Incorporating Intelligent Transportation Systems Into Planning Analysis

Summary Of Key Findings From A Seattle 2020 Case Study

Improving Travel Time Reliability With ITS

Table of Contents

Figures

Tables

Introduction

As Intelligent Transportation Systems (ITS) technologies mature, the options to deal with future transportation needs become both more varied and more complex. As political and financial constraints make conventional "build" approaches less attractive, technologies are becoming increasingly relevant in long-range planning. The growing role of ITS is reflected in the fact that ITS deployments are increasingly funded through the use of regular sources (i.e., not specific to ITS). The move to mainstream funding mechanisms necessitates the integration of ITS into the established transportation planning process, where ITS can be evaluated both against and in combination with conventional transportation components such as road widening or new facility construction.

Currently, however, the analytical tools employed in our metropolitan regions cannot adequately address the dynamic-response capabilities of ITS technologies. In addition, staff within planning organizations may have less experience with ITS than other types of transportation improvements. As a result, ITS is typically considered an operational detail to be worked out after infrastructure planning is complete. This approach ignores the potential for the introduction of ITS to change the decisions made during infrastructure planning, or even the overall type of system chosen.

To address these issues, a transferable methodology has been developed for public sector investment that facilitated quantitative evaluations of projected ITS costs and benefits in concert with various conventional improvements. The methodology is called the Process for Regional Understanding and Evaluation of Integrated ITS Networks (PRUEVIIN), pronounced "proven." PRUEVIIN is not a model itself or a software product — it is a technique featuring the combined application of both regional travel demand models and commercially available traffic simulation software in an innovative scenario-based framework.

The feasibility and capabilities of an analysis based on the PRUEVIIN methodology were demonstrated with a case study analysis of a broad freeway corridor within the Seattle, Washington metropolitan region. A variety of realistic alternative solutions for the target year 2020 were analyzed, each representing different combinations of conventional and ITS components. The alternatives assessed were not tied to actual Seattle area decision-making. However, planners and traffic engineers from the region reviewed the alternatives and found them to be plausible.

This report summarizes the key findings from the Seattle case study and the development of the PRUEVIIN methodology. The Seattle case study demonstrates that current analytical tools and data can be utilized to address key limitations of the current transportation planning process. Although requiring additional effort beyond current practice, analyses based on PRUEVIIN can reveal important positive and negative characteristics of proposed alternatives that contain a range of ITS technologies.

System Variability and Traditional Transportation Planning Analysis

Anyone who commutes or travels through major urban areas knows that roadway congestion can be highly variable and often unpredictable. Severe weather conditions or major accidents can turn a typical 30-minute drive into a two-hour ordeal. Sometimes unexpected congestion appears for no apparent reason and just as unexpectedly dissipates. Depending on how frequent and unpredictable congestion is, travelers as well as transportation system operators and planners within a region may be very concerned with how well the system performs under these critical conditions.

In current state-of-the-practice analysis to support transportation investment planning, however, these critical moments of severe congestion are not considered. Primarily because of issues of data collection, computational complexity, and the nature of the tools available to analysts, the evaluation of various alternative solutions is made by examining system performance under so-called "expected" conditions (Figure 1). Data collected on days used to determine "expected" conditions reflect:

- clear weather
- invariant, average travel demand
- no accidents.

Planning model analyses typically use these "expected" inputs to determine how well various alternative solutions will perform on average. In the past, these simplifying assumptions have allowed quantitative assessment of travel demand patterns in large metropolitan regions to be simple enough to be analyzed, calibrated, and understood with commercially available computers and planning software.

Unfortunately, the use of "expected" conditions as inputs does not lead to very realistic "expected" results as outputs. Real conditions almost never conform to the ideal of "expected" conditions. Instead, each day is an unpredictable collection of accidents and incidents, weather and roadway surface conditions, and variable travel demand.

Figure 1. Traditional "Expected" Conditions Analysis

It is precisely under these variable conditions, however, that ITS technologies can be most helpful. In the case of a major accident, coordinated incident management can reduce the amount of time a roadway is blocked while advanced traveler information (ATIS) systems can advise travelers of various alternative routes. Adaptive traffic signal control systems can respond to surges of demand to help clear out crowds departing an event at a downtown stadium. Clearly, any methodology that attempts to capture the impacts of ITS technologies must be able to consider a broader set of potential conditions than the current planning process. Further, the impact of relatively rare events must be appropriately weighted by their expected frequency.

