EXECUTIVE SUMMARY

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Incorporating ITS into Corridor Planning: Seattle Case Study

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Executive Summary

Introduction

The goals of this study were to develop a methodology for incorporating Intelligent Transportation Systems (ITS) into the transportation planning process and apply the methodology to esitmate ITS costs and benefits for one case study. A major result from the study included the development of an analysis method for quantitatively assessing ITS impacts, called the Process for Regional Understanding and EValuation of Integrated ITS Networks (PRUEVIIN). Other significant results include the assessment of benefits from an integrated set of ITS services at the regional and corridor level, and lessons learned about incorporating ITS into the planning process. The following sections set the context for and provide a summary discussion of these findings.

Key Study Accomplishments

1. Developed an analysis methodology (PRUEVIIN). PRUEVIIN evaluates the unique aspects of ITS strategies (impacts/benefits/costs) along with more traditional corridor improvements. Traditional corridor alternatives have in the past focused on capacity and other improvements designed to relieve expected or recurrent congested conditions. The techniques have focused on average travel and conditions. However, many of transportation problems, delays, and congestion that occur in the real world are the result of non-recurrent incidents or operational inefficiencies. Traditional corridor study methods and measures of effectiveness tend to be insensitive to solutions such as ITS strategies designed to address problems arising from these non-recurrent and operational issues. ITS strategies focus primarily on improving operations and the transportation system's response to changing conditions, improving reliability of the system and letting travelers know the true condition of the transportation system.
   A goal of the study was to develop a set of integrated methods that incorporate in the analysis the types of problems and solutions that ITS strategies are attempting to remedy. This includes the system's response to varying non-recurrent conditions and the impact of information. Another important aspect of this same goal was to implement the process in an integrated framework that can analyze the net effect of the traditional and ITS elements in an overall solution to the corridor's transportation needs. This is especially important since the impacts of each element (ITS and traditional) in an overall corridor solution may interact, producing results that are not simply the sum of the individual element improvements. The PRUEVIIN methodology accomplishes this goal.

   For the study an existing commercial planning model (EMME/2) and simulation model (INTEGRATION) were used. The INTEGRATION model supports analysis of trips from each origin to each destination (similar to the regional models) but can also trace how vehicles actually move through the network. The ability to trace individual

vehicles is a key feature for incorporating mode choice, route guidance, and other ITS strategies into the analysis. Key elements of the methodology are the capture of both ITS and traditional transportation improvements in both of these models; the interplay of the models to assess corridor improvements in the context of a regional network; and the development of a series of scenarios (representative travel days) to capture the conditions and effects of non-recurring congestion.

In this study the PRUEVIIN methodology was applied for an analysis year of 2020 (a typical 20 year planning time-frame), but the methodology can also be used for any time horizon, as well as for the conduct of near term "what-if" analyses by operational personnel. Since the inception of the study, PRUEVIIN has been used to support the Metropolitan Model Deployment Initiative (MMDI) evaluation program. A study in the Seattle area using the same sub-area was conducted for a horizon year of 1997-98 (*ITS Impacts Assessment for Seattle MMDI Evaluation: Modeling Methodology and Results*, Mitretek Systems, June 1999).

2. Produced Measures of Effectiveness (MOE's) for comparing alternatives. These measures reflect typical MIS issues and also capture the impacts of ITS strategies. A key phase in any MIS is the development of the MOE's that are used to evaluate the alternatives under study and reflect the issues/concerns of those in the community making the decision. Typically, measures of transportation service, costs, mobility and system performance, financial burden, and environmental/community impacts are considered. These measures, however, are usually only calculated based upon the average weekday or expected conditions. Variation in conditions (e.g. travel demand, weather, accidents) and the transportation system's response to them is not part of the analysis and consequently does not enter into the decision process. Incorporating variation in conditions is key to showing the benefits of ITS and other strategies focused on improving the operation of the system. In the study several new MOE's were analyzed that are more representative of the impacts of ITS. These new measures include reduction in travel time variability, probability of a severely delayed trip, vehicle-km traveled at various speed ranges, and number of stops per vehicle-km traveled.

