropriate response. These additional HAR's are estimated to cost a total of $120,000.

3. Regional traveler/transportation website. NCDOT will develop a website or set of pages at an existing website to provide static travel information. This information may include transit schedules, fares and routes, published road closures, weather, traffic policies, major generator and special event information, rideshare matching information, and links to the MPO, other city and NCDOT websites. This project is anticipated to cost $50,000 beyond the development costs being borne internally by NCDOT for various ITS web development projects.

4. Traveler information system. A clearinghouse will be established to store real-time data for traveler information. This system will include data from system detectors, intersections, detector stations, posted incident reports, IMAP incident reports, HAZMAT, and real-time bus schedule information. This information will also be accessible from a central location, whether it is stored locally or remotely. The development of this clearinghouse will be used in kiosks and websites, with the development geared for long-term projects, such as a voice activated telephone system. The anticipated cost to develop this clearinghouse is $100,000.

5. Web-based roadway information. As mentioned previously, NCDOT is in the process of developing a web-based real-time regional roadway information system to inform motorists of short-term and long-term road closures. This project will all be done internally to NCDOT, so all of the costs are internal to NCDOT.

Long-Term (2006 - 2011) Technologies

1. DMS. The long-term project involves installation of six additional in the Asheville region to provide motorists with important information as they travel. DMS will assist in traffic management for special events, aid tourists unfamiliar with the area, and provide information on delays and alternate routes during congested periods and in the event of traffic incidents. The expected cost for these improvements is $1,200,000.

2. Kiosks at major public venues. The NCDOT and the cities in the Asheville Region will develop and install five (5) kiosks that use web-based technologies to link to websites in the area that display local traffic and event information. In addition, these kiosks will display information of interest for tourists, including destinations, lodging, restaurants, and information centers. Potential locations include regional malls, rest areas, visitors' bureaus, chambers of commerce, arenas and coliseums, hotels, racetracks, convention centers, and others.

Kiosks provide NCDOT the opportunity to enter into ventures with private entities in two ways. The first is by selling or leasing kiosks at locations that are not public facilities. This may include large employers, malls, or hotels. Also, if additional kiosks are requested at locations, they may be sold or leased as well.

The second opportunity is to permit the generation of kiosk operating revenue by either selling advertising or licensing the kiosks. This would permit NCDOT to recover some of the costs of providing the data and hosting websites.

The cost of installing 5 kiosks throughout the Asheville region is approximately $300,000. There are additional costs associated with the long-term operations of kiosks, especially as more are added, for updating information and adding bandwidth.

The development costs of the kiosk content needs to be shared among the many interested parties. Traffic and transit data is only a small portion of the information that is available, and is typically the least used. The most used information is concerning local interests and directions to destinations. Therefore, the development costs of the content need to be borne by those who will benefit the most: tourist destinations, restaurants, and hotels.

3. Expand the traveler information system. The traveler information system identified as a short-term project limits the user input to selecting bus routes and identifying "hot spots" along major routes. As a long-term project, NCDOT will expand the system to provide additional real-time information, such as transit arrival, estimated travel times and video images from Asheville. The expansion of this system, with regard to integration and website development (including hardware) is estimated to cost $1,500,000.

4. 511 traveler information number. As part of a national program, a traveler information line will be set up using the telephone number 511. This number would operate much the same way as 911 provides emergency police service to callers, except the number would allow any caller to get instant, real-time information on directions to unfamiliar destinations, local highway conditions, weather, traffic delays, and public transit schedules.

Table E.1 Summary of ATIS Project and Estimated costs (based on year 2001 dollars)

Short-Term Projects			Long-Term Projects		
Description		Cost ($000)	Description		Cost ($000)
S-3	Dynamic Message Signs	$400	L-1	DMS Expansion	$1,200
S-6	Additional HAR Sites	$120	L-3	Kiosks at Major Public Venues	$300
S-7	Regional Traveler/Transportation Website	$50	L-4	Expand the Traveler Information System	$1,500
S-8	Traveler Information System	$100	L-5	511 Traveler Information Number	**
S-9	Web-Based Roadway Information	***			
Total		$270	**Total**		$3,000

**No direct costs
***Costs are borne internally by NCDOT
Source: This table is extracted from the Asheville regional report. Original table include all kind of ITS options but this table shows only ATIS deployments.

E.2 Eastern

E.2.1. Regional overview and existing ATIS deployments

The Eastern Region includes Onslow, Pitt, Craven, Carteret, Lenoir, Beaufort, Duplin, Pender, Pasquotank, Dare, Martin, Hertford, Bertie, Currituck, Greene, Chowan, Pamlico, Washington, Perquimans, Gates, Jones, Camden, Hyde and Tyyrell Counties and portions of Wayne, Cumberland, Sampson, Edgecombe, Bladen, Wilson, Halifax, Columbus, Robeson, Northampton and Johnston Counties. The Eastern Region has a population of approximately 1,236,000 people, and includes the area surrounding the cities of Jacksonville, Greenville and Goldsboro. Other cities in the Eastern Region include: Mount Olive, New Bern, Havelock, Morehead City, Newport, Kinston, Clinton, Washington, Warsaw, Tarboro, Burgaw, Elizabeth City, Manteo, Wanchese, Kill Devil Hills, Elizabethtown, Bladensboro, Williamston, Jamesville, Ahoskie, Murfreesboro, Windsor, Scotland Neck, Currituck, Corolla, Snow Hill, Chadbourn, Edenton, Bayboro, Plymouth, Rich Square, Hertford, Gatesville, Trenton, Camden, Swan Quarter and Columbia.

The Eastern region has the plan for several deployments to respond during hurricane evacuations. The Wilmington region is included in this Hurricane evacuation plan.

Hurricane Evacuation Plan

The eastern part of North Carolina is a frequent target of hurricanes. In order to effectively deal with these occurrences, NCDOT, along with other agencies, has developed a plan for evacuating coastal areas in the event of a hurricane. The evacuation plan incorporates one-way operation of Interstate 40, the major travel route to and from the eastern coastal area of North Carolina. There is also a plan for deployments of ITS elements that will support evacuation. These elements include DMS HAR, CCTV, count stations, wind gauges, information kiosks, and traffic signal improvements throughout eastern North Carolina. Table E.2 includes provides a summary of the proposed ITS elements for hurricane evacuation.

Table E.2 Summary of the Proposed ITS Elements for Hurricane Evacuation

	Device Type							
County	**CCTV**	**HAR**	**DMS (OH)**	**DMS (PORT)**	**DMS (PED)**	**ATR**	**GATE**	**WIND**
Bertie				1		1		
Bertie/Martin		1		1				
Bladen/Robeson		1		1				
Brunswick	1	1	2					
Camden				2				
Carteret	1	1		2				2
Chowan		1		1			1	
Chowan/Bertie								1
Chowan/Washington								1
Craven		1	3					1
Cumberland	2	1	1					
Currituck		1		3				
Dare	4	3		2	3	3		1
Duplin	1	1		1				
Harnett	1		1					
Johnson	3	2	1		2			
Johnston	3	1	2	1				
Jones				1				
Lenoir				1				
Martin				1				
Nash	1	1		1				
New Hanover	3	2	1	2				
Pender				1				
Perquimans			1			1		
Sampson					1			
Sampson/Duplin					1			
Wake	7	1	2					
Washington		1					1	
Wayne		1		2				
Wilson	1							

Source: Eastern regional report

E.2.2. Recommended Project and Technologies

Transportation needs

The identified user needs for the Eastern Region:

- Safety improvements
- Congestion/mobility/traffic management
- Traveler information
- Provider Information

For the Traveler Information:

- 24-hour, accurate pre-trip and en-route traveler information
- Real-time alternate route guidance
- Broadcast traffic conditions
- A statewide TMC or information clearinghouse with current traveler and road conditions
- Expand the SMARTLINK web-based, real-time traffic information
- More efficient integration of transit with other modes
- Access to up-to-date traveler information at public venues

Following describes the recommended ATIS projects for Eastern. Table E.3 shows items and costs for these recommended projects.

Short-Term (2000 - 2006) Projects

1. Traveler information kiosks at major public venues. The NCDOT, working with several cities and other locations in the Eastern Region, will develop and install 10 kiosks that use web-based technologies to link to the web sites in the area that display local traffic and event information. The kiosks will consist of an interactive computer, using an HTML-based touch-screen interface. The kiosk will be designed to feature (when available) real-time traffic and accident information (such as the location of accident sites at a particular time and place). Currently available information (Phase I deployment) will include general safety information, current weather with radar and area forecasts, and tourist information for the area. The kiosks will be updated using digital telephony services (ISDN) or T-1 lines.

Another feature may be an interactive kiosk at one or more key truck stops to provide information on truck safety, bridge information and restriction, signage and enforcement, and overall safety awareness. The kiosks would be updated using digital telephony services (ISDN). In addition, these kiosks will display information if interest for tourists, including destinations, lodging, restaurants, and information centers. Potential locations include: welcome centers, rest areas, hotels, Super K, shops in high use tourist areas, at Ferry Terminals, the State Aquariums, and other locations.

Kiosks provide the NCDOT with the opportunity to enter into public-private partnerships. The recommended contracting method is for the State to lease kiosks from a rural advanced traveler information service (RATIS) provider, similarly to how North Carolina's welcome center kiosk services are managed. Kiosks will be provided in public buildings as well as at locations that are not public facilities, with the owners' agreement. The kiosk contractor will be responsible for studying and selecting locations and securing space arrangements with private property owners. The second opportunity for partnering is to permit the contractor to cover the costs of kiosk operating, maintenance, and upgrading by either selling advertising or licensing the kiosks. The lease should be with an experienced, private RATIS firm.

The cost of installing 10 kiosks throughout the Eastern Region is approximately $775,000. There would be additional costs associated with the long-term operations of kiosks, especially as more are added, for updating information and adding bandwidth. These costs are approximated at $25,000 per year.

2. Web-based mapping and route identification. The web-based alternative route database will allow users to lookup route alternatives when the shortest time route is unavailable. This system will work in conjunction with the NCDOT road closure reporting system. Parts of this project are already being developed by NCDOT, including the development of real-time mapping and a dial-up information hotline.

This project is anticipated to cost $81,500.

3. Internet traveler information system. The NCDOT will develop a web site or set of pages at an existing web site to provide static travel information. This information may include transit schedules, fares and routes, published road closures, traffic policies, major generator and special event information, rideshare matching information, and links to other city and NCDOT websites. This project is anticipated to cost $95,000.

4. CCTV Links to Web Pages. The NCDOT will develop a similar web site for the Eastern Region as has previously been developed for the Triangle Region that displays static images of the CCTV cameras.

This project is anticipated to cost $37,500.

5. ATIS traveler information clearinghouse. An interim clearinghouse will be established to store real-time data for traveler information. This system will include data from system loops, intersections, detector station, posted incident reports, IMAP incident reports, and real time bus schedule information. This information will all be accessible from a central location, whether it is stored locally or remotely. The development of this clearinghouse will be used in the kiosks and web sites, with the development geared for long-term projects, such as a voice activated system. The anticipated marginal cost of this system to include a database for the Eastern Region is $200,000.

Long-Term (2006 - 2011) Projects

1. Voice Remote Access System (VRAS). En-route traveler information was identified as one of the key needs within the Region. One of the more effective methods of en-route traveler information is via a voice-activated system using standard cellular phones. This system will include a 511 number and the computer support to allow the entire system to be voice activated without the need for operators. This system will be developed statewide so there will not be any development costs particular to the Eastern Region. However, the Region will have to pay for the local information added to the statewide expansion and promoting costs that could be billboards, commercials, etc. It is anticipated that these responsibilities will cost $1,000,000.

2. Internet traveler information system (Phase II). The Internet system, both existing and that being developed in the short-term projects, will be expanded from a static system to a dynamic system with constant updates from the various detection stations in the Region. In addition, as more bandwidth becomes available, more options for the CCTV video feeds will be available for streaming video to the Internet from the various CCTV cameras in use. This expansion is anticipated to cost $250,000.

3. Regional archived data warehouse. ITS data collection components provide a significant amount of information that can be used in the long-term planning process, as well as for various optimization routines and strategies. The data collected through the ITS elements will be collected/warehoused in a database for future use in these processes. All of the data from the Region will be available at one central location for future use and reference. The anticipated cost of this system $750,000.

Table E.3 Project Summary

Short-Term Projects			Long-Term Projects		
Description		Cost ($000)	Description		Cost ($000)
S-1	Portable Dynamic Message Signs	$250	L-2	Voice Remote Access System	$1,000
S-6	Web based mapping and route identification	$82	L-3	Internet Traveler Information System (Phase 1)	$250
S-7	Traveler Information Clearinghouse (Phase I)	$200	L-4	Regional Archived Data Warehouse	$750
S-8	Internet Traveler Information System (Phase 1)	$95			
S-9	CCTV Links to Web pages	$38			
S-10	Kiosks at Major Public Venues	$775			
Total		$1,439	**Total**		$2,000

**No direct costs
***Costs are borne internally by NCDOT
Source: This table is extracted from the Eastern regional report. Original table include all kind of ITS options but this table shows only ATIS deployments.

E.3 Fayetteville

E.3.1. Regional overview and existing ATIS deployments

The Fayetteville ITS Planning Region has a population of only approximately 225,000. The Fayetteville Region encompasses parts of Cumberland and Harnett counties and includes the Cities of Fayetteville, Spring Lake and Hope Mills, in addition to Fort Bragg.

The deployed ATIS in Fayetteville is portable Highway Advisory Radio station.

E.3.2. Recommended Project and Technologies

Transportation needs

As a result of the meetings, summits, and breakout groups, four key program areas for the Fayetteville Region were identified:

- Safety improvements

- Congestion/mobility/traffic management
- Advanced traveler information
- Interagency data exchange

For the Traveler Information, following key transportation issues are identified:

- Lack of real time traffic information
- Lack of traveler information – about incidents while driving
- Highway Advisory Radio (HAR) is not as effective as it could/should be
- Lack of traveler information – Via Message Signs
- Lack of route guidance for getting around incidents
- Special Event Traffic Management
- Desire for in-vehicle traffic information
- Lack of traveler information – At rest areas and welcome centers
- Local Streets being used for route diversion
- Lack of traveler information – Via Cellular Phone
- Lack of pre-trip traveler information
- Lack of recreational information for rural communities
- Truckers should have access to traffic information

Following describes the recommended ATIS projects for Fayetteville. Table E.4 shows items and costs for these recommended projects.

Short-Term (2000 - 2006) Technologies

1. Additional HAR Sites. NCDOT will expand the existing HAR system by adding five additional HAR sites. These sites will permit a focused response to traffic incidents and issues by alerting motorists to their existence and detailing the appropriate response. These five additional HAR's are estimated to cost a total of $120,000.

2. Regional Traveler/Transportation Website. NCDOT will develop a website of series of pages at an existing website to provide static travel information. This information may include transit schedules, fares and routes, published road closures, traffic policies, major generator and special event information, rideshare matching information and links to FAMPO, other city and NCDOT websites. This project is anticipated to cost $50,000 beyond the development costs being borne internally by NCDOT for various ITS web development projects.

3. Traveler Information System. A clearinghouse will be established to store real-time data for traveler information. This system will include data from system detectors, intersections, detector stations, posted incident reports, IMAP incident reports, and real time bus schedule information. This information will also be accessible from a central location, whether it is stored locally or remotely. The development of this clearinghouse will be used in kiosks and websites, with the development geared for long-term projects, such as a voice activated telephone system. The anticipated cost to develop this clearinghouse is $100,000.

4. Web-Based Roadway Information. As mentioned previously, NCDOT is in the process of developing a web-based real-time regional roadway information system to inform motorists of short-term and long-term road closures. This project will all be done internally to NCDOT, so all of the costs are internal to NCDOT.

Long-Term (2006 - 2011) Technologies

1. DMS on Owen Drive. There are four sites that have been identified along Owen Drive between the coliseum and the hospital that would benefit from having DMS to provide information to motorists. The cost of these four signs is expected to total approximately $800,000.

2. Kiosks at Major Public Venues. NCDOT and the cities in the Fayetteville Region will develop and install five (5) kiosks that use web-based technologies to link to the websites in the area that display local traffic and event information. In addition, these kiosks will display information of interest for tourists, including destinations, lodging, restaurants, and information centers. Potential locations include regional malls, rest areas, visitors' bureaus, chambers of commerce, arenas and coliseums, hotels, racetracks, convention centers and others.

Kiosks provide NCDOT the opportunity to enter into ventures with private entities in two ways. The first is by selling or leasing kiosks at locations that are not public facilities, including large employers, malls, or hotels. In addition, if additional kiosks are requested at locations, they also may be sold or leased. The second opportunity is to permit the generation of kiosk operating revenue by either selling, advertising, or licensing the kiosks. This would permit NCDOT to recover some of the costs of providing the data and hosting websites.

The cost of installing 5 kiosks throughout the Fayetteville region is approximately $300,000. There are additional costs associated with the long-term operations of kiosks, especially as more are added, for updating information and adding bandwidth.

The development costs of the kiosk content needs to be shared amongst the many interested parties. Traffic and transit data is only a small portion of the information that is available, and is typically the least used. The most used information is concerning local interests and directions to destinations. Therefore, the development costs of the content needs to be borne by those who will benefit the most: tourist destinations, restaurants, and hotels.

3. Expand the Traveler Information System. The traveler information system identified as a short-term project limits the user input to selecting bus routes and identifying "hot spots" along major routes. As a long-term project, NCDOT will expand the system to provide additional real-time information, such as transit arrival, estimated travel times and video images from Fayetteville. The expansion of this system, with regard to integration and web site development (including hardware) is estimated to cost $1,500,000.

Table E.4 Project Summary

Short-Term Projects			Long-Term Projects		
Description		Cost ($000)	Description		Cost ($000)
S-5	Additional HAR Sites	$120	L-4	Dynamic Message Signs on Owen Drive	$800
S-6	Regional Traveler/Transportation Website	$50	L-5	Kiosks at Major Public Venues	$300
S-7	Traveler Information Clearinghouse	$100	L-6	Expands Traveler Information System	$1,500
S-8	Web-based Roadway Information	***			
Subtotal		$270	**Subtotal**		$2,600

**No direct costs
***Costs are borne internally by NCDOT
Source: This table is extracted from the Fayetteville regional report. Original table include all kind of ITS options but this table shows only ATIS deployments.