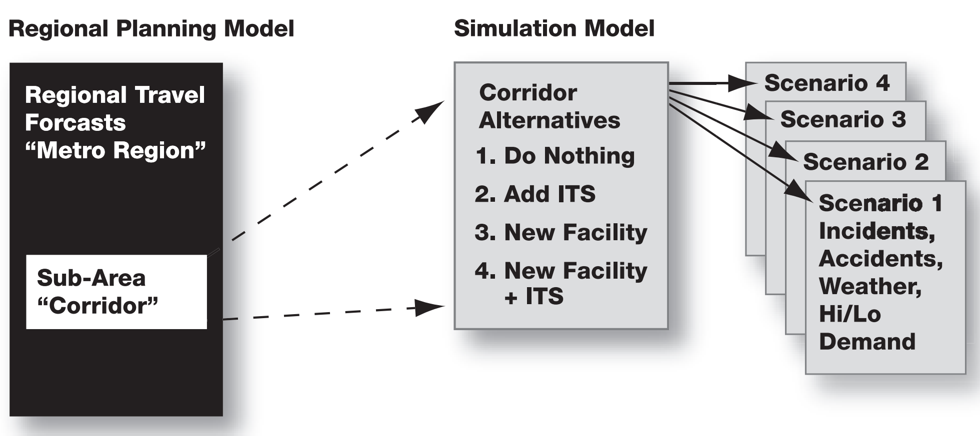
PRUEVIIN: Capturing System Variability Impacts

The PRUEVIIN methodology allows planners to deal with the two critical issues surrounding system variability in urban transportation systems analysis. First, PRUEVIIN provides a process for utilizing state-of-the-art traffic simulation models to identify ITS impacts on transportation system performance under non-average conditions. Second, it provides a statistical method to classify the frequency and intensity of system variability which links the simulation analysis to the wider regional travel demand modeling framework. This approach allows performance to be evaluated under a range of realistic conditions, rather than one artificial "expected" condition.

PRUEVIIN features modeling at two different scales of analysis (Figure 2). At the higher (regional) level, the analysis of overall travel patterns under average or expected conditions is determined using a traditional planning model. Travel demand data from this analysis corresponding to a smaller sub-area are then fed into a more detailed simulation model capable of modeling time-variant conditions and demands, as well as individual vehicles and their routes. Within the simulation model, detailed traffic operations, queuing, and the buildup and dissipation of congestion are captured, as well as the response of both travelers and ITS technologies to dynamic network conditions. In theory, one could model the entire region using only a simulation model, but this is not yet practical for current commercially available software.

As part of the Seattle 2020 case study, EMME/2 was used for the regional planning model, and INTEGRATION 1.5 for the detailed simulation model. Note that the PRUEVIIN methodology is not unique only to these two models. These two were chosen because of their previous application in the Seattle region.

Figure 2. PRUEVIIN Methodology Overview

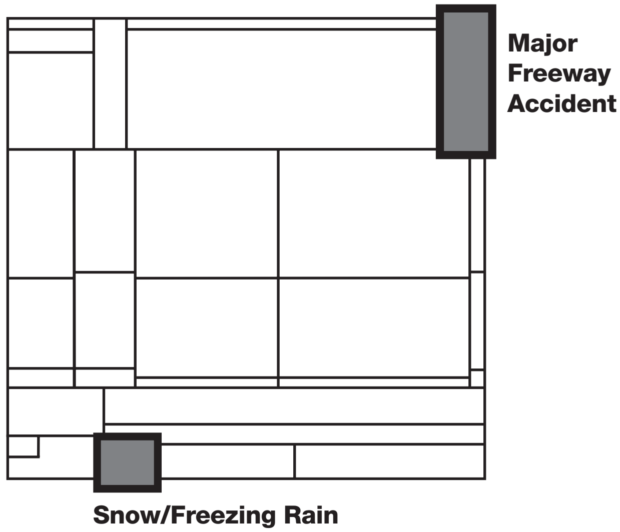


Representative Day Scenarios

A set of representative day scenarios are developed in the PRUEVIIN methodology that, when appropriately weighted, can be used to represent an entire year. To generate these scenarios, data were collected from various sources on the two-year period (1996-97) on travel demand, weather, and accident data in the corridor. Using cluster analysis and other statistical techniques, 30 separate scenarios were developed to capture the range of conditions actually seen in the corridor. Figure 3 depicts these scenarios where each of the 30 boxes in the diagram corresponds to a particular scenario. The relative size of the boxes corresponds to the relative frequency of occurrence – the larger the box, the more likely the scenario. Each scenario constitutes a particular combination of weather, travel demand level, and accident pattern. For example, the box in the upper right-hand corner represents a major freeway accident under good weather and 10 percent higher than normal travel demand. The smaller box in the lower half of the diagram corresponds to a scenario with snowy or icy roadway conditions.