3. Developed representative-day scenarios. A methodology was developed to determine the number and characteristics of the representative-day scenarios necessary to capture the variation in conditions and the effects of non-recurrent congestion. Previous studies have shown that ITS strategies can have significant impact on anomalous traffic conditions that, even though they are relatively rare, can contribute a disproportionate amount of delay and other costs. To assess the alternatives in this study that include ITS strategies, the analysis had to incorporate these anomalous traffic conditions. Since the network simulation model is capable of representing time-varying conditions, the AM peak travel conditions are characterized into a reasonable sample of scenarios that are both typical and anomalous of conditions in the study area.

Each scenario represents a combination of conditions common to the study area that may lead to the traveler experiencing very different conditions and possibly a different travel choice. The characterization of the sub-area conditions and the scenarios was obviously constrained by available data. These considerations focused attention on the following characteristics: traffic/trip volumes and their space-time patterns; weather conditions; and the effect of accidents and other incidents on traffic conditions. For the Seattle study it was determined that 30 scenarios were required to capture the yearly range of day-to-day variations in travel conditions. The probability of occurrence of each scenario during the year was also determined. For each of the 6 alternatives, the full set of scenarios was run. The resultant MOE's were then multiplied by the probability of the occurrence of the scenario. This produces an annualized value for each MOE. This annualized roll-up allows the even-playing-field examination of ITS elements alongside traditional capacity improvements.

4. Developed techniques to measure and calibrate the simulation model. This calibration approach accounted for the within-day and the day-to-day travel time variations in the transportation system. This is important because if system variability is overstated, then ITS-related benefits associated with adaptive control or ATIS will likely be overstated. Likewise, if system variability is understated, then the benefits of ITS technologies will likely be understated. The techniques developed include the use of an 18-month archive of travel time estimates along the I-5 freeway in Seattle, collected at 15-minute intervals between 6:00 AM and 9:30 PM.

Observations on Methodology Development and Application

1. It is possible using a reasonable amount of resources to integrate regional travel forecasting and sub-area simulation analyses to capture the impacts of ITS and other operational strategies. The Case Study has successfully interfaced the two model systems for this purpose.

2. Simulation tools require additional levels of detail and representative coding than are typically found in regional models. If accurate simulations are to be developed then extra time must be spent in network checking and detailing to ensure that all models represent the physical features of the system at the same level of precision. Likewise, executing the integrated system (regional model + sub-area simulation + feedback) will also require additional effort, especially when representative day scenarios are used for the estimation of ITS benefits.

3. There are increased needs for data collection to support the simulation tools beyond the data collection associated with the support of travel demand models. Additional information beyond what is carried in the regional model systems will need to be obtained, geocoded, and entered into the model system. This includes data on signal operational plans, time variation in demand, and the information on weather, incidents, construction, etc. used to construct the representative day scenarios.

4. The characteristics and size limits the regional model and simulation model platforms used in the study were a significant factor in the design of the methodology. Understanding these characteristics is crucial for properly transferring data between the two platforms. One specific issue is the use of very short "dummy" links, a common practice in planning models. However, these short links are incompatible with the high-volume freeway coding requirements of the simulation model. Therefore, in applying the methodology used in this study one needs to be aware that each pairing of modeling systems will have its own set of issues that will have to be examined.

5. There are also inherent differences in operation and performance between regional and simulation tools. Each represents travel and the behavior of individuals differently. For example, regional models, especially in horizon year forecasts, often have assigned volumes on links or across screenlines which exceed coded capacity (the actual physical capacity of the facility). On the other hand, simulation models by their design cannot assign volumes to links beyond their capacity. Since these two models define capacity differently, special care must be taken. In the horizon year analyses, one should therefore always check for this over saturation condition prior to attempting a simulation run. The trips assigned over saturation can either be deferred to outside the assignment period or diverted around the sub-area. In the study a deferred trip measure of effectiveness was defined to show the level of oversaturation when it did occur. The explicit treatment of queuing in simulation and not in the regional system presents similar issues. These differences in impedance calculation led to the conclusion to only feedback the relative changes between alternatives from the simulation to the regional model. If absolute values from the simulation are fed directly back into the regional model a discontinuity between links within the simulation area and those without is created.