E.4 Metrolina

E.4.1. Regional overview and existing ATIS deployments

The Metrolina Region encompasses Mecklenburg, Cabarrus, Gaston, Union Counties, and a portion of Rowan and Iredell County. It has a population of approximately 1,121,000 people. Interstate 85 runs west/northeast through the Metrolina, connecting the region with Gastonia to the west and Concord to the northeast. Highway 29 and 74 run west/southeast through the Metrolina, connecting the region with Gastonia to the west and Monroe to the southeast.

Metrolina Region provides Travel information through Metrolina TMC Web page with link status map and camera images and Charlotte network television station linked to 7 CCTV in the Charlotte CBD. At the heart of the existing deployments in the Metrolina Region is the Metrolina Regional Transportation Management Center (MRTMC). This center currently manages the system of cameras and message boards on I-77 and I-85 and in the future will be the central hub for the entire Metrolina Region ITS Architecture.

NCDOT Divisions 9, 10 and 12 have a very aggressive plan for ITS deployment over the next few years, including numerous projects that are on the Transportation Improvement Plan (TIP) as well as some that projects are planned but not funded. The project lists are shown in Table E.5. Some of the projects are included as recommended short- and long-term deployments.

Table E.5 Funded and Unfunded Projects in Divisions 9, 10 and 12

Division 9	**Funded**						
	Project Name	**Number**	**CCTV**	**DMS**	**Other facility**	**Installation Location**	**Cost**
	I-85	I-3802	28	5	Δ	Along I-85 from NC 73 in Cabarrus County to US 29-601 Connector in Rowan County.	
Division 10	**Funded**						
	Project Name	**Number**	**CCTV**	**DMS**	**Other facility**	**Installation Location**	**Cost**
	US 74 HOV (Independence Blvd)	U-0209F	9	3	Δ	Along US 74	$ 3,959,697
	US 29 Reversible Lanes	U-3115	-	-	Widening	US 29, SR 2771 (I-85 Connector) in Mecklenburg County to Rocky River in Cabarrus County	$ 1,649,376
	Earmark #1	____			Communication Links (for US 74 HOV lane)		$ 1,572,842
	Earmark #2	____			Communication Links (for US 74 HOV lane)		$ 1,000,000
	I-485 (Charlotte Outer Loop)	R-2248BB	2	1	Δ	Along I-485 from north of I-85 to NC 27	$ 1,523,300
	I-485 (Charlotte Outer Loop)	R-2248C	1	-	Δ	Along I-485 from north of NC 27 (Mount Holly Road) to northeast of SR 2042 (Oakdale Road)	$ 2,088,900
	I-485 (Charlotte Outer Loop)	R-2248D	1	1	Δ	Along I-485 from east of SR 2042 to US 21	$ 2,238,900
	I-77	I-3311A	6	2	Δ	Along I-77 from I-85 to Charlotte Outer Loop North	$ 3,935,450
	I-85	I-3803A	5	2	Δ	Along I-85 from US 29-NC 49 Connector to SR 2467	$ 3,209,900
	I-485 (Charlotte Outer Loop)	R-2248E	1	1	Δ	Along I-485 from US 21 to I-85 North	$ 3,556,000
	I-77	I-3311B	4	1	Δ	Along I-77 from Charlotte Outer Loop North to NC 73 (Sam Furr Road)	$ 2,645,850
	Future US 74 (Monroe Bypass)	R-3329A	5	2	Δ	Along US 74-Monroe Bypass Connector from I-85/US 74 to SR 1520	$ 3,447,400
	I-85	I-3803B	2		-	Along I-85 from US 29-NC 49 Connector to SR 2467	$ 925,450
	I-85	I-3802	28	5	Δ	Along I-85 from NC 73 in Cabarrus County to US 29-601 Connector in Rowan County.	$ 7,214,400
	Unfunded						
	Project Name	**Number**	**CCTV**	**DMS**	**Other facility**	**Installation Location**	**Cost**
	I-85 (I-77 to US 29-NC49)	Unfunded	3	1	Δ	Along I-85 from I-77 to US 29-NC 49	$ 3,230,650

	I-85 (I-77 to Gaston County line)	Unfunded	8	2	Δ	Along I-85 from I-77 to the Mecklenburg/Gaston County line	$ 4,865,850
	I-277 (Belk/Brookshire Freeway)	Unfunded	9	10	Δ	Along I-277	$ 4,274,850
	I-485 (Charlotte Outer Loop)	Unfunded	30	11	Δ	I-485/Charlotte Outer Loop expansion	$27,668,450
	US 74 (Monroe Bypass)	Unfunded	7	2	Δ	Along the US 74/MonroeBypass from west of US 601 to west of SR 1758	$ 4,943,000
	Off Freeway Surveillance for Alternate Routes	Unfunded	60	-	Δ		$ 2,547,400
Division 12	**Unfunded**						
	Project Name	**Number**	**CCTV**	**DMS**	**Other facility**	**Installation Location**	**Cost**
	I-85 (Gaston County)	Unfunded	-	2	Δ	I-85 expansion in Gaston County	$ 17,023,900

Δ Fiber optic cable and conduit

E.4.2. Recommended Project and Technologies

Transportation needs

As a result of the meetings, summits, and breakout groups focused on three key areas for the Metrolina area were identified:

- Automobiles
- Transit
- Commercial vehicles

For the Traveler Information, following key transportation issues are identified:

- Too few operational dynamic message signs with current traveler information
- Poor traffic control at major trip generators and highway access points
- Lack of real-time transit information, including travel times, pre-trip and at bus stops
- Poor advance warning of and traffic control in work zones
- Lack of user-friendly, customized traffic information
- Lack of access to traveler information through kiosks and television
- Poor availability and content of digital traveler information broadcasts to portable communication devices (personal digital assistants, pagers, email, etc.)
- Lack of information on park-and-ride facilities
- Lack of remote, interactive voice access to location-specific traveler information
- Lack of remote voice access to traveler information

Following describes the recommended ATIS projects for Metrolina. Table E.6 shows items and costs for these recommended projects.

Short-Term (2001-2006) Technologies

1. Web-Based Roadway Information. NCDOT is in the process of developing a web-based real-time regional roadway information system to inform motorists of short-term and long-term road closures. This project will all be done internally to NCDOT, so all of the costs are internal to NCDOT.

2. Value Added Information from MRTMC. There are many private companies that are beginning to repackage ITS data to provide to customers. MapQuest, as described later in this report, is currently providing this information on their website. NCDOT will investigate opportunities to sell or provide this information to these companies. This will require little effort from the DOT aside from identifying potential partners and preparing legal documents relating to the partnership. Data messaging and other efforts required to convert information into a format compatible with the needs of the private partner will be the responsibility of the partner. All of the costs associated with this project are internal to NCDOT.

3. Traveler Information System. A clearinghouse will be established to store real-time data for traveler information. This system will include data from system detectors, intersections, detector stations, posted incident reports, IMAP incident reports, and real time bus schedule information. This information will also be accessible from a central location, whether it is stored locally or remotely. The development of this clearinghouse will be used in kiosks and websites, with the development geared for long-term projects, such as a voice activated telephone system. The anticipated cost to develop this clearinghouse is $250,000.

NCDOT currently provides road conditions and traveler information over the www.ncsmartlink.org web site. However, the site currently only shows conditions in the Triangle and Salisbury area. Using information from the MRTMC, real-time roadway information will be uploaded to the website to permit users to change travel times and routes based on traffic conditions. A link to the MRTMC web page will be provided upon completion of system acceptance testing in late spring 2001.

4. Additional Highway Advisory Radio (HAR) Sites. NCDOT will expand the existing HAR system by adding two additional HAR sites. These sites will permit a focused response to traffic incidents and issues by alerting motorists to their existence and detailing the appropriate response. The two additional HAR's are estimated to cost a total of $24,000.

Long-Term (2006-2011) Technologies

1. Kiosks at Major Public Venues. NCDOT and the cities in the Metrolina Region will develop and install twenty (20) kiosks that use web-based technologies to link to the websites in the area that display local traffic and event information. In addition, these kiosks will display information of interest for tourists, including destinations, lodging, restaurants, and information centers. Potential locations include regional malls, rest areas, visitors' bureaus, chambers of commerce, arenas and coliseums, hotels, racetracks, convention centers and others.

Kiosks provide NCDOT the opportunity to enter into ventures with private entities in two ways. The first is by selling or leasing kiosks at locations that are not public facilities, including large employers, malls, or hotels. In addition, if additional kiosks are requested at locations, they also may be sold or leased. The second opportunity is to permit the generation of kiosk operating revenue by either selling, advertising, or licensing the kiosks. This would permit NCDOT to recover some of the costs of providing the data and hosting websites.

The cost of installing 20 kiosks throughout the Metrolina region is approximately $1,200,000. There are additional costs associated with the long-term operations of kiosks, including maintenance and upkeep of the kiosks themselves and the cost associated with keeping the information on the kiosks up to date.

There is also a recurring cost of providing the data link between the kiosk and the central server. The development costs of the kiosk content needs to be shared amongst the many interested parties. Traffic and transit data is only a small portion of the information that is available, and is typically the least used. The most used information is concerning local interests and directions to destinations. Therefore, the development costs of the content needs to be borne by those who will benefit the most: tourist destinations, restaurants, and hotels.

2. Expand the Traveler Information System. The traveler information system identified as a short-term project limits the user input to selecting bus routes and identifying "hot spots" along major routes. As a long-term project, NCDOT will expand the system to provide additional real-time information, such as transit arrival and estimated travel times. The expansion of this system, with regard to integration and web site development (including hardware) is estimated to cost $1,500,000.

Table E.6 Project Summary

Short-Term Projects			Long-Term Projects		
Description		Cost ($000)	Description		Cost ($000)
S-15	Web-based Roadway Information	***	L-11	Traveler Information Kiosks (20)	$1,200
S-16	Value Added Information from MRTMC	***	L-12	Expand Traveler Information System	$1,500
S-17	Traveler Information System	$250			
S-18	Additional HAR Sites	$24			
Subtotal		$274	**Subtotal**		$2,700

**No direct costs
***Costs are borne internally by NCDOT
Source: This table is extracted from the Metrolina regional report. Original table include all kind of ITS options but this table shows only ATIS deployments.

E.5 Piedmont

E.5.1. Regional overview and existing ATIS deployments

The Piedmont Region encompasses Rockingham, Stanley, Lee, Chatham, Franklin, Richmond, Granville, Stokes, Vance, Scotland, Person, Davie, Anson, Montgomery, Caswell, Warren, Rowan counties and portions of Hoke, Moore, Randolph, Robeson, Harnett, Bladen, Columbus, Surry, and Yadkin, counties. It has a population of approximately 1,387,000 people, and includes the area surrounding the cities of Asheboro, Salisbury, Pinehurst, Oxford, Henderson and Laurinburg. Other cities in the Piedmont Region include: Reidsville, Eden, Southern Pines, Albemarle, Sanford, Pittsboro, Siler City, Louisburg, Rockingham, Hamlet, Roxboro, Mount Airy, Mocksville, Raeford, Spring Hope, Wadesboro, Pembroke, Yanceyville and Yadkinville.

The deployed ATIS projects in the Piedmont Region are 1 HAR on I-85 in Orange County, 1 HAR on I-85 in Vance County, and 2+ portable HAR.

11.1.1.1 Recommended Project and Technologies

Transportation needs

The identified user needs resulted in the development of four key program areas for the Piedmont Region:

- Safety improvements
- Congestion/mobility/traffic management
- Traveler information
- Provider Information

For the Traveler Information, following key transportation issues are identified:

- 24-hour, accurate pre-trip and en-route traveler information

- Real-time alternate route guidance
- Broadcast traffic conditions
- A statewide TMC or information clearinghouse with current traveler and road conditions
- Expand the SMARTLINK web-based, real-time traffic information
- More efficient integration of transit with other modes
- Access to up-to-date traveler information at public venues

Following describes the recommended ATIS projects for Piedmont. Table E.7 shows items and costs for these recommended projects.

Short-Term (2000 - 2006) Projects

1. Kiosks at Major Public Venues. NCDOT and several cities and other locations in the Piedmont Region will develop and install ten (10) kiosks that use web-based technologies to link to the web sites in the area that display local traffic and event information. The kiosks will consist of an interactive computer, using an HTML-based touch-screen interface. The kiosk will be designed to feature (when available) real-time traffic and accident information (such as the location of accident sites at a particular time and place).

Currently-available information (Phase I deployment) will include general safety information, current weather with radar and area forecasts, and tourist information for the area. Another feature may be an interactive kiosk at one or more key truck stops to provide information on truck safety, truck escape ramps on mountain grades, signage and enforcement on grades, and overall safety awareness. The kiosks would be updated using digital telephony services (ISDN).

In addition, these kiosks will display information if interest for tourists, including destinations, lodging, restaurants, and information centers. Potential locations include: rest areas, truck stops, hotels, chambers of commerce, malls, recreation areas, and other locations.

Kiosks provide NCDOT the opportunity to enter into ventures with private entities in two ways. The first is by leasing kiosks in both public buildings and locations that are not public facilities. This may include large employers, malls, or hotels. In addition, if additional kiosks are requested at locations, they may be sold or leased as well. The second opportunity is to permit the generation of kiosk operating revenue by either selling advertising or licensing the kiosks. This would permit NCDOT to recover some of the costs of providing the data and hosting web sites.

The cost of installing 10 kiosks throughout the Piedmont Region is approximately $775,000. There would be additional costs associated with the long-term operations of kiosks, especially as more are added, for updating information and adding bandwidth. These costs are approximated at $25,000 per year.

2. Web-based Alternative Route Database. The web-based alternative route database will allow users to lookup route alternatives when the shortest time route is unavailable. This system will work in conjunction with the NCDOT road closure reporting system. Parts of this project are already being developed by NCDOT, including the development of real-time mapping and a dial-up information hotline. This project is anticipated to cost $81,500.

3. Internet Traveler Information System. NCDOT will develop a web site or set of pages at an existing web site to provide static travel information. This information may include transit schedules, fares and routes, published road closures, traffic policies, major generator and special event information, rideshare matching information, and links to other city and NCDOT websites. This project is anticipated to cost $95,000.

4. CCTV Links to Web Pages. NCDOT will develop a similar web site for the Piedmont Region as has previously been developed for the Triangle Region that displays static images of the CCTV cameras. This project is anticipated to cost $37,500.

5. Traveler Information Clearinghouse. A clearinghouse will be established to store real-time data for traveler information. This system will include data from system loops, intersections, detector station, posted incident reports, IMAP incident reports, and real time bus schedule information. This information will all be accessible from a central location, whether it is stored locally or remotely. The development of this clearinghouse will be used in the kiosks and web sites, with the development geared for long-term projects, such as a voice activated system. The anticipated marginal cost of this system to include a database for the Piedmont Region is $200,000.

Long-Term (2006 - 2011) Projects

1. Voice Remote Access System (VRAS). En-route traveler information was identified as one of the key needs within the Region. One of the more effective methods of en-route traveler information is via a voice-activated system using standard cellular phones. This system will include a 511 number and the computer support to allow the entire system to be voice activated without the need for operators. This system will be developed statewide so there will not be any development costs particular to the Piedmont Region. However, the Region will have to pay for the local information added to the statewide expansion and promoting costs that could be billboards, commercials, etc. It is anticipated that these responsibilities will cost $1,500,000.

2. Internet Traveler Information System (Phase II). The Internet system, both existing and that being developed in the short-term projects, will be expanded from a static system to a dynamic system with constant updates from the various detection stations in the Region. In addition, as more bandwidth becomes available, more options for the CCTV video feeds will be available for streaming video to the Internet from the various CCTV cameras in use. This expansion is anticipated to cost $250,000.

3. Regional Archived Data Warehouse. ITS data collection components provide a significant amount of information that can be used in the long-term planning process, as well as for various optimization routines and strategies. The data collected through the ITS elements will be collected/warehoused in a database for future use in these processes. All of the data from the Region will be available at one central location for future use and reference. The anticipated cost of this system $750,000.

Table E.7 Project Summary

Short-Term Projects			Long-Term Projects		
Description		Cost ($000)	Description		Cost ($000)
S-3	Portable Changeable Message Signs	$250	L-2	Voice Remote Access System (VRAS)	$1,500
S-6	Kiosks at major public venues	$775	L-3	Internet Traveler Information System (Phase II)	$250
S-7	Web-based Alternative Route Database	$81.5	L-4	Regional Archived Data Warehouse	$750
S-8	Internet Traveler Information System	$95			
S-9	CCTV Links to Web Pages	$37.5			
S-10	Traveler Information Clearinghouse	$200			
Subtotal		$1,439	**Subtotal**		$2,500

**No direct costs
***Costs are borne internally by NCDOT
Source: This table is extracted from the Piedmont regional report. Original table include all kind of ITS options but this table shows only ATIS deployments.

E.6 Triad

E.6.1. Regional overview and existing ATIS deployments

The Triad Region encompasses Guilford, Forsyth, Davidson, and Alamance Counties, as well as part of Randolph County. The Triad Region has a population of approximately 958,000 inhabitants and includes the area surrounding the Cities of Greensboro and Winston-Salem. The Triad Region includes portions of NCDOT Divisions 7, 8, and 9. Interstate 40 runs east/west through the Triad Region, connecting the region with Raleigh to the east and Statesville to the west. Interstate 85 runs east/southwest through the Triad Region, connecting the region with Durham to the east and Charlotte to the southwest.

Various media sources provide travel time, speeds or conditions and TV picture of roadway conditions in Triad region. Also City of Greensboro has public access cable channel that shows video form the CCTV cameras. At the heart of the existing deployments in the Triad Region are the Eastern and Western Triad Regional Transportation Management Centers (ETRTMC and WTRTMC). This center currently manages the system of cameras and message boards on several roads in the Greensboro and Winston-Salem areas and in the future will be combined to form a single TMC that will be the central hub for the entire Triad Region ITS Architecture.

NCDOT Divisions 7 and 9 have a very aggressive plan for ITS deployment over the next few years. This includes a number of projects that are on the Transportation Improvement Plan (TIP) as well as some that are planned but not funded. Table E.8 shows the lists of these projects. Some of these projects are included as recommended short and long term deployments.