Clearly, the more frequent the scenario, the more overall weight it carries when impacts are annualized.

Figure 3. Frequency of Representative Scenarios



The simulation model is used to identify system performance in terms of travel times, throughput, and other measures in each scenario. These measures are then averaged together in a weighted sum to identify annualized impact figures for each alternative evaluated in PRUEVIIN. Other significant measures can also be calculated such as day-to-day travel time variability in the system.

The Seattle I-5 North Corridor 2020 Case Study

To test the concepts and practicality of the PRUEVIIN methodology, a 120-square-mile urbanized corridor from the Seattle, Washington metropolitan area was selected as a testbed. The North Corridor (Figure 4) features a geographically constrained roadway network carrying traffic along a north-south axis to and from the Seattle central business district in the south. The two primary facilities for north-south movement within the corridor are the Interstate 5 (I-5) freeway and one mixed expressway/arterial state route (SR 99). These routes also carry significant travel demand to other major destinations in or near the corridor boundaries such as the University of Washington. In addition to the natural constriction of traffic caused by the two bodies of water to the east and west of the corridor, vehicles must also cross the Ship Canal, a waterway that bisects the corridor just west of Lake Washington. I-5 and SR 99 comprise the only high-capacity facilities to cross the Ship Canal. Currently, the corridor encounters serious congestion in both weekday morning and evening commute periods. Increased travel demand and even higher congestion are predicted for the 2020 target year.

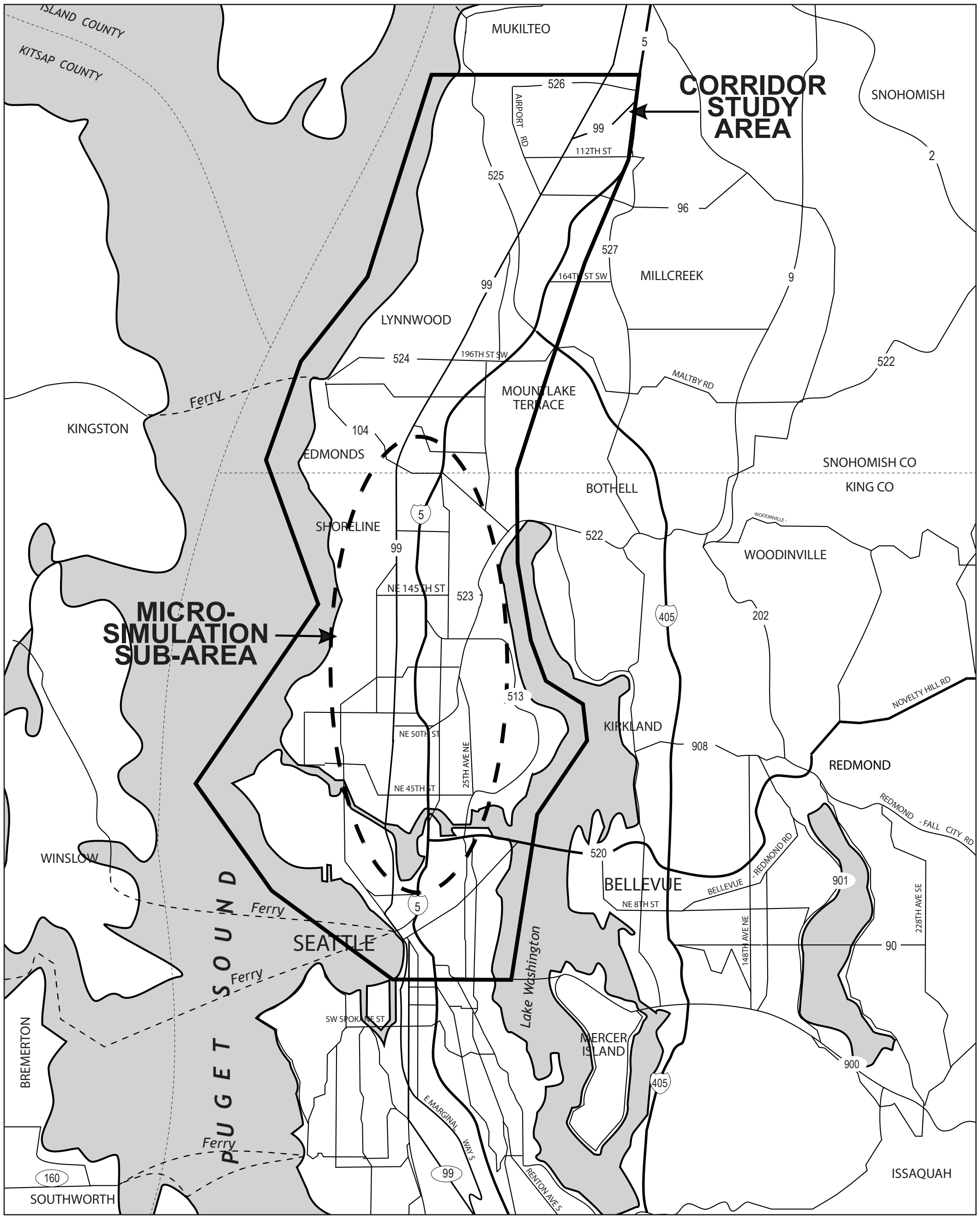
Three alternatives without significant ITS deployment were analyzed: a "do-nothing" baseline and two traditional construction options. The first construction option was an upgrade to high-occupancy (HOV) vehicle facilities on I-5; the second a single occupancy vehicle (SOV) enhancement to SR 99 bringing current arterial segments up to expressway status.