6. Validation is a crucial step in developing an integrated model system. The regional model system parameters and coding should be examined and modified to reflect the new services under study. For example, if ramp meters are to be examined in the analysis it is important to represent the bottlenecks in capacity due to traffic merging for all unmetered intersections in the network. This is achieved by assigning a merge bottleneck penalty to all intersections, and then for the ramp-metered intersections, the merge bottleneck on the main lanes downstream of the ramp is removed. This is a very different approach from simply increasing the capacity on the links downstream of the ramp to above the mid-link flow levels.

Background

As ITS capabilities become ready for deployment through use of regular funding sources, they will need to be integrated into the established transportation planning process. This process involves choices among competing projects within financial and other constraints. ITS components will in many cases be combined with more conventional transportation components as part of an alternative to address a specific transportation

problem. This raises many questions about how to select and evaluate ITS projects as an integral element of traditional transportation construction projects.

In addition, transportation planners often have less experience with ITS compared to other types of transportation improvements, and hence analytical techniques that adequately address the ITS component have not been developed. In light of this, any approach to study these issues has to include:

- Reviewing existing procedures and developing a quantitative investment analysis methodology for state/local use in transportation planning.
- Developing case study-based estimates of relative costs and benefits of ITS versus conventional investments.
- Identifying where improved methods of project

To address these issues the ITS Joint Program Office (JPO) of the United States Department of Transportation (USDOT) tasked Mitretek Systems to investigate the incorporation of ITS into the transportation planning process. A review of current state-of-the-practice revealed that consideration of ITS is typically not an integral part of transportation planning. Rather, ITS is considered an operational detail worked out after infrastructure planning. In many cases ITS was considered too difficult to evaluate with respect to transportation planning and then relegated to operational analysis because of a lack of evaluation tools. In response to the JPO tasking, Mitretek initiated a multi-year, two phase study effort. The goal of the study was to develop a methodology for public sector investment analysis. The methodology needed to be able to analyze ITS investments and to produce case-study based estimates of the relative benefits of ITS infrastructure investments versus conventional transportation investments. A secondary goal of the study was to identify areas where improved methods or tools are needed for this type of analysis.

This study was conducted in two phases with the overall objective of both phases being to identify how best to incorporate ITS into the transportation planning process. The phase 1 analysis involved a look at the current process of prioritization of projects addressing many different transportation problems and needs across a region, such as those reflected in the Transportation Improvement Program (TIP) approval process. These results have previously been published (*Incorporating ITS into Planning: Phase 1 Final Report*, USDOT, FHWA-JPO, Washington, DC, September 1997).

The phase 2 analysis focused on the development and evaluation of alternative solutions to a given transportation problem that, depending upon evaluation results, could then be incorporated into the Transportation Plan and eventually the TIP. An example of this type of analysis is the approach taken when conducting a Major Investment Study (MIS). Although this second type of analysis is the focus of this report, methodologies utilizing cost and benefit information have been developed that are of value in both types of analyses. Phase 2 of the study started in July 1996 and selected the Seattle area to develop

specific methodologies for the evaluation of project alternatives in the context of a MIS. The results of this phase are the focus of this report.

Case Study Approach

Rather than relying on a hypothetical transportation network and problem statement, Mitretek took the approach of conducting a case study. Specifically, we selected a sub-region or corridor in the Seattle area that would be suitable for analysis, i.e., where alternate solutions to a particular transportation problem can be developed, and where a variety of ITS strategies are applicable. For illustration, if the problem to be addressed is effects from congestion along an urban corridor, the list of alternative solutions might include "do-nothing", construct a new road, add lanes to existing routes, provide HOV lanes, provide ramp metering, provide incident management systems, add bus or light rail service, as well as combinations of these listed capabilities. In this study ITS services were analyzed both separately and in combination with conventional construction options.