Table E.8 Funded and Unfunded Projects in Divisions 9, 10 and 12

Division 7	**Funded**						
	Project Name	**Number**	**CCTV**	**DMS**	**Other facility**	**Installation Location**	**Cost**
	I-40 Communications	I2201E	-	-	Δ	I-40 from SR 1850 at Kernersville to east of SR 1554	$1,775,500
	I-40 DMS 1	I2201F	-	1	Δ	Along I-40 from SR 1554 to SR 1616	$1,452,850
	I-85 DMS 1	I-2402A	-	2	-	Along I-85 bypass between Greensboro and ER 3300	$600,000
	I-85 DMS 2	I-2402B	4	4	-	Along I-85 bypass between SR 3300 and SR3314	$2,451,700
	I-85 CCTV 1	I-2402C	7	-	-	Along I-85 between SR 3314 and SR 3000	$1,350,700
	I-85 DMS 3	I-2402D	-	2	-	Along I-85 between SR 3000 and SR 3041	$600,000
	Division 7 DMS 1	I-2402S	18	-	Δ	Guilford County (location not specified	$6,960,650
	Western Loop 1	U-2524AB	5	2	Δ	Along the Western Loop from I-85 near Groometown to High Point Road	$1,533,150
	Western Loop 2	U-2524AC	4	2	Δ	Along the Western Loop from High Point Road to SR 1541	$1,431,200
	Western Loop 3	U-2524BA	4	3	Δ	Along the Western Loop from I-40 to SR 2147	$1,864,350
	Western Loop 4	U-2524BB	2	1	Δ	Along the Western Loop from SR 2147 to Bryan Blvd	$1,052,200
	Western Loop 5	U-2524C	5	-	Δ	Along the Western Loop from Bryan Blvd. to SR 2340	$1,200,850
	Division 7 DMS 2	U-2524D	-	1	Δ	the intersection of Greensboro Bypass and Old Battleground Rd	$634,550
	Eastern Loop 1	U-2525A	3	2	Δ	Along the Eastern Loop from SR 3041 to US 70 Relocation	$1,224,050
	Eastern Loop 2	U-2525B	4	1	Δ	Along the Eastern Loop from the US 70 Relocation to US 29	$1,700,000
	Eastern Loop 3	U-2525C	6	1	Δ	Along the Eastern Loop from US 29 to SR 2303	$2,075,200
	Unfunded						
	Project Name	**Number**	**CCTV**	**DMS**	**Other facility**	**Installation Location**	**Cost**
	I-85 DMS 3	Unfunded	5	3	Δ	Along I-85 from the I-40 split to the Guilford/Randolph County Line	$3,123,250
	US 29 DMS 1	Unfunded	11	3	Δ	Along US 29 from the Rockingham/Guilford County line to I-40	$6,084,550
	US 220 DMS 1	Unfunded	5	3	Δ	Along US 220 from the Rockingham/Guilford County line to US 70	$4,827,400
	US 220 DMS 2	Unfunded	5	2	Δ	Along US 220 from I-40 to the Guilford/Randolph County line	$2,638,700
	Division 7 Detection	Unfunded	-	-	800 detectors for	Throughout Division 7	$12,500,000

					incident detection		
Division 9	**Funded**						
	Project Name	**Number**	**CCTV**	**DMS**	**Other facility**	**Installation Location**	**Cost**
	US 421 CCTV 1	R-0952A	2	-	Δ	Along US 421 between US 158 and SR 2662	$729,450
	US 421 CCTV 2	R-0952B	8	2	Δ	Along US 421 between SR 2662 to SR 1850	$4,205,900
	W-S Western Loop 1	R-2247A	3	1	Δ	The Winston-Salem Western Loop from US 158 to I-40	$4,330,350
	Northern Beltway 1	R-2247BA	4	-	Δ	The Northern Beltway interchange with I-40	$414,550
	Northern Beltway 2	R-2247BB	-	-	Δ	the W-S Northern Beltway between I-40 and US 421	$277,000
	Northern Beltway 3	R2247CA	4	-	Δ	The W-S Northern Beltway at the interchanges with US 421 and Peace Haven Road	$2,263,600
	Northern Beltway 4	R-2247CB	4	2	Δ	Along the W-S Northern Beltway from US 421 to SR 1314	$1,668,400
	Northern Beltway 5	R-2247D	5	1	Δ	The W-S Northern Beltway from SR 1314 to NC 67	$1,856,600
	Northern Beltway 6	R2247E	5	3	Δ	Along the W-S Northern Beltway from NC 67 to US 52	$3,429,200
	Northern Beltway 7	U-2579	11	7	Δ, 76 non-intrusive detector	Along the W-S Northern Beltway from US 52 to US421/I-40	$6,909,550
	US -52 1	U-2826A	6	1	Δ	Winston-Salem along US 52	$769,584
	US-52 2	U-2826B	6	2	Δ	Winston-Salem along US 52 from I-40 Business to Patterson Avenue	$3,845,200
	US-52 3	U-2826C	6	3	Δ, 96 non-intrusive detector	Along US 52 from the I-40 Bypass to the proposed W-S Western Loop interchange	$6,319,350
	I-40 Business 1	U-2827B	-	-	Δ	Along I-40 Business/US 421 from 4th Street to Water Street in Winston-Salem	$463,980
	I-40 Business 2	U2827C	-	-	Δ, 64 non-intrusive detector	Along I-40 Business/US 421 from US 311 to US 158	$3,058,800
	Unfunded						
	Project Name	**Number**	**CCTV**	**DMS**	**Other facility**	**Installation Location**	**Cost**
	I-40	Unfunded	10	2	Δ	Along I-40 from US 52 to Sandy Ridge Road	$5,296,500
	US-52 1	Unfunded	8	4	Δ	Along US 52 from University to Stokes/Surry County Line	$4,903,900
	US-421 1	Unfunded	5	2	Δ	Along US 421 from Lewisville Clemmons Road to Yadkin River	$2,638,700
	US 311 1	Unfunded	5	2	Δ, 48 non-intrusive detector	Along US 311 from I-40 to the Forsyth/Guilford County Line	$3,075,200

	NC 150	Unfunded	5	1	Δ	Along NC 150 from the Davidson/Forsyth County line to I-40	$1,870,650
Other unfunded Triad Region Project	**Unfunded**						
	Project Name	**Number**	**CCTV**	**DMS**	**Other facility**	**Installation Location**	**Cost**
	I-85	Unfunded	10	6	Δ	Along I-85 from the Guilford/Randolph County Line to the US 29/70/52 merge in Davidson County	$8,953,250
	I-85/I-40	Unfunded	15	6	Δ	Along I-85/I-40 from NC 6 to the I-85/I-40 split in Orange County	$11,326,500

Δ Fiber optic cable and conduit

E.6.2. Recommended Project and Technologies

Transportation needs

As a result of the meetings, summits, and breakout groups, three key areas for in the Triad Region were identified:

- Automobiles
- Transit
- Commercial Vehicles

For the Traveler Information, following key transportation issues are identified:

- Lack of 24-hour, accurate location specific pre-trip and en-route traveler information (route guidance)
- Lack of 24-hour, real-time alternate route information
- Additional DMS with current traveler information
- Traveler information customized to type of motorist
- Advanced warning of work zones and better traffic control for work zones
- Centralized information clearinghouse with current traveler and road conditions information (weather, visibility-fog)
- Provide real-time or near real-time video of traffic conditions
- Web-based, real-time transit information
- Better planning to reduce changes in travel modes
- Include ride-sharing in transit management
- Improve route choices for public transit-3
- Increase incentives to use transit
- Allow drivers to update traffic and roadway conditions database

- Lack of access to up-to-date traveler information at public venues
- Provide remote, interactive voice access to traveler information
- Improve route choices for public transit
- Arterial Congestion

Following describes the recommended ATIS projects for Triad. Table E.9 shows items and costs for these recommended projects.

Short-Term (2006) Technologies

1. Traffic Detection Plan. The first phase of a regional traveler information system is the development of a regional traffic detection plan. This plan will identify the locations throughout the region where detection is required. Based on this plan the locations of new and existing detection can be easily identified. The development of this plan for the entire region is anticipated to cost approximately $250,000. The freeway segment of this plan will account for approximately 50% of the project cost. The remaining $125,000 will be to identify system detector locations in Burlington-Graham, Greensboro, Winston-Salem and High Point which will be used to implement signal plans in the event of a major regional incident.

2. Web-based alternative route database. The web-based alternative route database will enable users to look up route alternatives throughout the Triad Region. This system will work in conjunction with the NCDOT road closure reporting system. Parts of this project are already being developed by NCDOT, including the development of real-time mapping and a dial-up information hotline. The anticipated cost of this project is $81,500.

3. Enhancements to local cable television. The Cities of Greensboro and Winston-Salem currently broadcast live video and traveler information over their cable access channels during peak travel time.

The cities of High Point and Burlington-Graham are planning to broadcast similar information. This system will be enhanced to provide additional video images from throughout the region and increase coverage beyond the peak travel times. As video from other regions becomes available, specifically the Triangle and Metrolina Regions, this information will also be broadcast. The anticipated cost of implementing the new channels and upgrading the existing equipment is $1,000,000. The Burlington-Graham connection will be most effective when full motion video is available from both Winston-Salem and Greensboro and the Triangle Region.

4. Internet Traveler Information System. NCDOT will develop a website or set of pages at an existing website to provide static traveler information. This information may include transit schedules, transit fares and routes, published road closures, traffic policies, major generator and special event information, rideshare matching information, and links to other city and NCDOT websites. NCDOT is already preparing a base website for this information to be used throughout the state. A majority of the costs of this project are internal to NCDOT. The anticipated external cost of this project is $150,000.

5. CCTV Links to Web Pages. NCDOT will develop a website for the Triad Region — similar to one previously developed for the Triangle Region — that displays static images of the CCTV cameras. The base web site design has already been developed by NCDOT, and the majority of the costs associated with the modifications and web hosting are being borne internally to NCDOT. The anticipated external cost of this project is $75,000, which includes the video capture devices, servers, and other required hardware and software.

6. Kiosks at major public venues. NCDOT and the surrounding cities in the Triad Region will develop and install 10 kiosks that use web-based technologies to link to the websites in the area that display local traffic and event information. In addition, these kiosks will display information of interest for tourists, including destinations, lodging, restaurants, and information centers. Potential locations include the Greensboro Coliseum, Winston-Salem Coliseum, Winston-Salem Transit Center, Greensboro Four Seasons Mall and Hotel, Winston-Salem Adams Mark Hotel, Triad Region Airport, Burlington Mall Outlet Center, Visitor and Convention Center, and the High Point Oak Hollow Mall.

Kiosks provide NCDOT with the opportunity to enter into ventures with private entities in two ways. The first is by selling or leasing kiosks at locations that are not public facilities, including large employers, malls, or hotels. In addition, if additional kiosks are requested at locations, they also may be sold or leased. The second opportunity is to permit the generation of kiosk operating revenue by either selling, advertising, or licensing the kiosks. This would permit NCDOT to recover some of the costs of providing the data and hosting websites.

The cost of installing 10 kiosks throughout the Triad Region is approximately $1,250,000. There are additional costs associated with the long-term operations of kiosks, including maintenance and upkeep of the kiosks themselves and the cost associated with keeping the information on the kiosk up to date.

There is also a recurring cost of providing the data link between the kiosk and the central server. The development costs of the kiosk content needs to be shared amongst the many interested parties. Traffic and transit data is only a small portion of the information that is available, and is typically the least used. The most used information is concerning local interests and directions to destinations. Therefore, the development costs of the content needs to be borne by those who will benefit the most: tourist destinations, restaurants, and hotels.

7. Traveler Information Clearinghouse. A clearinghouse will be established to store data for traveler information collected from various sources throughout the region, including NCDOT, the cities and transit agencies. This system will feature data from system loops, intersections, detector station, posted incident reports, IMAP incident reports, and live bus schedule information. All this information will be accessible from a central location, whether it is stored locally or remotely. The clearinghouse will be used in to provide live and historical data to kiosks and websites, with the development geared for long-term projects, such as a voice activated system. The anticipated estimated cost of this system is $1,500,000.

7. 511 Dial-up Conversion. In the summer of 2000, the Federal Communications Commission (FCC) ruled that the phone number 511 will be reserved for traffic and traveler information nationwide. The Piedmont Authority for Regional Transportation (PART), which encompasses the Triad Region, will be applying for federal funds to convert existing dial-up phone numbers to 511 for traveler and traffic information. The number will provide travelers information on transit schedules, weather conditions, congestion, accidents, and construction activities in the Triad Region. Currently, the

Winston-Salem Transit Authority (WSTA) provides separate telephone numbers for several services including bus routes, trolley rides, park & ride, park & shuttle, ridesharing and vanpooling, bike & ride, transportation for the physically disabled, and transportation for the elderly. The 511 conversion will create one number for each of these services.

To assist in the conversion, funding is available from section 5001(a)(5) of the Transportation Equity Act for the 21st Century (TEA-21), Public Law 105-178, 112 Stat. 107, 419 (1998). The maximum amount of money granted to an application is $50,000 per fiscal year and supports system design, conversion support including hardware and software modifications, and system acceptance and testing. No additional monies should be required for the conversion.

8. Travel Demand Management (TDM). NCDOT is currently working with business in urban areas throughout the state to implement TDM. TDM consists of reducing peak hour commuters by varying work arrival and departure times or by offering telecommuting or other methods to reduce travel demand on the network. NCDOT is currently offering many employees the opportunity to work at home on a part time basis. Although there is no direct cost to NCDOT associated with this project, there is the potential for better implementation by offering incentives to companies and through a more focused marketing and outreach campaign to document the effort and the potential benefits. The incentives and outreach campaign can all be performed by NCDOT employees at no direct cost. These TDM efforts should be implemented in the Triad Region as well.

Long-Term (2011) Technologies

1. Value Added Information from ETRTMC and WTRTMC. There are many private companies that are beginning to repackage ITS data to provide to customers, as described later in this report. NCDOT will investigate opportunities to sell or provide this information to these companies. This will require little effort from the DOT aside from identifying potential partners and preparing legal documents relating to the partnership. Data messaging and other efforts required to convert information into a format compatible with the needs of the private partner will be the responsibility of the partner. All of the costs associated with this project are internal to NCDOT.

2. VRAS – Voice Remote Access System. En-route traveler information was identified as one of the key needs within the region. One of the more effective methods of en-route traveler information is via a voice activated system using standard cellular phones. This system will include a 511 number and the computer support to allow the entire system to be voice activated without the need for operators. This system would potentially be combined with a statewide effort and/or a public/private venture, and tied into existing systems. This system is anticipated to cost $1,000,000.

This project will also be undertaken on a statewide level to provide travel information throughout the state via telephone. The design of the 511 systems in the Triad Region will include hooks and other tie-ins to a larger statewide system.

3. Internet Traveler Information System. The Internet system, both existing and that being developed in the short-term projects, will be expanded from a static system to a dynamic system with constant updates from the various detection stations in the region. In addition, as more bandwidth becomes available, more options for the CCTV video feeds will be available for streaming video to the Internet from the various CCTV cameras in use. This expansion is anticipated to cost $1,500,000.

4. Regional Archived Data Warehouse. ITS data collection components provide a significant amount of information that can be used in the long-term planning process, as well as for various optimization routines and strategies. The data collected through the ITS elements will be collected/warehoused in a database for future use in these processes. All data from the region will be available at one central location for future use and reference. The anticipated cost of this system is $750,000.

Table E.9 Project Summary

Short-Term Projects			Long-Term Projects		
Description		Cost ($000)	Description		Cost ($000)
S-1	Web-based Alternative Route Database	$81.5	L-1	Voice Remote System	$1,000
S-2	Enhancement to Local Cable Access	$12.5	L-2	Internet Traveler Information System (Phase II)	$350
S-3	Internet Traveler Information System	$95	L-3	Regional Architecture Data Warehouse (Clearinghouse Phase II)	$100
S-4	CCTV Links to Web	$37.5	L-6	Additional CCTV Camera on Arterials	$5,250
S-5	Kiosks at major public venues	$775			
S-6	Traveler Information Clearinghouse	$250			
S-8	Portable VMS	$250			
Subtotal		$1,251.5	**Subtotal**		$6,700

**No direct costs
***Costs are borne internally by NCDOT
Source: This table is extracted from the Triad regional report. Original table include all kind of ITS options but this table shows only ATIS deployments.

E.7 Triangle

E.7.1. Regional overview and existing ATIS deployments

The Triangle Region encompasses Wake, Durham and Orange Counties, and a portion of Johnston County. It has a population of approximately 941,000 people, and includes the area surrounding the cities of Raleigh, Durham, and Chapel Hill. Other cities in the Triangle Region include: Cary, Garner, Apex, Wake Forest, Carrboro and Clayton.

The deployed ATIS in the Triangle Region are Internet web Sites, Traffic Patrol Broadcasting through WRAL-TV online, and Call-in Telephone. They have cooperative Agreements for use of live video images with NCSHP, WRAL-TV, WTVD-TV, NBC-17. The Triangle Regions provides the transit information through Carolina Trail ways/Greyhound, and Triangle Transit Authority, Traveler information. Also Kiosks are planned to install in state welcome center. At the heart of the existing deployments in the Triangle Region is the Triangle Regional Transportation Management Center (TRTMC). This center currently manages the system of cameras and message boards on I-40 and in the future will be the central hub for the entire Triangle Region ITS Architecture.

NCDOT Division 5 and 7 have an aggressive plan for ITS deployment over the next few years, including numerous projects that are on the Transportation Improvement Plan (TIP) as well as some that projects are planned but not funded. These projects are all listed and described in Table E.10. Some of the projects are included as recommended short- and long-term deployments.

.