A package of ITS components was examined in combination with each of the construction alternatives and the "do-nothing" baseline to create three additional alternatives. ITS components implemented in these alternatives include upgraded advanced traveler information systems, adaptive traffic signal control systems and associated arterial surveillance systems, transit signal priority, and a broader incident management system.

For each alternative, high-level travel demand patterns were determined for the surrounding region using the regional planning model. Patterns for the North Corridor were then adapted for the detailed simulation model that encompassed all freeway, expressway, and arterial routes within the 120-square-mile testbed. The relative performance of the six alternatives was determined using the two models and the representative day scenario evaluation methods to test the capability of the PRUEVIIN methodology.

The use of representative day scenarios and nontraditional measures like travel time variability makes the careful validation and calibration of the models particularly critical, since outlier data can have significant impact on overall results. As a part of the case study, a base year 1997 network was analyzed against empirical data describing the rise and fall of point-to-point travel times in the network every 15 minutes, as well as individual roadway link volumes and other measures.

Figure 4. Seattle I-5 North Corridor Study Area



Measures of Effectiveness and Summary of ITS Impacts

The performance of each alternative was examined for the morning weekday peak travel period of 6:00 A.M.-9:30 A.M. An analysis of other peak and off-peak periods would follow the same PRUEVIIN methodology, although only the morning peak period was studied for the Seattle 2020 case study. Statistics are collected in the simulation from all vehicles that begin trips in the network between 6:15 A.M. and 8:30 A.M.

For these trips, delay is calculated as the difference between the average travel time in each scenario and travel times under no congestion. Throughput measures the number of trips starting in the 6:15 A.M. and 8:30 A.M. timeframe that can finish before the end of the modeled peak period at 9:30 A.M.

The coefficient of trip-time variation is calculated by examining the variation in travel times across all scenarios for each trip. This statistic is an indicator of travel time reliability in this study – the higher the coefficient, the higher the variability of trip times.

The impact of ITS technologies is summarized in Tables 1-3. The addition of ITS to the alternatives considered cuts average traveler delay by 15-20 percent, increases corridor throughput by 4-10 percent, and reduces trip travel time variability by 17-30 percent.