The alternative solutions were examined in detail, in close coordination with a local transportation consulting firm with which Mitretek contracted to support the study (specifically, the team of Parsons Brinckerhoff Quade Douglas and CH2MHill). The study team developed an analysis methodology to adapt and extend conventional transportation improvement modeling and impact analyses. The resulting methodology is designed to be more sensitive to the impacts of the selected ITS strategies and to provide for comparability across the evaluated alternatives. The analysis methodology developed and its results were reviewed with planning staff in the region at various points in the study to assess appropriateness and usefulness.

Scope

For the purposes of this study, it was assumed that a MIS type effort was needed as part of the normal transportation planning process to assess specific alternatives to solve a specific transportation problem in the Seattle area. The geographic scope of the study is a large corridor or sub-area of the transportation network. This geographic context, which parallels that called out in MIS guidance, allows for a variety of transportation alternatives to be considered and evaluated, without being so broad as to dilute the evaluation process with an intractable number of potential alternatives.

The range of transportation improvement projects considered in the study included construction of new roads or lane miles, conventional signal installations, transit improvements, Transportation Demand Management measures, Advanced Traveler Information Systems, Advanced Traffic Management Systems, and Advanced Public Transportation Systems. The study scope did not include Automated Highway Systems or Commercial Vehicle Operations.

The scope of the study does include the identification of a study area, the definition of alternatives to be considered, the development of specific analysis approaches, and the results from applying these analysis approaches. In our case we chose to evaluate several

traditional transportation build alternatives in the corridor, with and without ITS components. Simulation modeling and other analytical techniques were applied to these selected cases to quantify benefits and assess the alternatives against a common set of measures of effectiveness (MOE's).

To support the decisions that must be made within the planning process, a wide variety of analytical techniques are used to provide estimates of the potential transportation impacts and costs of alternative investment strategies. Analysis techniques differ in level of detail and effort required to use them at different stages in the planning process (translating to the amount of resources required). While all of these techniques are important and are often used in combination in a conducting a planning study, this study focuses on the analysis requirements of a corridor level planning study and makes extensive use of both planning and simulation models.

Since this is a federally sponsored study providing guidance for transportation planners in metropolitan regions, the specific alternatives assessed are not tied to "actual" Seattle decisions. The study has a wider scope than the actual Seattle situation and considered alternatives beyond those that might be supported in the Seattle environment.

Study Corridor Description

The Seattle I-5 North Corridor was selected for the case study. (See Figure ES-1) The North Corridor contains the two primary continuous north-south routes into the Seattle Central Business District (CBD), I-5 and State Route (SR) 99. The dominant traffic flow direction is associated with commuting to and from the Seattle CBD and the areas immediately south. However, these two routes also carry the significant contra-flow traffic to Boeing-Everett and other points north of the Seattle CBD. These routes provide the only high capacity access of the six routes crossing the Ship Canal, the waterway that bisects Seattle west of Lake Washington. The I-5 North Corridor becomes a bottleneck to mobility for Seattle's topographically constrained regional travel. Significant highway capacity increases through construction are unlikely in the densely developed areas extending north from the CBD and across the Ship Canal. The diversity of modes and facility types in the study corridor promotes the idea of using ITS operational approaches.

In keeping with an MIS approach, a general problem statement is formulated to guide the identification of alternatives, including ITS, and the measures of effectiveness for the case study. The problem statement for the I-5 North Corridor is "Develop and evaluate alternatives to reduce congestion and improve mobility along the North Corridor extending from the Seattle CBD north to SR 526."