Table E.10 Funded and Unfunded Projects in Divisions 5 and 7

Division 5	**Funded**						
	Project Name	**Number**	**CCTV**	**DMS**	**Other facility**	**Installation Location**	**Cost**
	I-85 CCTV1	I-0306DB	1	-	Δ	Along I-85 from west of Broad Street to west of Camden Avenue	$2,036,253
	I-40 CCTV1	I-2204BA	2	-	Δ	Along I-40 from NC 147 in Research Triangle Park to I-540	$911,203
	I-40 CCTV2	I-3306B	4	2	Δ	Along I-40 from Orange County Line to NC 147 (Durham Freeway)	$5,556,484
	SR 3009 Extension	U-2582B	2	1	Δ	Between Raleigh – SR 3009 Extension Edwards Mill Road from south of SR 1728 Wade Avenue to SR 1664 Duraleigh	$865,986
	DMS funded Only						
	Project Name	**Number**	**CCTV**	**DMS**	**Other facility**	**Installation Location**	**Cost**
	I-540 Communications1	R-2000AA	1	2	Δ	Along I-540 (Northern Wake Expressway) from NC 55 west of Morrisville to the east limits of the Research Triangle Park	$1,769,770
	I-540 Communications2	R2000AB	1	2	Δ	Between I-540 (Northern Wake Expressway) from the east limits of the Research Triangle Park to 0.6 miles southwest of I-40	$1,900,168
	I-540 Communications3	R-2000AC	1	4	Δ	Along I-540 (Northern Wake Expressway) from 0.6 miles southwest of I-40 to 0.1 miles southwest of I-40	$1,554,863
	I-540 Communications4	R-2000F	3	2	Δ	Along I-540 (Northern Wake Expressway) from east of US 1 south of Perry Creek Road to south of Buffaloe Road	$2,758,735
	I-540 Communications5	R-2000G	3	2	Δ	Between I-540 (Northern Wake Expressway) south of SR 2215 (Buffaloe Road) to US 64 East near Knightdale	$3,238,075
	S. Wake Expwy1	R-2721	5	4	Δ	Between Southern Wake Expressway from US 1 South to US 401 South	$5,952,639
	S. Wake Expwy2	R-2828	4	4	Δ	Between Southern Wake Expressway from US 401 to I-40	$5,212,502
	E. Wake Expwy.Communications2	R-2829	5	5	Δ	Between Southern Wake Expressway from US 401 to I-40	$6,116,364
	W. Wake Expwy Communications	R-2635	5	5	Δ	Along Western Wake Expressway from US 1 South to NC 55	$ 5,713,398
	Unfunded						
	Project Name	**Number**	**CCTV**	**DMS**	**Other facility**	**Installation Location**	**Cost**
	I-85 Communications1	I-0306C	2	2	Δ	Along I-85 from east of SR 1401 Cole Mill Road to west of Broad Street	$2,375,673
	US 64 CCTV1	R-2547BA	1	-	Δ	Along US 64 from I-440 Raleigh Beltline to New Hope Road	$913,252

	US 64 (bypass) DMS	R-2547BB	2	1	Δ	Between US 64 (Knightdale Bypass) from New Hope Road to east of SR 2601 (Clifton Road)	$2,074,011
	US 64 DMS	R-2547C	1	1	Δ	Along US 64 from East Wake Expressway to SR 2502	$2,443,120
	US 64 CCTV2	R-2547CC	1	-	Δ	Along US 64 from SR 2502 to existing US 64 east of SR 1003	$1,287,388
	Durham N. Loop CCTV	R-2630A	5	4	Δ	Between Durham Northern Loop/Eno Drive from I-85 west of Durham to US 501	$4,440,823
	Durham N. Loop DMS1	R-2630B	5	4	Δ	Between Durham Northern Loop/Eno Drive from US 501 to I-85 northeast of Durham	$4,314,789
	Durham N. Loop DMS2	R-2631B	2	1	Δ	Between Durham Northern Loop from I-85 northeast of Durham to NC 98 east of Durham	$3,045,189
	E. Wake Expwy.Communications1	R-2641	-	-	Δ	Along East Wake Expressway from the proposed US 64 bypass to US 64 East	$963,375
	New Route Communications	R-3330	2	2	Δ	Between the new route from Northern Wake Expressway to US 64 east of Knightdale	$4,396,188
	I-40 Communications	T-002	9	-	Δ	Between I-40 from Wade Avenue to I-440	$ 2,489,474
	I-440 Beltline Communications	T-003	15	7	Δ	Along I-440 Beltline	$12,820,381
	NC 147 Communications	T-007	7	2	Δ	Along NC 147 from I-40 to NC 55 and from US 15/501 to I-85	$ 3,690,700
	I-540 Communications6	R-2000S	5	2	Δ	Between I-540 from 0.1 miles southwest of I-40 to east of US 1	$11,085,856
	Raleigh - I-440 Communications $	U-2719	2	-	Δ	Along Raleigh – I-440 Cliff Benson Beltline from I-40 to north of SR 1728 Wade Avenue	2,442,525
Division 7	**Unfunded**						
	Project Name	**Number**	**CCTV**	**DMS**	**Other facility**	**Installation Location**	**Cost**
	Durham - US15-501	U-2807	1	-	Δ	Along Durham – US 15-501 from SR 1010 Franklin Street in Chapel Hill to US 15-501 bypass in Durham	$ 2,419,778
	I-85 Communications2	I-0305A	2	-	Δ	Along I-85 from SR 1006 near Hillsborough to the east of SR 1709	$ 2,488,482
	I-85 Communications3	I-0305B	2	-	Δ	Along I-85 from east of SR 1709 to the Durham County Line	$ 2,511,758

Δ Fiber optic cable and conduit

E.7.2. Recommended Project and Technologies

Transportation needs

As a result of the meetings, summits, and breakout groups, four key program areas for the Triangle Region were identified:

- Safety improvements
- Congestion/mobility/traffic management
- Advanced traveler information
- Interagency data exchange

For the Traveler Information, following key transportation issues are identified:

- Too many single occupant vehicles
- Need access to traveler and transit information at work and public places
- Need web-based, real-time transit information
- Need more traffic conditions (including congestion status and incidents) radio broadcasts, including commercial radio and highway advisory radio (HAR), customized to the type of motorist
- Incident management should include all alternate routes
- Lack of 24-hour, real-time alternate route information
- Traveler information should include travel time estimates
- Need single access point to transit schedules by all transit providers
- Need complete, point-to-point, real-time transit route information
- Lack of 24-hour, accurate, location-specific pre-trip and en-route traveler information (route guidance)

- Need a centralized information clearinghouse with current traveler and road conditions information (weather, visibility-fog)
- Need web-based incident and closure information using Geographic Information System (GIS) based road maps
- Need more operational DMS with current traveler information
- Need advance warning of and better traffic control for work zones
- Keep motorists better informed of incident clearance measures
- Need traveler information customized to type of motorist
- Too many changes in travel mode
- Provide early warning of heavy truck traffic

Following describes the recommended ATIS projects for Triangle. Table E.11 shows items and costs for these recommended projects.

Short-term (2000 - 2005) Technologies

1. **Regional Traveler/Transportation Website.** NCDOT will develop a website or series of pages at an existing website to provide static travel information. This information may include transit schedules, fares and routes, published road closures, traffic policies, major generator and special event information, rideshare matching information, and links to other city and NCDOT websites. The costs for this project are being borne internally by NCDOT for various ITS web development projects. Development beyond the basic linking of sites may require additional financial resources.

2. **Web-Based Roadway Information.** As mentioned previously, NCDOT is in the process of developing a web-based, real-time regional roadway information system to

inform motorists of short-and long-term road closures. This project will all be done within NCDOT so all of the costs are internal to NCDOT.

3. Interagency Coordination of Traveler Information. NCDOT is in the process of developing a method of sharing and coordinating traveler information throughout the Triangle Region. For the purposes of the short-term (five year horizon), this coordination will occur via telephone and low bandwidth communications. Higher speed communication will be used as the regional communication network is developed.

Most of this project involves interagency coordination, that is identifying the data and information that is valuable to share and developing a coordinated response plan. These costs are all being borne internally by NCDOT.

Long-term (2006 - 2010) Technologies

1. Traveler Information Clearinghouse. A clearinghouse will be established to store real-time data for traveler information. This system will feature data from system loops, intersections, detector stations, posted incident reports, IMAP incident reports, and real-time bus schedule information. All this information whether it is stored locally or remotely will be accessible from a central location. The development of this clearinghouse will be used in kiosks and websites, with the development geared for long-term projects, such as a voice activated system. The anticipated cost of this system is $250,000.

2. Regional Archived Data Warehouse. ITS data collection components provide a significant amount of information that can be used in the long-term planning process, as well as for various optimization routines and strategies. The data collected through the ITS elements will be collected/warehoused in a database for future use in these processes.

All data from the region will be available at one central location for future use and reference. The anticipated cost of this system is $100,000.

3. Value-Added Information from the TRTMC. There are many private companies that are beginning to repackage ITS data to provide to customers, as described later in this report. NCDOT will investigate opportunities to sell or provide this information to these companies. This effort will require little effort from the Department, aside from identifying potential partners and preparing legal documents relating to the partnership. Data messaging and other efforts required to convert information into a format compatible with the needs of the private partner will be the responsibility of the partner. All of the costs associated with this project are internal to NCDOT.

4. Kiosks at Major Public Venues. NCDOT and the cities in the Triangle Region will develop and install 10 kiosks that use web-based technologies to link to the websites in the area that display local traffic and event information. In addition, these kiosks will display information of interest for tourists, including destinations, lodging, restaurants, and information centers. Potential locations include regional malls, rest areas, visitors' bureaus, chambers of commerce, arenas and coliseums, hotels, racetracks, convention centers, and others.

Kiosks provide NCDOT with the opportunity to enter into ventures with private entities in two ways. The first is by selling or leasing kiosks at locations that are not public facilities, including large employers, malls, or hotels. In addition, if additional kiosks are requested at locations, they also may be sold or leased. The second opportunity is to permit the generation of kiosk operating revenue by either selling, advertising, or licensing the kiosks. This would enable NCDOT to recover some of the costs of providing the data and hosting websites.

The cost of installing 10 kiosks throughout the Triangle Region is approximately $600,000. There are additional costs associated with the long-term operations of kiosks, especially as more are added, for updating information and adding bandwidth.

The development costs of the kiosk content needs to be shared among the many interested parties. Traffic and transit data is only a small portion of the information that is available, and is typically the least used. The most used information is concerning local interests and directions to destinations. Therefore, the development costs of the content needs to be borne by those who will benefit the most: tourist destinations, restaurants, and hotels.

5. Expand the Traveler Information System. The traveler information systems identified as a short-term project limits the user input to selecting bus routes and identifying "hot spots" along major routes. As a long-term project, NCDOT will expand the system to provide additional real-time information, such as transit arrival, estimated travel times and video images from the Triangle Region. The expansion of this system, with regard to integration and web site development (including hardware), is estimated to cost $1,500,000.

Table E.11 Project Summary

Short-Term Projects			Long-Term Projects		
Description		Cost ($000)	Description		Cost ($000)
S-14	Interagency Coordination of Traveler Information	***	L-7	Traveler Information Clearinghouse	$250
S-15	Web-Based Roadway Information	***	L-8	Regional Archived Data Warehouse	$100
S-16	Regional Traveler/Transportation Website	***	L-9	Value Added Information from TRTMC	***
			L-10	Expand the Traveler Information System	$1,500
			L-11	Kiosks at major public venues	600
	Subtotal	$0		**Subtotal**	$2,450

**No direct costs
***Costs are borne internally by NCDOT
Source: This table is extracted from the Triangle regional report. Original table include all kind of ITS options but this table shows only ATIS deployments.

E.8 Western

E.8.1. Regional overview and existing ATIS deployments

The Western Region includes Catawba, Cleveland, Burke, Caldwell, Wilkes, Rutherford, Lincoln, Haywood, McDowell, Watauga, Alexander, Jackson, Macon, Transylvania, Ashe, Cherokee, Madison, Polk, Yancey, Avery, Mitchell, Swain, Alleghany, Clay, Iredell and Graham Counties and portions of Surry and Yadkin Counties. The Western Region has a population of approximately 1,209,000 people, and includes the area surrounding the cities of Hickory, Boone, Forest City and Waynesville. Other cities in the Western Region include: Conover, Newton, Statesville, Shelby, Kings Mountain, Boiling Springs, Morganton, Lenoir, Wilkesboro, Millers Creek, Mulberry, Spindale, Lincolnton, Etowah, Marion, Blowing Rock, Dobson, Taylorsville, Sylva, Cullowhee, Franklin, Highlands, Brevard, Jefferson, Andrews, Murphy, Marshall, Mars Hill, Burnsville, Newland, Spruce Pine, Elkin, Bryson City, Sparta and Hayesville.

The existing ATIS deployment in the Western Region is not revealed in the reports.

E.8.2. Recommended Project and Technologies

Transportation needs

The meetings, summits, and breakout groups resulted in the identification of four key program areas for the Western Region:

- Safety improvements
- Congestion/mobility/traffic management
- Advanced traveler information
- Provider Information

For the Traveler Information, following key transportation issues are identified:

- 24-hour, accurate pre-trip and en-route traveler information
- Real-time alternate route guidance
- Broadcast traffic conditions
- A statewide TMC or information clearinghouse with current traveler and road conditions
- Expand the SMARTLINK web-based, real-time traffic information
- More efficient integration of transit with other modes
- Access to up-to-date traveler information at public venues

Following describes the recommended ATIS projects for Western. Table E.12 shows items and costs for these recommended projects.

Short-Term (2000 – 2006) Technologies

1. Traveler Information Kiosks at Major Public Venues. The NCDOT, working with several cities and other groups in the Western Region, will develop and install 10 kiosks that use web-based technologies to link to web sites in the area that display local traffic and event information. The kiosks will consist of an interactive computer, using an HTML-based touch-screen interface, and a printer. The kiosk will be designed to feature, when available, real-time traffic and accident information (such as the location of accident sites at a particular time and place). Currently available information (Phase I deployment) will include general safety information, current weather with radar and area forecasts, and tourist information for the area. The kiosks will be updated using digital telephony services (ISDN) or T-1 lines.

Another feature may be an interactive kiosk at one or more key truck stops to provide information on truck safety, truck escape ramps on mountain grades, signage and enforcement on grades, and overall safety awareness.

In addition, these kiosks will display information of interest to tourists, including destinations, lodging, restaurants, and information centers. One element of the deployment plan for these kiosks will be to do a detailed market forecast on the effectiveness of each competing location. Although exact locations are to be determined, potential sites to consider include rest areas, hotels, Super K's, shops on the Blue Ridge

Parkway, shopping centers and other high-use tourist areas, Grandfather Mountain, ski resorts, Deep Gap, ASU, WCU, visitor centers at the Smoky Mountains, Cherokee, Jackson County, Franklin County, Murphy, and other locations. It is expected that approximately 10 locations will be chosen from this list, although other sites may be substituted as more information becomes available.

Kiosks provide the NCDOT with the opportunity to enter into public-private partnerships. The recommended contracting method is for the State to lease kiosks from a rural advanced traveler information service provider, similarly to how North Carolina's welcome center kiosk services are managed. Kiosks will be provided in public buildings as well as at locations that are not public facilities, with the owners' agreement. The kiosk contractor will be responsible for studying and selecting locations and securing space arrangements with private property owners. The second opportunity for partnering is to permit the contractor to cover the costs of kiosk operating, maintenance, and upgrading by either selling advertising or licensing the kiosks. The lease should be with an experienced, major private RATIS firm.

The cost of installing 10 kiosks throughout the Western Region is approximately $800,000. This cost includes high-speed telephony services purchased through state contract. ISDN or T-1 lines will provide the capability of updating weather and traffic/incident information on a real-time basis. There will be additional costs associated with the long-term operations of kiosks, especially as more are added, for updating information, and adding bandwidth. These costs are approximated at $20,000 per kiosk for the first year (including installation and software) and $10,000 per year for operations and maintenance in succeeding years.

2. Web-based Mapping and Route Identification. The web-based alternative route database will allow users to look up route alternatives when the quickest route is unavailable. This system will work together with the NCDOT road closure reporting system. Parts of this project are already being developed by the NCDOT, including the development of real-time mapping and a dial-up information hotline. This project is anticipated to cost $130,000.

3. Enhancements to Broadcast Video and Data. This project will provide coverage of traffic information on local access cable. The coverage will be enhanced by informative narratives that describe incidents at key locations. Six cities in the Western Region are candidates for the development of this type of project.

All infrastructure costs will be borne by the cable provider, and thus are not included in this cost estimate. The public sector cost for this project is anticipated to be $12,500 per location, for a total of $75,000.

4. Internet Traveler Information System. The NCDOT will develop a web site or set of pages at an existing web site to provide static travel information. This information may include published road closures, traffic policies, major generator and special event information, rideshare matching information, and links to other city and NCDOT websites. This project is anticipated to cost $65,000. The Department will develop a web site for the Western Region (similar to the one previously developed for the Triangle Region) that displays static images of the CCTV cameras. This aspect of the project is anticipated to cost $110,000 (Total project cost: $175,000).

5. ATIS Traveler Information Clearinghouse. An interim clearinghouse will be established to store realtime data for traveler information. This system will include data from system loops, intersections, detector station, posted incident reports, IMAP incident reports, and real time bus schedule information. This information will all be accessible from a central location, whether it is stored locally or remotely. The development of this clearinghouse will be used in the kiosks and web sites, with the development geared for long-term projects, such as a voice activated system. The anticipated marginal cost of this system to include a database for the Western Region is $100,000.

Long-Term (2006 - 2011) Technologies

1. **Voice Remote Access System (VRAS).** En-route traveler information was identified as one of the key needs within the Region. One of the more effective methods of en-route traveler information is via a voice-activated system using standard cellular phones. This system will include a 511 number and the computer support to allow the entire system to be voice activated without the need for operators. This system is anticipated to cost $1,000,000.

2. **Internet Traveler Information System (Phase II).** The Internet system, both existing and that which is being developed in the short-term projects, will be expanded from a static system to a dynamic system with constant updates from various detection stations in the Region. In addition, as more bandwidth becomes available, more options for the CCTV video feeds will be available for streaming video to the Internet from the various CCTV cameras in use. This expansion is anticipated to cost $200,000.

3. **Regional Archived Data Warehouse.** ITS data collection components provide a significant amount of information that can be used in the long-term planning process, as well as for various optimization routines and strategies. The data collected through the ITS elements will be collected/warehoused in a database for future use in these processes. All of the data from the Region will be available at one central location for future use and reference. The anticipated cost of this system $100,000.

Table E.12 Project Summary

Short-Term Projects			Long-Term Projects		
Description		Cost ($000)	Description		Cost ($000)
S-2	Portable Dynamic Message Signs	$800	L-3	Voice Remote Access System (VRAS)	$1,000
S-5	Traveler Information Kiosks at major public venues	$800	L-4	Internet Traveler Information System Enhancement (Phase I)	$200
S-6	Web-Based Mapping and Route Identification	$130	L-5	Regional Archived Data Warehouse	$100
S-7	Enhancements to Broadcast Video & Data	$75			
S-8	Internet Traveler Information System (Phase I)	$175			
S-9	Traveler Information Clearinghouse	$100			
	Subtotal	$2,080		**Subtotal**	$1,300

**No direct costs
***Costs are borne internally by NCDOT
Source: This table is extracted from the Western regional report. Original table include all kind of ITS options but this table shows only ATIS deployments.