Table 1. Impact of ITS, Do-Nothing Alternative

Measure per Average AM Peak Period	Do-Nothing	Do-Nothing Plus ITS	Percent Change
Delay Per Vehicle (min)	10.9	9.3	-15%
Corridor Throughput (trips)	172,000	180,000	+4%
Coefficient of Trip Time Variation	0.31	0.22	-30%

Table 2. Impact of ITS, HOV/Busway Alternative

Measure per Average AM Peak Period	HOV/Busway	HOV/Busway Plus ITS	Percent Change
Delay Per Vehicle (min)	13.0	10.4	-20%
Corridor Throughput (trips)	177,000	184,000	+4%
Coefficient of Trip Time Variation	0.27	0.22	-17%

Table 3. Impact of ITS, SOV Capacity Enhancement Alternative

Measure per Average AM Peak Period	SOV Capacity Enhancement	SOV Plus ITS	Percent Change
Delay Per Vehicle (min)	13.9	11.7	-16%
Corridor Throughput (trips)	168,000	186,000	+10%
Coefficient of Trip Time Variation	0.39	0.31	-30%

"Brittle" Alternatives: An Example from the Seattle 2020 Case Study

The importance of considering conditions beyond the nominal "expected" day typically employed in transportation planning (clear weather, average demand, no accidents) is illustrated by the identification of alternatives that are susceptible to major failure under likely but less than perfect conditions. An example from the Seattle 2020 North Corridor case study is the case of the SOV Capacity Enhancement alternative.

SR 99, which parallels the I-5 freeway in the corridor, is currently both an undivided arterial and a limited access expressway at various points along its length. Under the SOV Capacity Enhancement alternative, the arterial portions are converted to expressway status. Using the regional travel demand model (and the assumption of "average" conditions), the alternative appeared effective at increasing corridor throughput and reducing travel times for the trips that utilize the upgraded SR 99 facility. All alternative routes in the corridor were severely congested and travel demand was drawn to the upgraded facility to take advantage of travel time savings.

Analysis with the traffic simulation, however, revealed that the new expressway facility breaks down under poor weather or heavier than normal travel demand. Averaging out the number of breakdown and non-breakdown conditions expected during the year, the new expressway provided only marginally higher annualized throughput and significantly worse travel time variability than the "do-nothing" alternative. Based on an analysis of the simulation results, the SOV Capacity Enhancement can be characterized as being "brittle" – good performance when conditions were fairly close to ideal, but significantly worse under likely but less than perfect days.

The addition of ITS technologies to the alternative showed particularly significant improvement. The reason ITS is so effective lies in the reason why the SOV Capacity Enhancement alternative is so brittle. Given the high cost of obtaining right-of-way in the urbanized corridor, the SR 99 expressway must be served by relatively short off-ramps ending in stoplights. Despite their limited length, the short off-ramps must serve relatively high travel demand. These short ramps cannot hold many vehicles attempting to exit SR 99 and periodically cause backups into the mainline lanes of the expressway itself. When this happens, the capacity of the

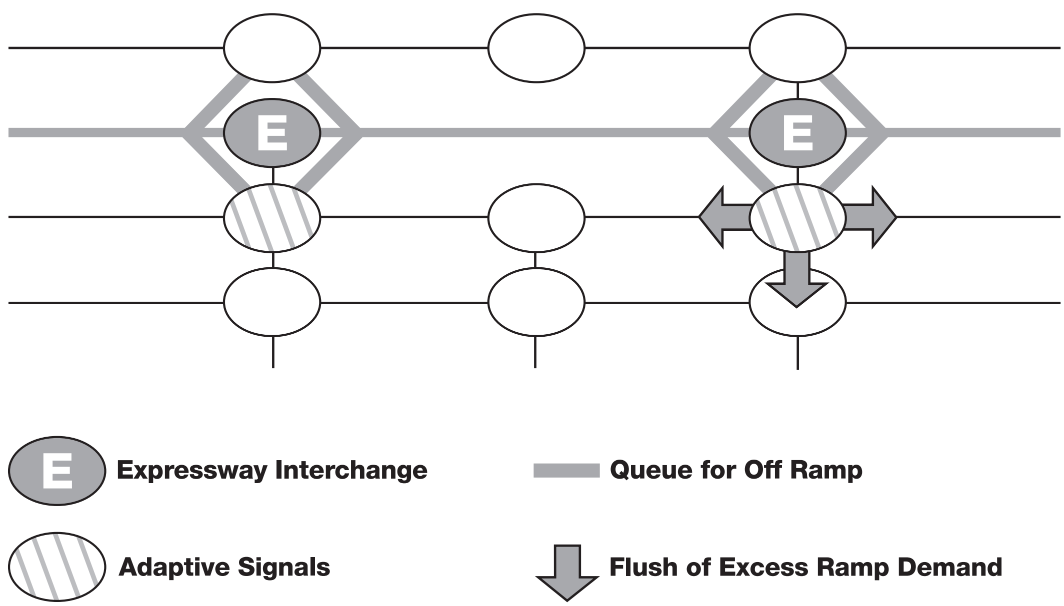
Analysis with the traffic simulation, however, revealed that the new expressway facility breaks down under poor weather or heavier than normal travel demand.