In all, six alternatives including a baseline were analyzed for the target year of 2020. (See Figure ES-2) The ITS Rich alternative contains significant improvements in advanced traveler information services (ATIS), advanced traffic management systems (ATMS) surveillance and signal coordination enhancements, transit priority, and incident management. Two traditional construction alternatives were also defined: major improvements to a single-occupancy vehicle (SOV) expressway and a set of high-occupancy vehicle (HOV) plus busway improvements. These were analyzed alone and in combination with the same package of ITS Rich improvements. For each alternative a

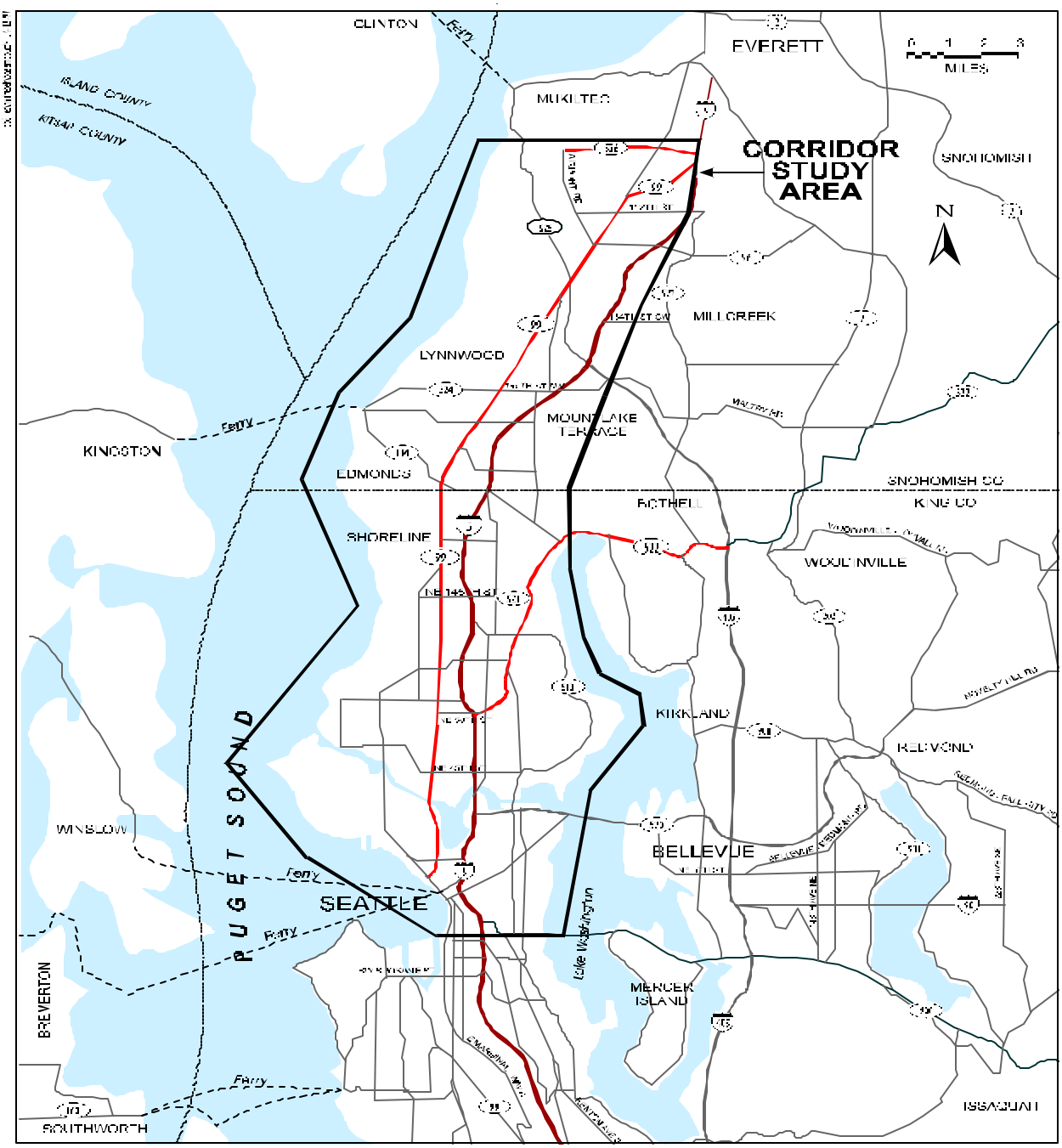


Figure ES-1. Detailed Analysis Area for the North Corridor

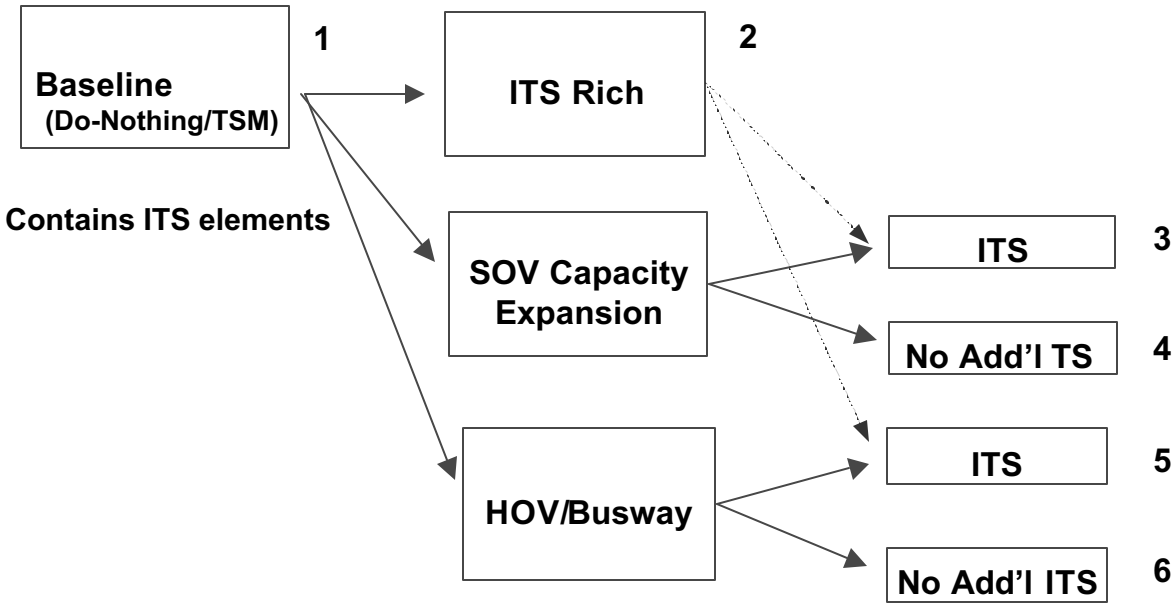


Figure ES-2. Description of Alternatives

number of measures of effectiveness were calculated. All alternatives were compared to a Baseline (Do-Nothing/TSM). The dotted line leading from the ITS Rich alternative indicates that the other ITS enhancements are derived from it, but each has been tailored to complement the specific build option.

Overview of PRUEVIIN

The Process for Regional Understanding and EValuation of Integrated ITS Networks (PRUEVIIN*)* was developed and applied as part of this study. PRUEVIIN is a two-level hierarchical modeling system for assessing the impacts of ITS at the regional and corridor scale. (See Figure ES-3) At the higher (regional) level, the analysis of overall travel patterns and the system's response to average/expected conditions is analyzed using a traditional regional planning model. Output from this analysis is then fed into a more detailed sub-area simulation model capable of modeling time-varying conditions and demands, as well as individual vehicle-level capabilities and routing decisions. At this level, the detailed traffic operations, queuing, and buildup/dispersion of demand are captured, as well as the real-time response of travelers to information. Feedback is then carried out to ensure that the impacts to expected conditions, estimated in the sub-area model, are reflected in the regional analysis. In theory, one could model the entire region using only a simulation model, but this is not yet practical for desktop PCs and current software. The EMME/2 planning model (macro scale) was used for the regional planning model, and INTEGRATION 1.5 (meso scale) for the detailed simulation model. One of