E.9 Wilmington

E.9.1. Regional overview and existing ATIS deployments

The Wilmington Region encompasses parts of New Hanover, Brunswick, and Columbus counties. The Wilmington Region has a population of approximately 259,000 people and includes the cities Wilmington, Carolina Beach, Wrightsville Beach, Castle Hayne, Shallotte, Long Beach, and Whiteville.

Wilmington is also in the eastern part of North Carolina and a frequent target of hurricanes. As mentioned above, Wilmington area is included in the North Carolina Hurricane Evacuation Plan with the Eastern area. Table E.13 includes provides a summary of the proposed ITS elements for hurricane evacuation.

E.9.2. Recommended Project and Technologies

Transportation needs

As a result of the meetings, summits, and breakout groups, four key program areas for the Wilmington Region were identified:

- hurricane evacuation
- en-route driver information
- pre-trip travel information
- route guidance

For the Traveler Information, following key transportation issues are identified:

- Lack of real time traffic information
- Lack of traveler information – via message signs
- Lack of traveler information – at rest areas and welcome centers
- Too few dynamic message signs with current traveler information
- Lack of access to traveler information through kiosks and television
- Lack of 24-hr, real time alternate route information
- Better directional signing, speed limit, pedestrian warnings
- 1-800 Central phone number for traffic information
- Link local, regional websites to NCSMARTLINK
- Link traffic information to local TV, Cable
- Better alternate route guidance
- Traveler Information Kiosks (@ Rest areas, hotels, shops, malls, Visitor Centers, airports, etc.)

Following describes the recommended ATIS projects for Wilmington. Table 5.15 shows items and costs for these recommended projects.

Short-Term (2000 - 2006) Technologies

1. **Regional Traveler/Transportation Website.** NCDOT will develop a website or set of pages at an existing website to provide static travel information. This information may include transit schedules, fares and routes, published road closures, traffic policies, major generator and special event information, rideshare matching information and links to FAMPO, NCSmartLink, other city and NCDOT websites. This project is anticipated to cost $50,000 beyond the development costs being borne internally by NCDOT for various ITS web development projects.

2. **Traveler Information System.** A clearinghouse will be established to store real-time data for traveler information. This system will include data from system detectors, intersections, detector stations, posted incident reports, IMAP incident reports, and real time bus schedule information. This information will also be accessible from a central location, whether it is stored locally or remotely. The development of this clearinghouse will be used in kiosks and websites, with the development geared for long-term projects, such as a voice activated telephone system. The anticipated cost to develop this clearinghouse is $100,000.

3. **Web-Based Roadway Information.** As mentioned previously, NCDOT is in the process of developing a web-based real-time regional roadway information system to inform motorists of short-term and long-term road closures. This project will all be done internally to NCDOT, so all of the costs are internal to NCDOT.

Long-Term (2006 - 2011) Technologies

1. Kiosks at Major Public Venues. NCDOT and the cities in the Wilmington Region will develop and install five (5) kiosks that use web-based technologies to link to the websites in the area that display local traffic and event information. In addition, these kiosks will display information of interest for tourists, including destinations, lodging, restaurants, and information centers. Potential locations include regional malls, rest areas, visitors' bureaus, chambers of commerce, arenas and coliseums, hotels, racetracks, convention centers and others.

Kiosks provide NCDOT the opportunity to enter into ventures with private entities in two ways. The first is by selling or leasing kiosks at locations that are not public facilities. This may include large employers, malls, or hotels. In addition, if additional kiosks are requested at locations, they may be sold or leased as well. The second opportunity is to permit the generation of kiosk operating revenue by either selling advertising or licensing the kiosks. This would permit NCDOT to recover some of the costs of providing the data and hosting websites.

The cost of installing 5 kiosks throughout the Wilmington region is approximately $300,000. There are additional costs associated with the long-term operations of kiosks, especially as more are added, for updating information and adding bandwidth.

The development costs of the kiosk content needs to be shared amongst the many interested parties. Traffic and transit data is only a small portion of the information that is available, and is typically the least used. The most used information is concerning local interests and directions to destinations. Therefore, the development costs of the content needs to be borne by those who will benefit the most: tourist destinations, restaurants, and hotels.

2. Expand the Traveler Information System. The traveler information system identified as a short-term project limits the user input to selecting bus routes and identifying "hot spots" along major routes. As a long-term project, NCDOT will expand the system to provide additional real-time information, such as transit arrival, estimated travel times and video images from Wilmington. The expansion of this system, with regard to integration and web site development (including hardware) is estimated to cost $250,000.

Table E.13 Project Summary

Short-Term Projects			Long-Term Projects		
Description		Cost ($000)	Description		Cost ($000)
S-2	Dynamic Message Signs	$2,000	L-5	Kiosks at major public venues	$300
S-5	Regional Traveler/Transportation Website	$50	L-6	Expansion of Traveler Information System	$250
S-6	Traveler Information System	$100			
S-7	Web-Based Roadway Information	***			
	Subtotal	$2,150		**Subtotal**	$550

**No direct costs
***Costs are borne internally by NCDOT
Source: This table is extracted from the Wilmington regional report. Original table include all kind of ITS options but this table shows only ATIS deployments.

APPENDIX F. TRAFFIC COUNT ESTIMATION

1. Available traffic counts for study area

   a.

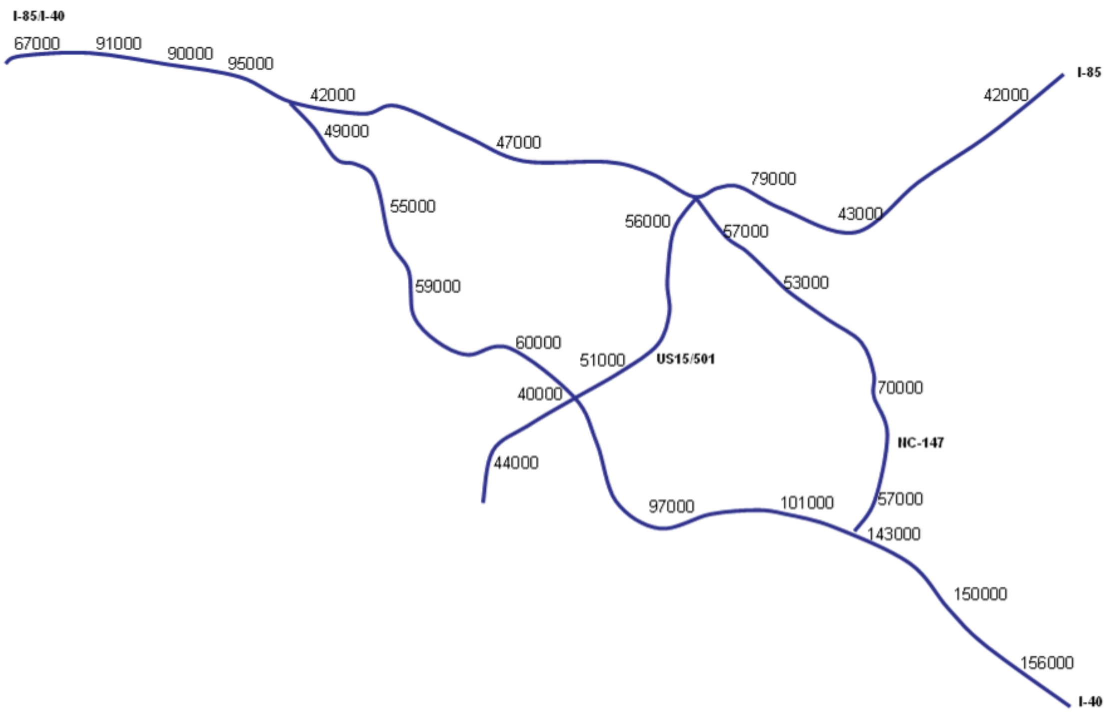


Figure F.1 ADT (Average Daily Traffic) 2005

Source: TRM (Triangle Regional Model)

b. ATR (Automatic Traffic Record) Station A3101
- Loop detectors are located on I-85, 0.1 miles west of US 501 bypass
- 2001 and 2002 data (this station has been out of service since 2002)
- Weekday/Weekend factor

Weekday	1.06
Weekend	0.85

- Weekday directional factor

North	0.45
South	0.55

- Weekend directional factor

North	0.49
South	0.51

- Weekday hourly distribution

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
North	1.12%	0.77%	0.67%	0.64%	0.77%	1.35%	3.52%	6.13%	5.89%	4.98%	5.16%	5.48%	5.95%	6.12%	6.37%	7.22%	7.90%	7.73%	6.20%	4.73%	3.89%	3.29%	2.35%	1.77%
South	1.69%	1.09%	1.10%	1.22%	1.49%	2.09%	4.51%	7.38%	6.40%	5.05%	4.89%	5.19%	5.51%	5.40%	5.56%	6.09%	6.68%	6.82%	5.50%	4.29%	3.79%	3.27%	2.67%	2.32%
Average	1.41%	0.93%	0.89%	0.93%	1.13%	1.72%	4.01%	**6.76%**	6.14%	5.02%	5.03%	5.34%	5.73%	5.76%	5.96%	6.65%	7.29%	7.27%	5.85%	4.51%	**3.84%**	**3.28%**	**2.51%**	**2.04%**

0 = 12 am to 12:59 am
1 = 1 am to 1:59 am
2 = 2 am to 2:59 pm
and so on

- Weekend hourly distribution

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
North	1.79%	1.21%	1.05%	0.86%	0.76%	0.91%	1.55%	2.51%	3.49%	4.89%	5.96%	6.44%	7.22%	7.44%	7.48%	7.50%	7.27%	6.79%	6.20%	5.28%	4.47%	3.81%	2.90%	2.20%
South	1.84%	1.75%	1.16%	1.69%	1.18%	1.22%	1.92%	2.93%	3.80%	4.98%	5.68%	6.04%	6.75%	6.79%	7.06%	7.64%	7.11%	6.66%	5.98%	5.29%	4.16%	3.51%	2.80%	2.08%
Average	1.82%	1.48%	1.10%	1.28%	0.97%	1.07%	1.73%	2.72%	3.64%	4.94%	5.82%	6.24%	6.99%	7.12%	7.27%	7.57%	7.19%	6.72%	6.09%	5.28%	**4.32%**	**3.66%**	**2.85%**	**2.14%**

0 = 12 am to 12:59 am
1 = 1 am to 1:59 am
2 = 2 am to 2:59 pm
and so on

2. Weekday AM peak hour volume estimation (for incident case study)
    a. AM 7:00~8:00 has the highest hourly volume during the morning according to the above ATR data.
    b. AM peak directional distribution

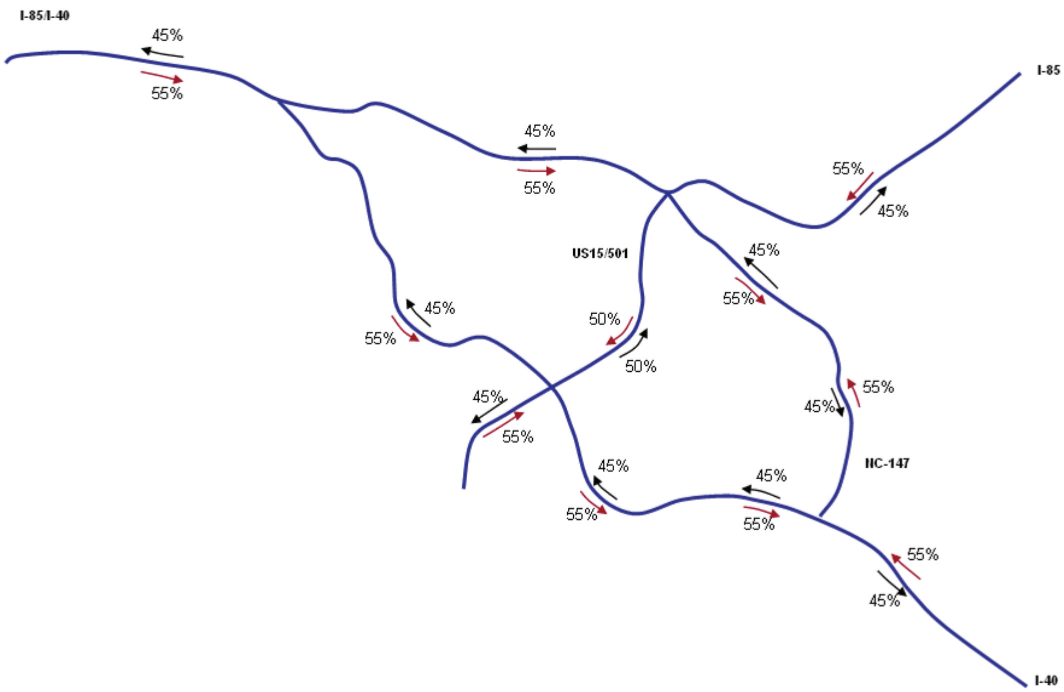


Figure F.2 AM Peak Directional Distribution

c. Weekday AM 7:00~8:00 hourly volume (vph)

= ADT *weekday factor * weekday directional factor*hourly factor

= ADT *1.06* weekday directional factor*0.0676

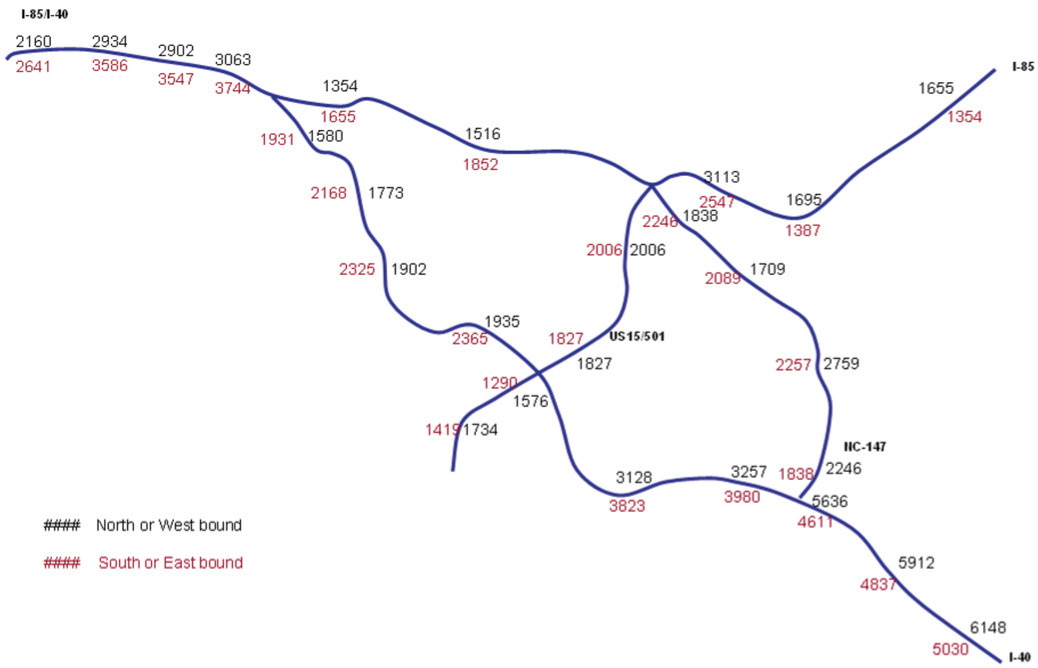


Figure F.3 AM Peak Hour Volume Estimates

3. Weekday off peak hours (20:00~24:00) volume estimation (for work zone case study)
   a. It is considered that work zone has more severe effect during weekday 20:00~24:00 because weekday 20:00~24:00 traffic volume is larger than weekend 20:00~24:00 traffic volume.
   b. Off peak directional distribution

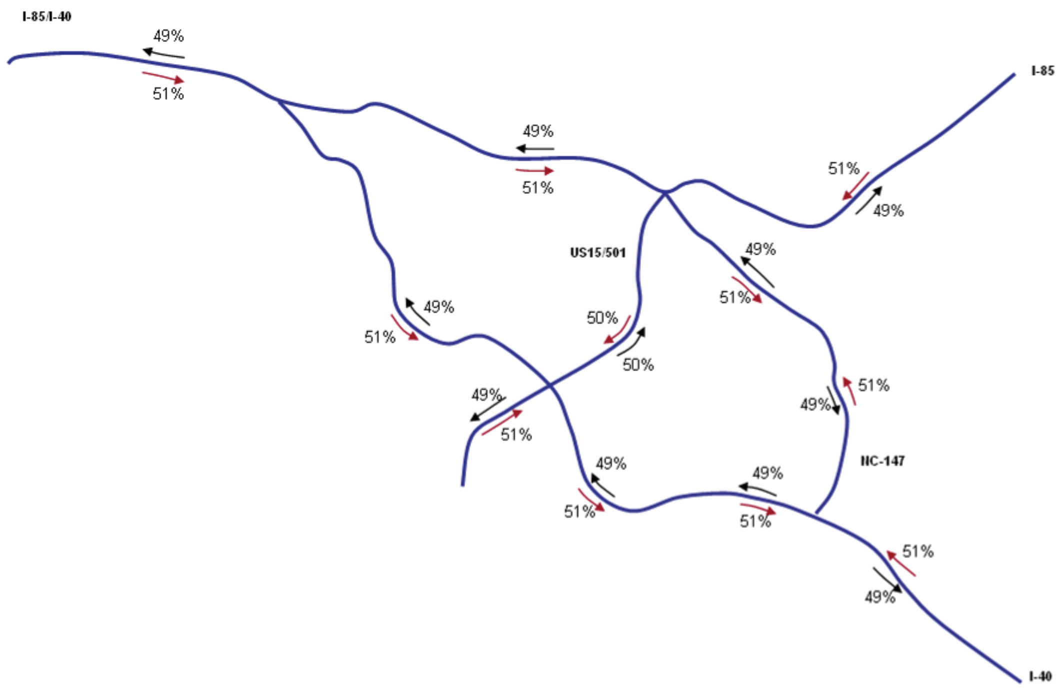


Figure F.4 Off Peak Directional Distribution

c. Weekday 20:00~24:00 hourly volume (vph)

= ADT * weekday factor * weekday directional factor*hourly factor

= ADT * 1.06 * weekday directional factor*hourly factor

Where, hourly factors are;