The addition of ITS technologies to the alternative showed particularly significant improvement.

expressway plummets and the result is rapid and intense congestion that is not easily resolved. The periodic breakdowns become persistent under high travel demand (which causes faster queue buildup on the ramps) or poor weather conditions (which exacerbates the drop in capacity when cars begin to back up on the expressway).

Adaptive signal control linked with queue detection on the off-ramps can react to potential breakdown conditions and are set to flush vehicles from the off-ramps at the expense of the cross-street traffic (Figure 5). Although this causes some additional delay for the cross-streets, the expressway facility (and in turn the overall system) is spared from major breakdown.

Figure 5. Effect of Adaptive Signals in SOV Enhancement Alternative



Key Findings from the Case Study

- **Analyzing system performance beyond traditional notions of "average" conditions can reveal important strengths and weaknesses of various combinations of ITS and infrastructure elements.**

  Examination of higher than normal demand conditions, as well as adverse weather impacts, revealed that an arterial-to-expressway upgrade to SR 99 in the Seattle 2020 case study would likely be subject to unacceptable breakdown conditions on a regular basis.

- **Analysis, based on the PRUEVIIN methodology, can be conducted as a feasible extension to the traditional planning process, or to complement analyses conducted using a sketch-planning tool like IDAS.**

  It has been estimated that a PRUEVIIN application would add roughly 30 percent to the cost of conducting the analysis for a traditional major investment study. Even ITS-specific sketch-planning tools like ITS Deployment Analysis System (IDAS) do not use representative day scenarios or simulation modeling to explicitly identify delays under the worst congestion conditions. An analysis based on the PRUEVIIN methodology could be used to help better refine estimates made using default parameters within IDAS.

- **ITS technologies had positive benefits in all alternatives studied, although impacts differed depending on the underlying infrastructure.**

  The deployment of adaptive signal control and queue length detection sensors had a much more significant impact when deployed with the arterial-to-expressway alternative than in either of the other two alternatives studied.

- **The impact of ITS technologies is seen most strikingly in non-traditional performance measures.**

  While improvements in travel time could be demonstrated, the deployment of ITS was largest in terms of reduced travel time variability and high-speed stops.

- **Archived data plays a key role in PRUEVIIN analyses.**

  The Seattle area was selected for the case study based not only on the geography and nature of the corridor, but also because the Washington State Department of Transportation (WSDOT) and other local agencies had good archives of travel demand on various key facilities, as well as good records of accidents and incidents over the period studied.

The PRUEVIIN methodology development effort and the Seattle I-5 North Corridor case study illustrate that current analytical tools, data, and staff can be extended to address key limitations of the current transportation planning process. Analyses based on the concepts of PRUEVIIN allow planners to move beyond the constraints of the artificial "average" conditions now built into traditional analyses. This not only reveals important characteristics of proposed alternatives, but also allows ITS to be considered directly and fairly in the planning process. The outcome of incorporating ITS into the planning process through an analytical methodology like PRUEVIIN is a better understood, more robust, and more cost-effective transportation system for the future.

For more information, consult the full technical report *Incorporating ITS Into Corridor Planning: Seattle Case Study Final Report*, available on-line from the Electronic Document Library (EDL) www.its.dot.gov/itsweb/welcome.htm. The report is number 11303.

ITS Web Resources

ITS Joint Program Office:
www.its.dot.gov

ITS Cooperative Deployment Network:
www.nawgits.com/icdn.html

ITS Electronic Document Library (EDL):
www.its.dot.gov/itsweb/welcome.htm

ITS Professional Capacity Building Program:
www.pcb.its.dot.gov

Federal Transit Administration
Transit ITS Program:
www.fta.dot.gov/research/fleet/its/its.htm

Intelligent
Transportation
Systems

U.S. Department of Transportation
400 7th Street, SW
Washington, DC 20590

FHWA-OP-02-031 May 2002 EDL #13605