· 20:00~21:00: 0.0384

· 21:00~22:00: 0.0328

· 22:00~23:00: 0.0251

· 23:00~24:00: 0.0204

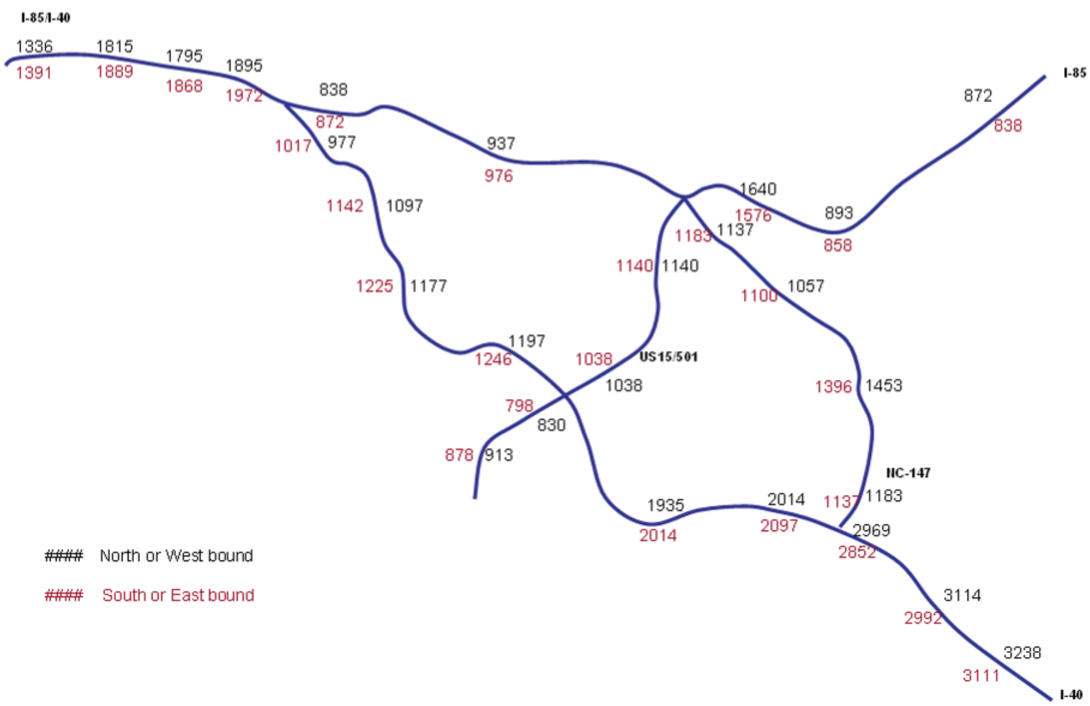


Figure F.5 Hourly Volume 20:00 to 21:00

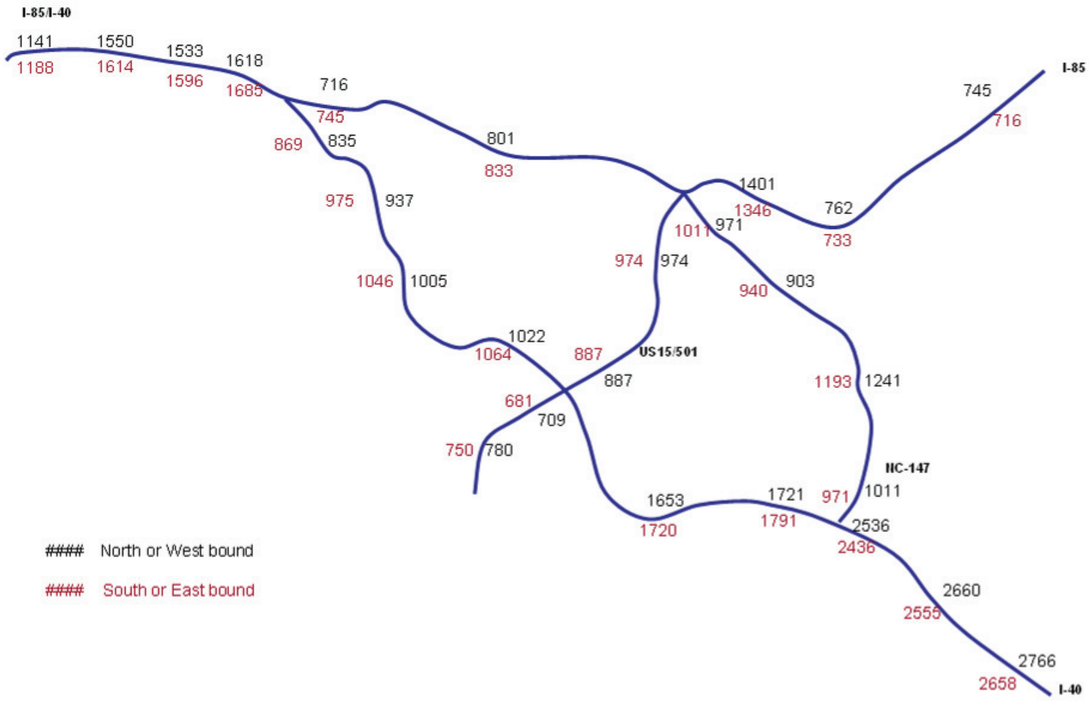


Figure F.6 Hourly Volume 21:00 to 22:00

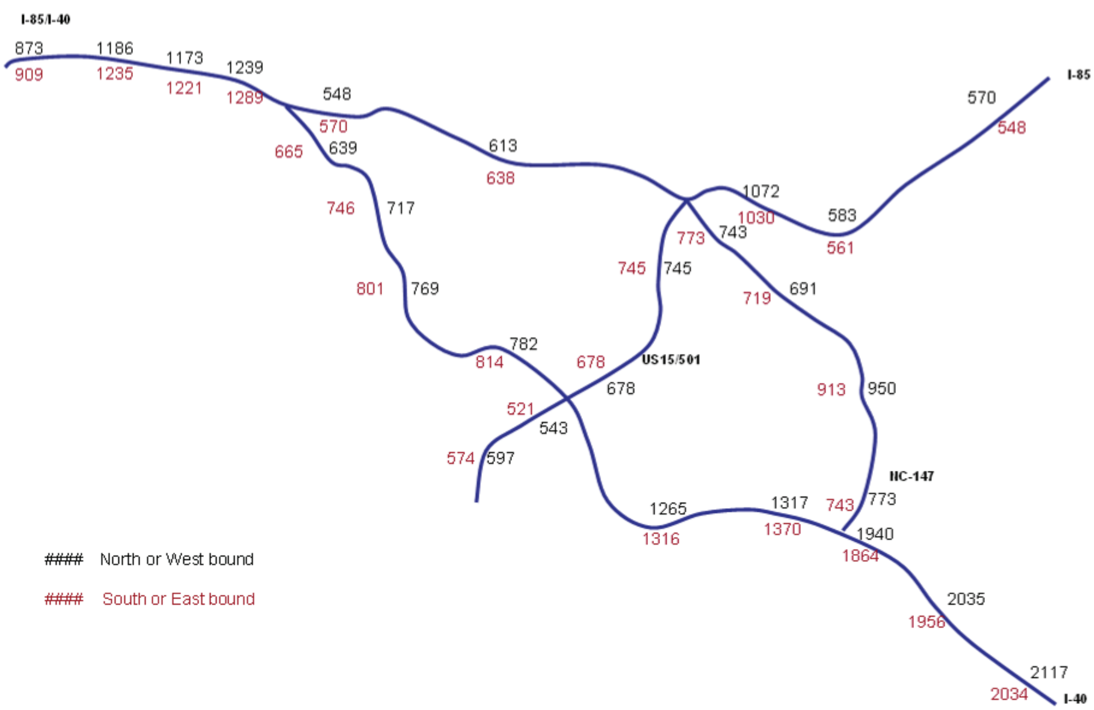


Figure F.7 Hourly Volume 22:00 to 23:00

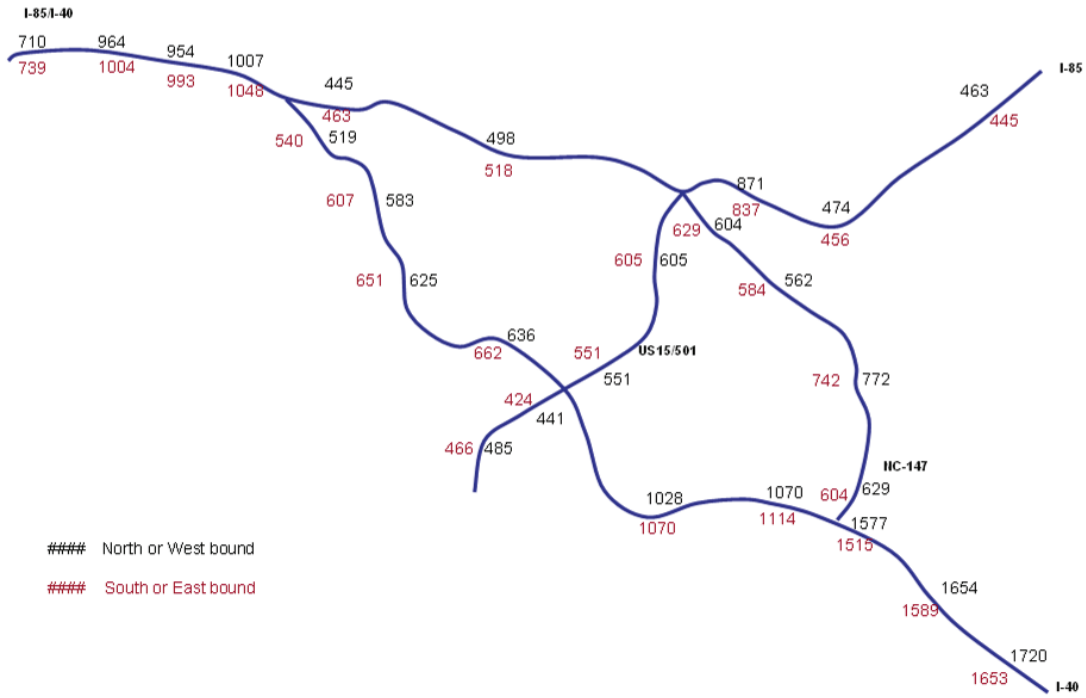


Figure F.8 Hourly Volume 23:00 to 24:00

4. Ramp volumes for Freeval input

   a. Location of key Exits, distances (distances were estimated based on Exit numbers), and number of lane

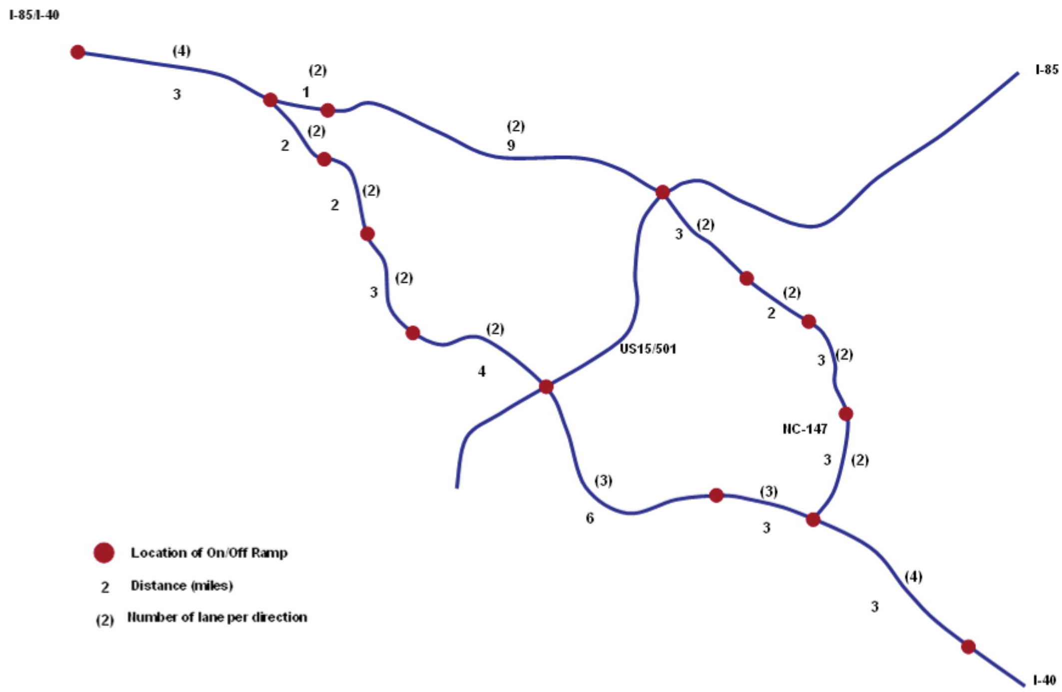


Figure F.9 Ramp Locations and Approximate Link Distances

b. Weekday AM 7:00 ~ 8:00 Westbound (For incident cases 1 and 2)

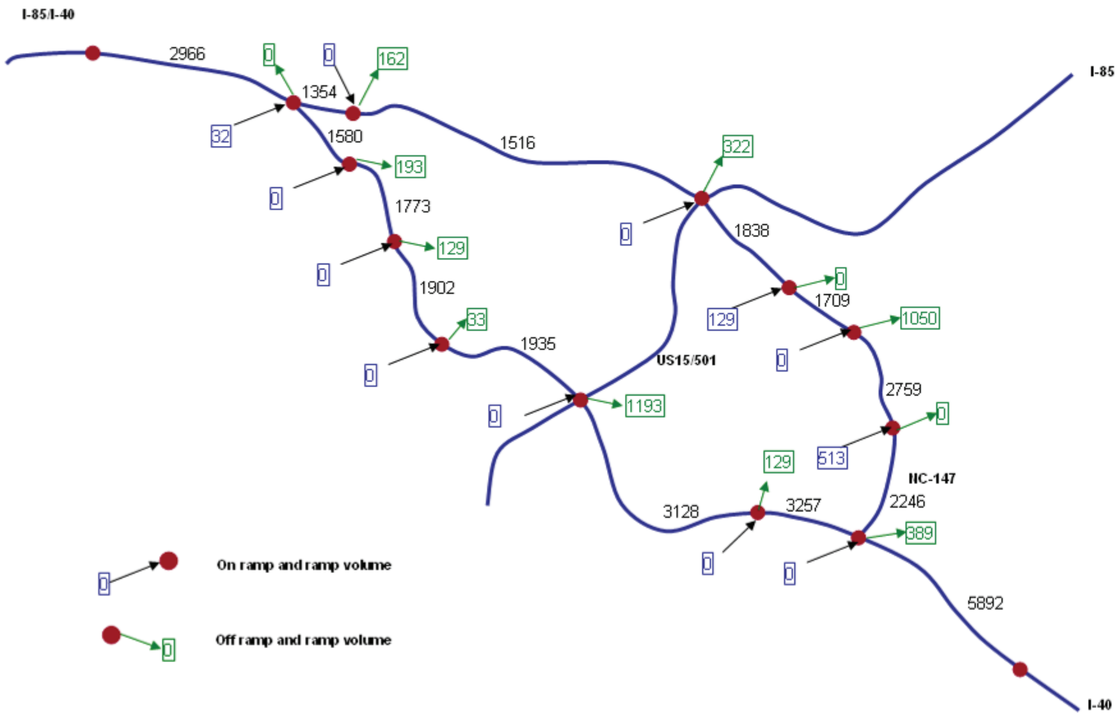


Figure F.10 AM Peak Hour Westbound Ramp Volumes (Incident Cases 1 and 2)

c. Weekday AM 7:00 ~ 8:00 Eastbound (For incident cases 3 and 4)

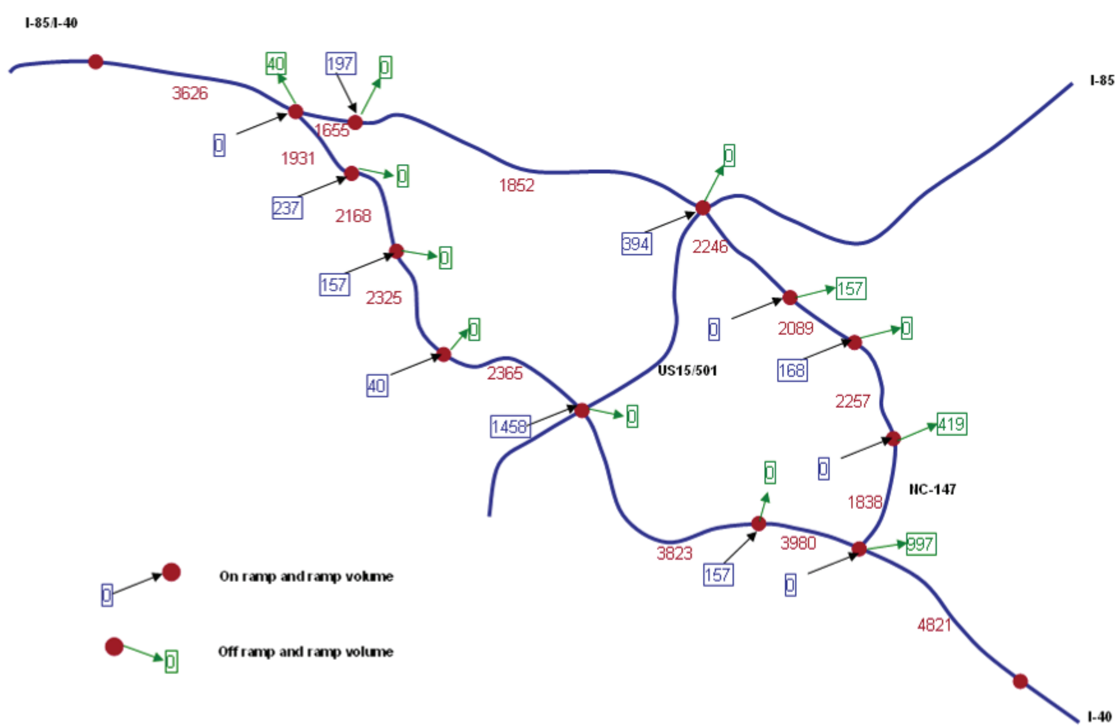


Figure F.11 AM Peak Hour Eastbound Ramp Volumes (Incident Cases 3 and 4)

d. Weekday 20:00~21:00 Westbound (For work zone case 1)

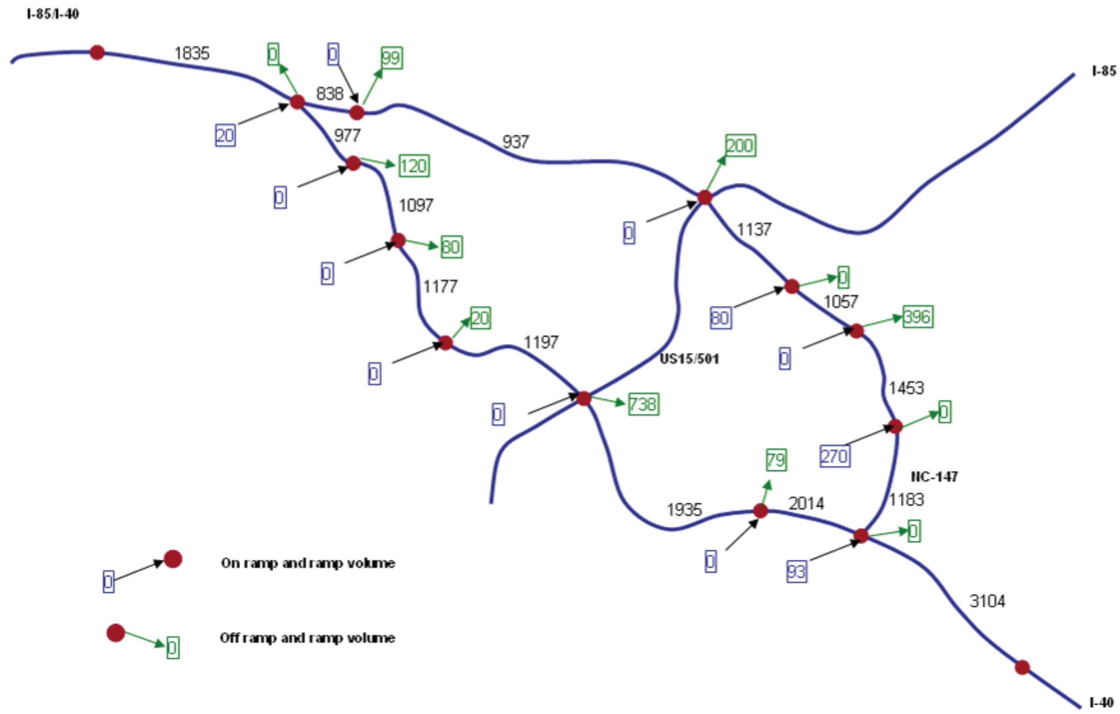


Figure F.12 Hourly Westbound Ramp Volume 20:00 to 21:00 (Work Zone Case 1)

e. Weekday 21:00~22:00 Westbound (For work zone case 1)

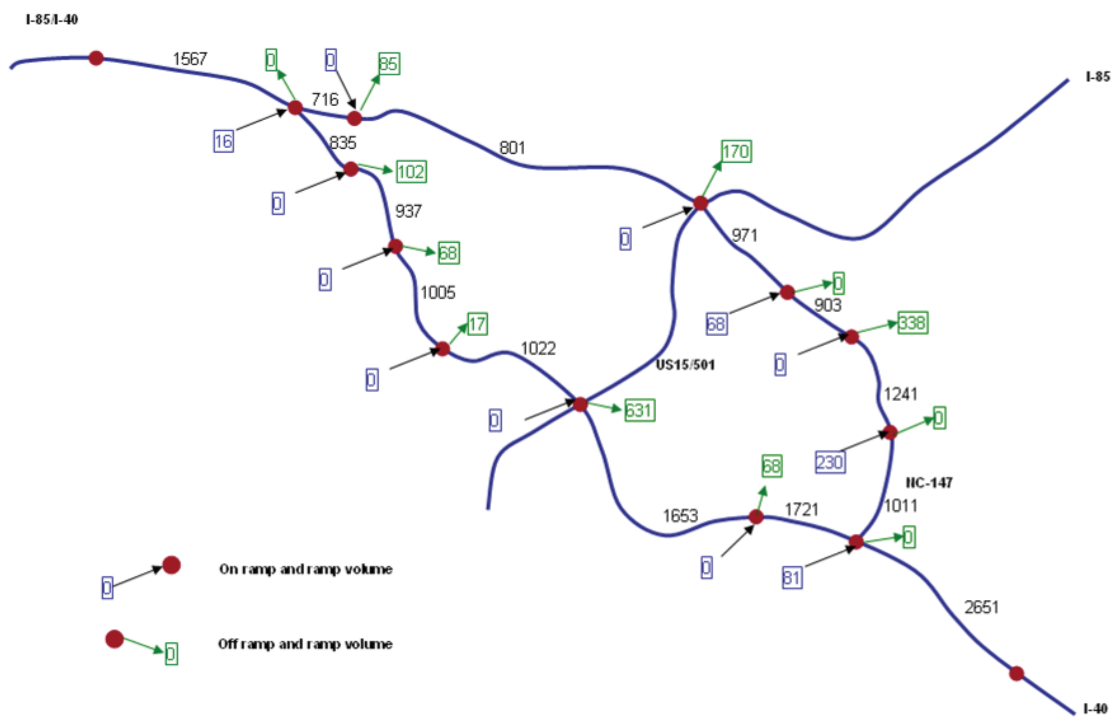


Figure F.13 Hourly Westbound Ramp Volume 21:00 to 22:00 (Work Zone Case 1)

f. Weekday 22:00~23:00 Westbound (For work zone case 1)

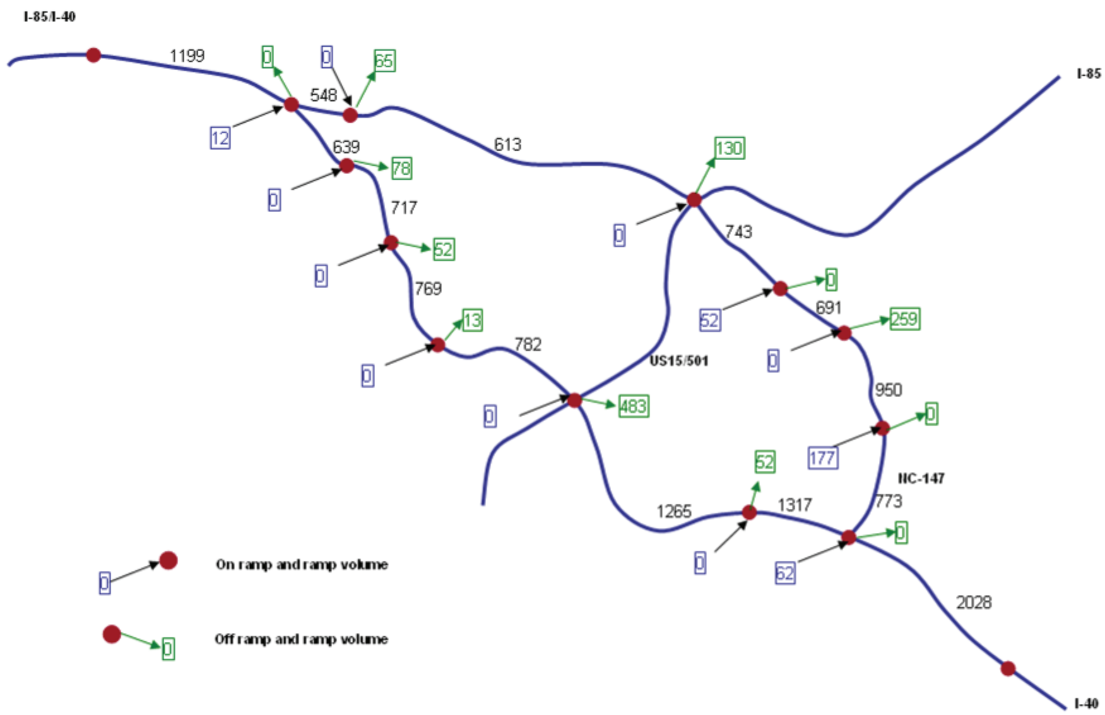


Figure F.14 Hourly Westbound Ramp Volume 22:00 to 23:00 (Work Zone Case 1)

g. Weekday 23:00~24:00 Westbound (For work zone case 1)

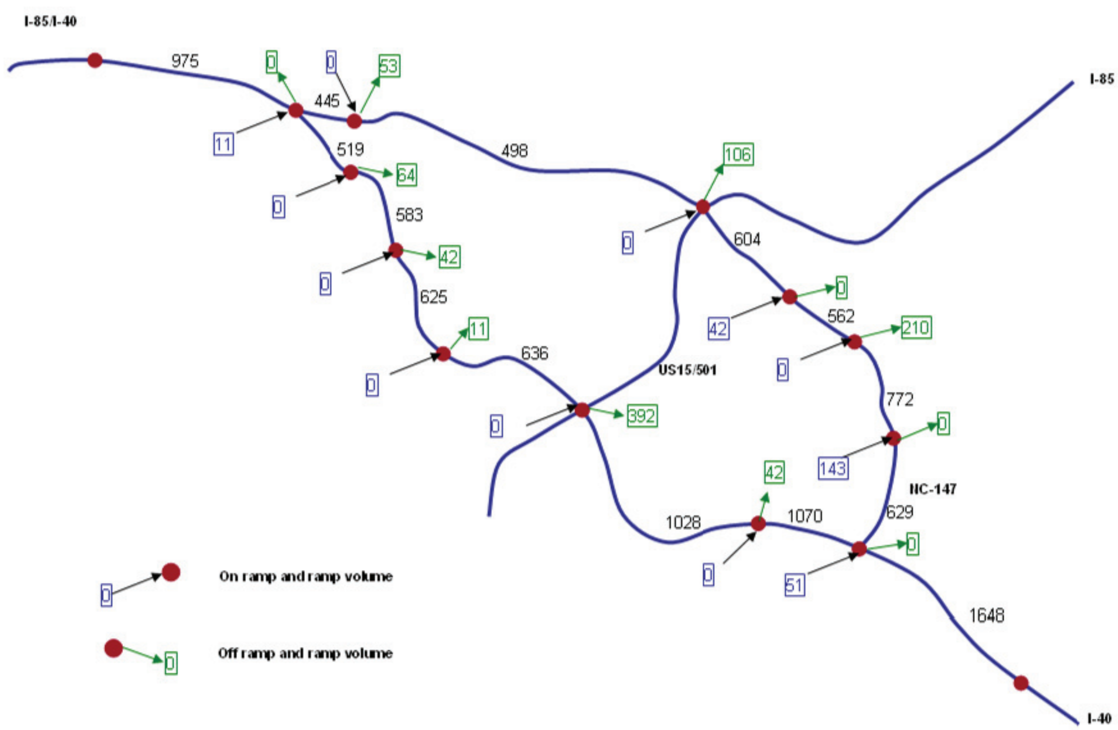


Figure F.15 Hourly Westbound Ramp Volume 23:00 to 24:00 (Work Zone Case 1)

h. Weekday 20:00~21:00 Eastbound (For work zone case 2)

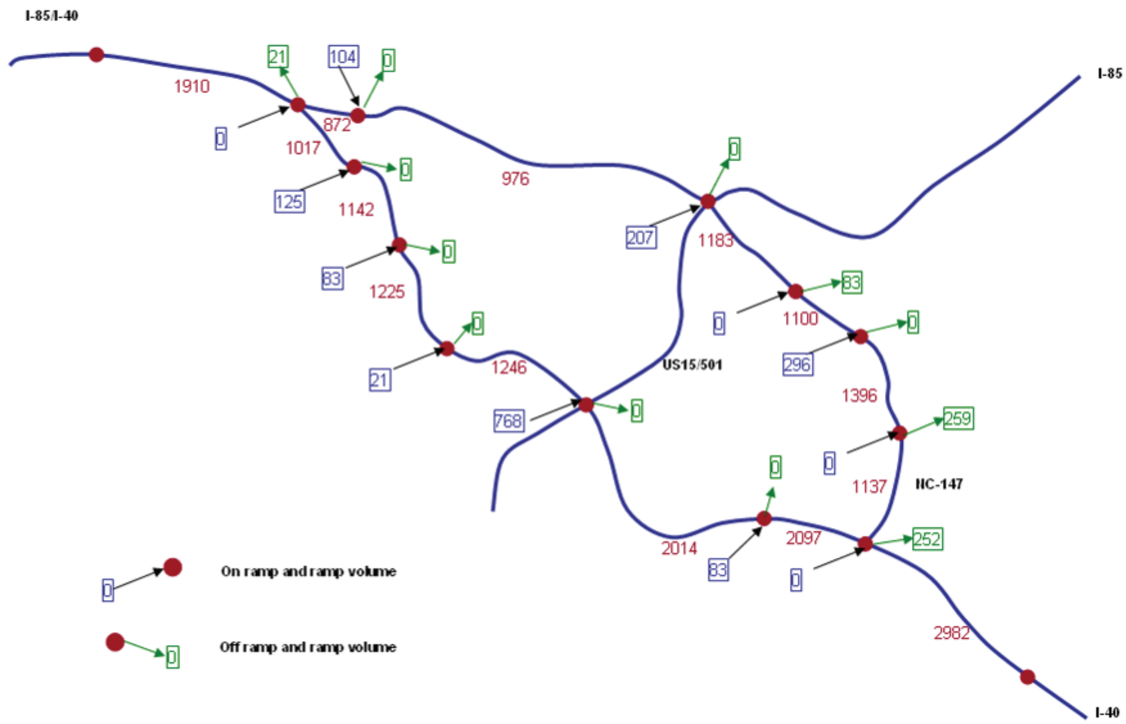


Figure F.16 Hourly Eastbound Ramp Volume 20:00 to 21:00 (Work Zone Case 2)

i. Weekday 21:00~22:00 Eastbound (For work zone case 2)

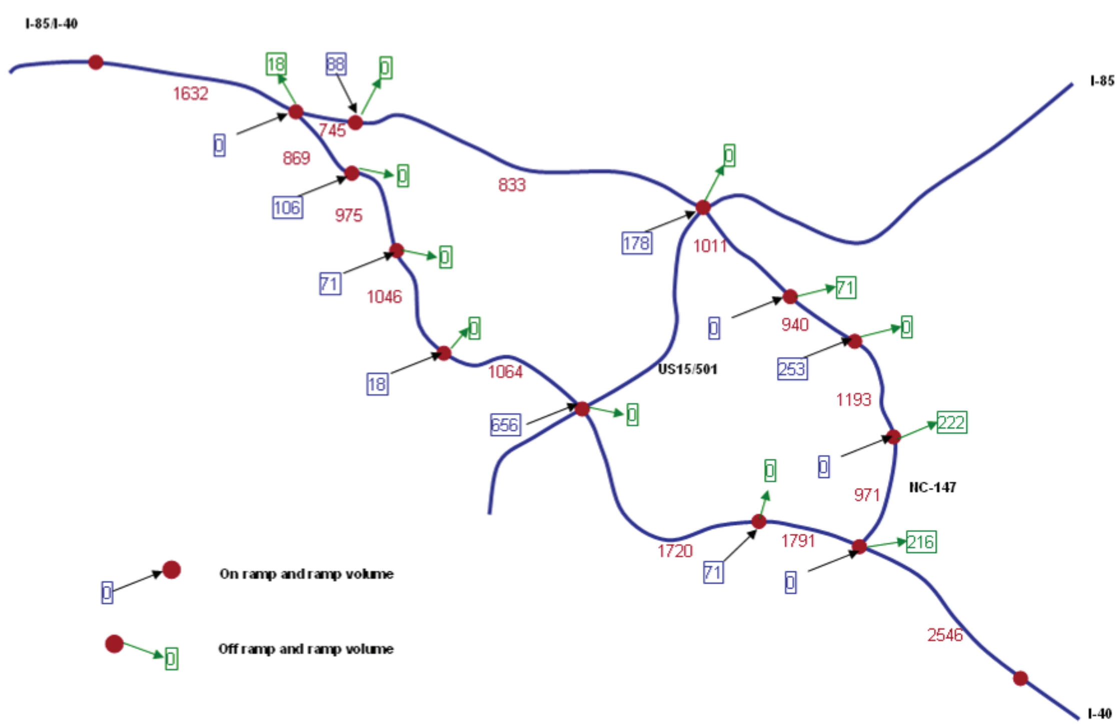


Figure F.17 Hourly Eastbound Ramp Volume 21:00 to 22:00 (Work Zone Case 2)

j. Weekday 22:00~23:00 Eastbound (For work zone case 2)

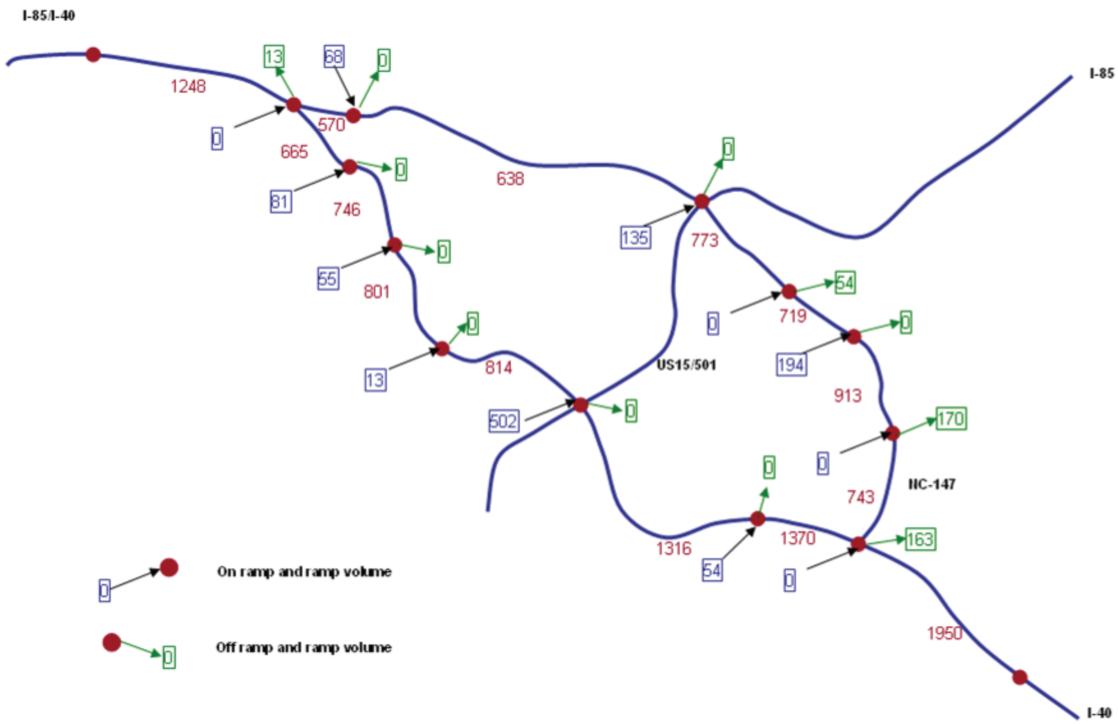


Figure F.18 Hourly Eastbound Ramp Volume 22:00 to 23:00 (Work Zone Case 2)

k. Weekday 23:00~24:00 Eastbound (For work zone case 2)

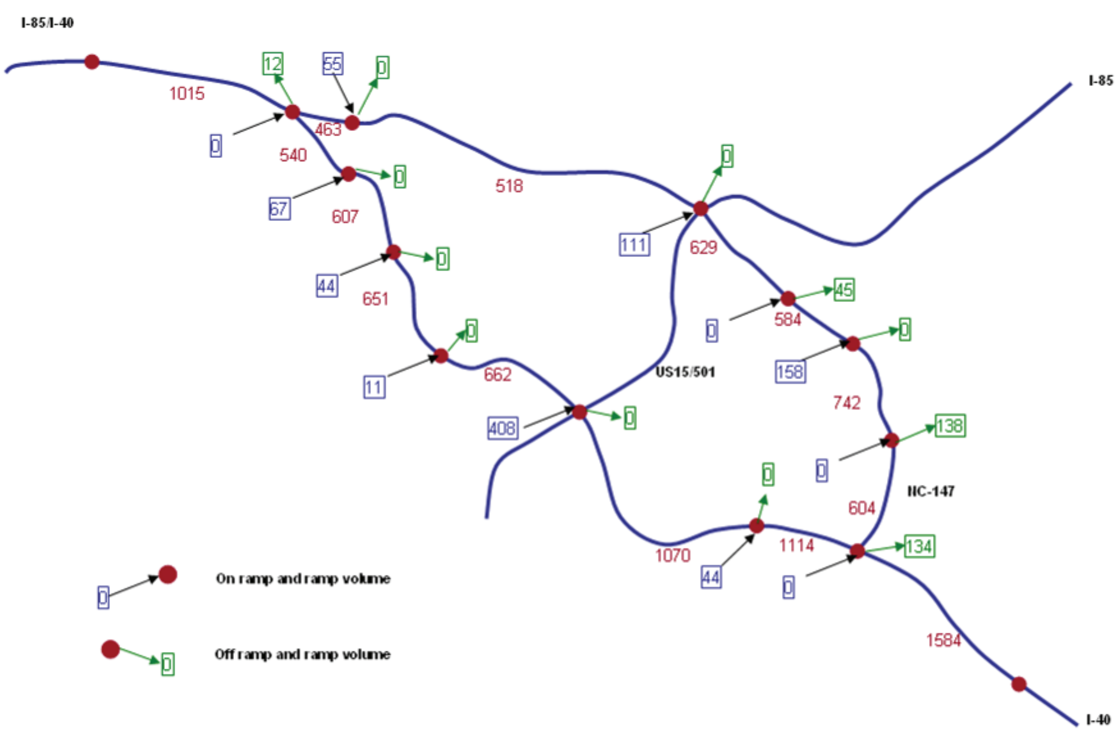


Figure F.19 Hourly Eastbound Ramp Volume 23:00 to 24:00 (Work Zone Case 2)

APPENDIX G. SUB AREA ANALYSIS FOR DYNASMART-P NETWORK PREPARATION

1. Make corrections in ‘Loaded Highway’ geographic file
   - Change number of lane from two to three lanes (I-40 Exit 270 ~ Exit 279)
   - Capacity change (??)
     Hourly capacity: 4282 →6423
     AM Peak capacity (4 hour): 14987→22480
     Off Peak capacity (16 hour): 30573→45860
2. Subarea analysis
   - Create boundary
   - Create network (Centroids: node ID<=2389)
   - Do subarea analysis
     - Open road geographic file, created network file, OD matrix
     - Create Sub_OD (planning-> planning utility->subarea analysis)
       i. Create interzonal demand (planning-> planning utility-> interzonal travel times)
       ii. Matrix-> fill-> formula : if [demand]=>0 then [demand] else 0
     - Create sub network geographic file
       i. Create sub_link (tool-> export)
3. Export TransCAD data to DYNASMART-P

3.1 Node information

Table G.1 Required data fields for importing NODEINFO file

Field Name	Data Type	Description
ID	Integer	Node ID assigned by GIS software
LONGITUDE	Float / Double	Longitude coordinate of the node
LATITUDE	Float / Double	Latitude coordinate of the node
CTRL_TYPE	Integer	Defined for signal control type of the node with the following values: 1. No control 2. Yield sign 3. 4-way stop sign 4. Pre-timed control 5. Actuated signal control 6. 2-way stop sign
ZONE_NO	Integer	If the node is a destination node for a zone, then this field is supplied with the corresponding zone TAZ number; otherwise, put it as 0.

Source: Dynabuilder user guide

- Node data view in Transcad
  - Control type
    i. add control field to node table
    ii. fill using Tag option (using layer: Network, Tag with signals)
        ➔ CTDN, control density (1, 2, 3, 4, 5, 99)
    iii. fill using Tag option (using layer: Network, Tag with Special)
        ➔ Special: Link type

1 = Interstate/Freeway
2 = Suburban Freeway
3 = Urban Freeway
4 = Rural Highway
21 = Freeway to freeway ramps
22 = Freeway to freeway loop ramp with weave
23 = Freeway to freeway loop ramp
24 = Freeway to arterial ramp/loop
25 = Arterial to freeway ramp/loop
26 = Arterial to arterial ramp/loop
31 = Centroid connector
41 = HOV link
54 = Parking lot link
55 = Transit only link
99 = All other highway link types

  - Zone number
    i. add NewTAZ field to node table
    ii. Sort increasing with ID
    iii. Select TAZ>=0
    iv. Fill with sequence (start =1 , step=1)

- Open excel file and edit
  - change to control type style
    i. 1: no control (TAZ): if signal controller density is 99, then no control.
    ii. 5: Actuated signal control (Others)

3.2 Link information

Table G.2 Required data fields for importing LINKINFO file

Field Name	Data Type	Description
ID	Integer	Link ID assigned by GIS software
FROM_ID	Integer	From node ID, which should be consistent with the node ID given in NODEINFO
TO_ID	Integer	To node ID, which should be consistent with the node ID given in NODEINFO
DIR	Integer	Defined as the direction of a link, with the following values: 1. from FromID to ToID -1. from ToID to FromID 0. two way

Field Name	Data Type	Description
LENGTH	Float / Double	Length of the link (feet).
TYPE	Integer	Defined as the type of link, with the following value: 1. Freeway 2. Freeway segment with detector 3. On-ramp 4. Off-ramp 5. Arterial 6. Non-freeway HOT link 7. Highway 8. Non-freeway HOV link 9. Freeway HOT link 10. Freeway HOV link
LANES	Integer	Number of lanes of the link
ZONE_NO	Integer	If this link is a generation link for a zone, then supply with the corresponding zone TAZ number; otherwise, put it as 0.

Source: Dynabuilder user guide

- Network dataview in transcad
  - change (From node, To node)
    dataview-> formula fields-> node field-> ID (ZONE id)->both option-> O.K.
  - save as *.xls

- open excel file to edit
  - length: mile➔ feet
    Length (ft) = Length (mile) *5280)
  - Type
    using post speed ➔ define aterial, freeway
    Type = if (Speedlimit>=55, 1, 5)
  - Lanes and direction
    i. sort by direction
    ii. edit to "From node to To node" direction
  - Generation link ➔ if from node is TAZ, then Generation link.

3.3 Zone information

Table G.3 Required data fields for importing ZONEINFO file

Filed Name	Data Type	Description
ID	Integer	Zone ID assigned by GIS software
TAZ	Integer	Transportation Analysis Zone ID provided by users for planning purpose

Source: Dynabuilder user guide

- Import zone info file.

3.4 Demand (OD matrix)

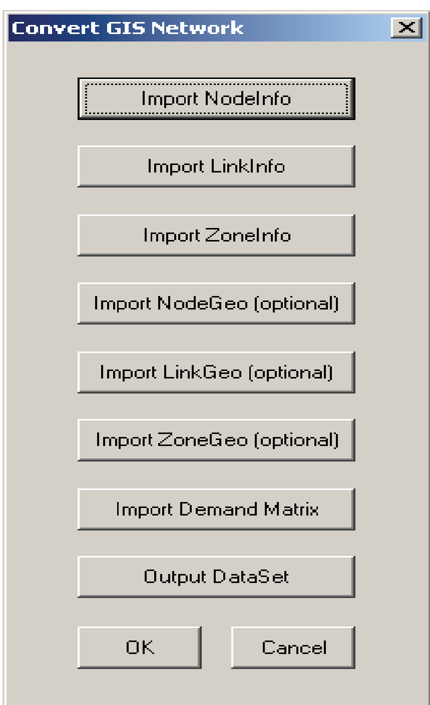
- SUB_OD matrix in TransCAD
    i. Open SUB_OD matrix in Transcad
    ii. Give new index with newTAZ (DYNASMART-P need sequential OD numbers)
    iii. Matrix-> export to ASCII file (.txt -> cell with a field for each matrix
    iv. Open Demand.txt file and add header and footer.

Header

// The first part begins here
// # of zones
760
// OD demand matrix
// from zone id, to zone id, one-hour demand rate

Footer
// The second part begins here
// # of periods
1
// temporal profile
1 1

4. Import data to DYNASMART-P (Dynabuilder)



5. Run and error check in DYNASMART-P program

- Errors: Control data

Edit control type

6160 5 0 0 => 6160 1 0 0

Node number, type, number of phase, cycle length

- Errors: Memory is not enough

Solution: decrease network size, aggregate the OD, or decrease K in K shortest path algorithm.

- Errors: Memory is not enough

Flag for the sequential loading mode is incorrect.
Check last field of system.dat

- ☐ Allow U-turn movement

```
Movement.dat
change the last column from 0 to 1 in movement.dat to enable
> > u-turns.
```

- ☐ Increase capacity of centroid connectors (1→9)

- ☐ Delete traffic controls of intersections at links with centroid connectors

Edit control.dat

Edit some major intersection

Max.green→100

Assume all links has left turn bay (to increase capacity of left turn movement)

6. Edit using DYNASMART-PED

- Centroid connectors

All connectors have only one lane when imported from TransCAD,

So we give these connectors a large number of lanes, 9 lanes, to have high capacity.

Similar to TransCAD creates congestions for traffic moves in and out of these connectors. Without fixing these problems, DYNASMART-P results will look pretty bad because all these connectors have only one lane and inbound traffic got stuck before getting into these connectors.

menu->tools-> increase connector capacity and save

- Signal in links to centroid connectors: delete these signal

Dynabuilder makes traffic signals for intersections in links to centroid connectors; actually some of them do not exist in real network. We should not add connectors adjacent to a signal intersection. In this case, we should remove the signal or remove the connector.

Edit signals with unrealistically high congestion (gave protected left turn phase) : 6013, 3378, 3364, 3338, 3398, 3401, 5893, 5952, 6079, 5384, 5390, 5450, 5452, 3567, 5905, 3385, 3330, 6112, 5175, 5172, 5171, 4141, 3598, 3603, 3654, 5899, 5217, 9539, 9568, 12027, 4872, 5334, 5354, 4696, 4611, 4654, 4828, 5356

delete traffic control: 3568, 9988, 5995,

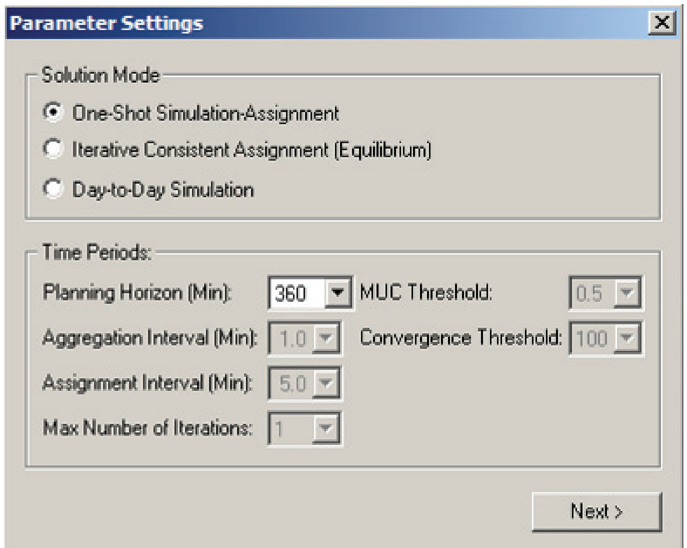
Demand level Calibration

- Demand data
  - Separate two vehicle type: passenger (SOV + HOV) and CV
  - Do Subarea analysis for each demand
  - Do Export and import steps separately
  - Give file name
    i. passenger (SOV + HOV) demand ➔ demand.dat
    ii. CV demand ➔ demand_truck.dat

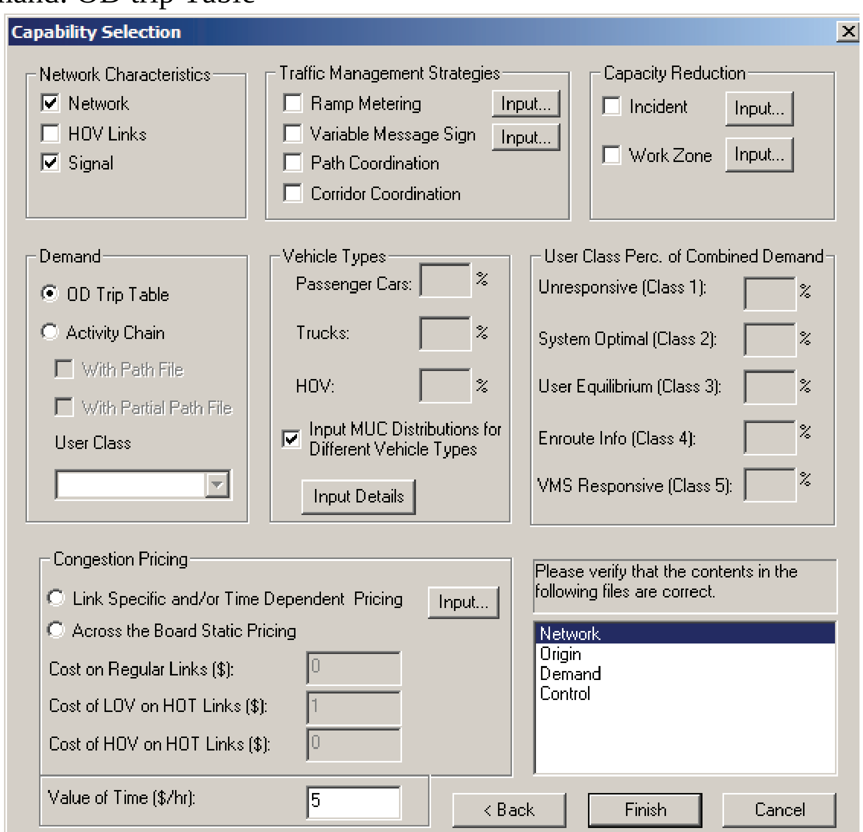
  - Demand level
    i. AM peak demand (7:00 ~ 8:00 am)
      - Hourly ratio from traffic count data of 4 hour AM peak OD matrix
        i. 6:00~7:00 ➔ 0.175
        ii. 7:00~8:00 ➔ 0.295
      - Prepare 3 level demand for passenger car
        i. 0~ 60 min: 0.175 (for feeding network)
        ii. 60~120 min: 0.295
      - Prepare OD matrix for each period and each vehicle type
        (Open *OD.bin file in TransCAD→ add new field and fill using formula 'demand* volume rate'→ save as text file)
      - Do Export and import steps for getting Demand matrices
      - Start multiplication factor one then calibrate it
      - Statistic collection time (analysis period: 60~120min)

    i. Weekday 4 hour demand (20:00~24:00)
      - Hourly ratio from traffic count data of 16 hour Off peak OD matrix
        i. 19:00~20:00 ➔ 0.094
        ii. 20:00~21:00 ➔ 0.077
        iii. 21:00~22:00 ➔ 0.066
        iv. 22:00~23:00 ➔ 0.050
        v. 23:00~24:00 ➔ 0.041
      - Prepare 3 level demand for passenger car
        i. 0~ 60 min: 0.094 (for feeding network)
        ii. 60~180 min: 0.143 (0.077+0.066=0.143)
        iii. 180~300 min: 0.091 (0.050+0.041=0.091
      - Prepare OD matrix for each period and each vehicle type
        (Open *OD.bin file in TransCAD→ add new field and fill using formula 'demand* volume rate'→ save as text file)
      - Do Export and import steps for getting Demand matrices
      - Start multiplication factor one then calibrate it
      - Statistic collection time (analysis period: 60~400min)

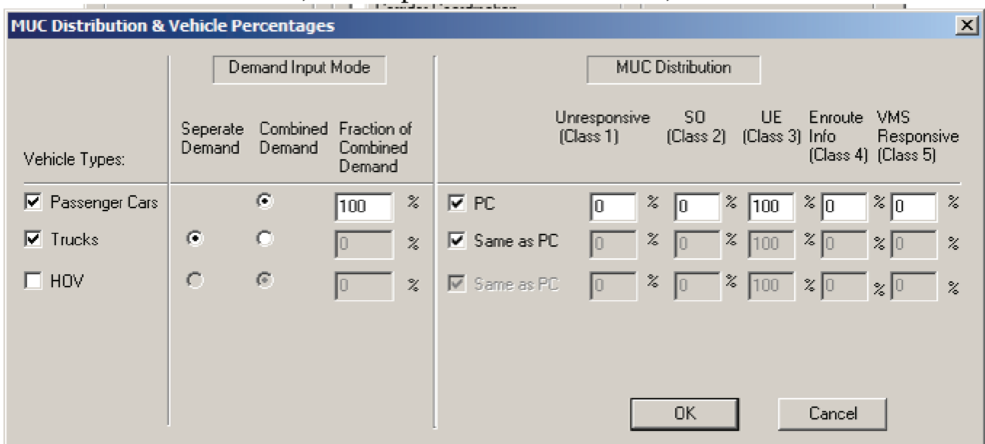
- System parameter setting for base network run (Option 1)
  - One-shot Simulation-Assignment
  - Planning horizon: 400 Minute
  - Other parameters: default values



- Scenario setting for base network run
  - Demand: OD trip Table



- Vehicle types: Check ‘Input MUC distributions for different vehicle types’ → Click ‘input detail’ button\
- For Trucks demand, use Separate Demand table, MUC Distribution is same as PC



- Compare link flows with traffic count
  - resize demand level by changing multiplication factor

7. Validation

- Look travel time between important origin and destination nodes and compare with other route.