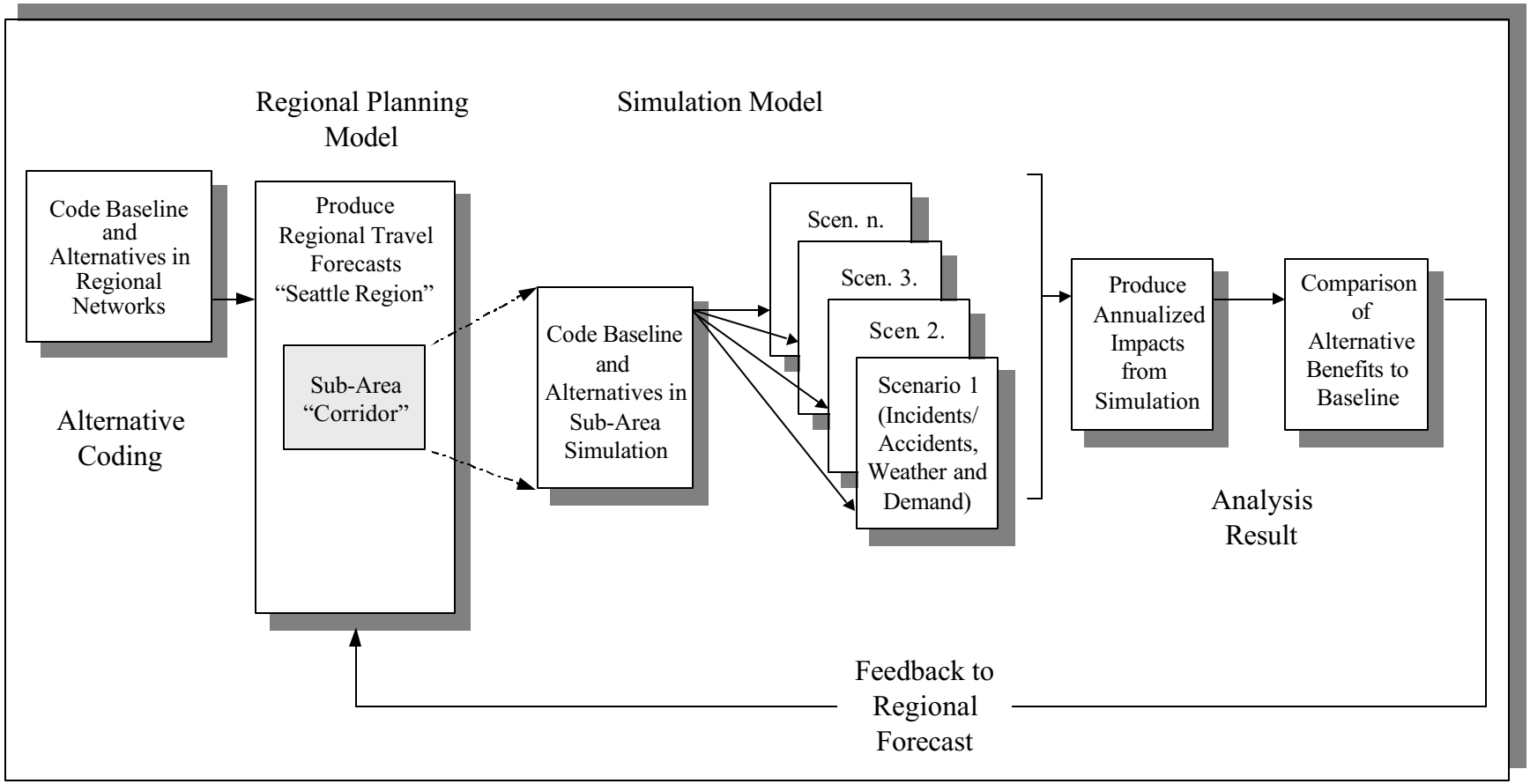


Figure ES-3. Analysis Methodology Overview

the challenges in the study was to develop expertise in mapping both the inputs and analysis results between the two modeling levels. The modeling system contains several pre- and post-processors that manage the interfaces between the models and generate results from model output data. A unique approach is taken to account for the variability in the transportation system. The weather, travel demand, and accident/incident rate variation are analyzed for the corridor over a period of time. A set of representative-day scenarios is developed that, when appropriately weighted, can be used to represent an entire year. This step requires a trade-off between adequately capturing the variability in these multiple parameters and still keeping the number of scenarios to a manageable level.

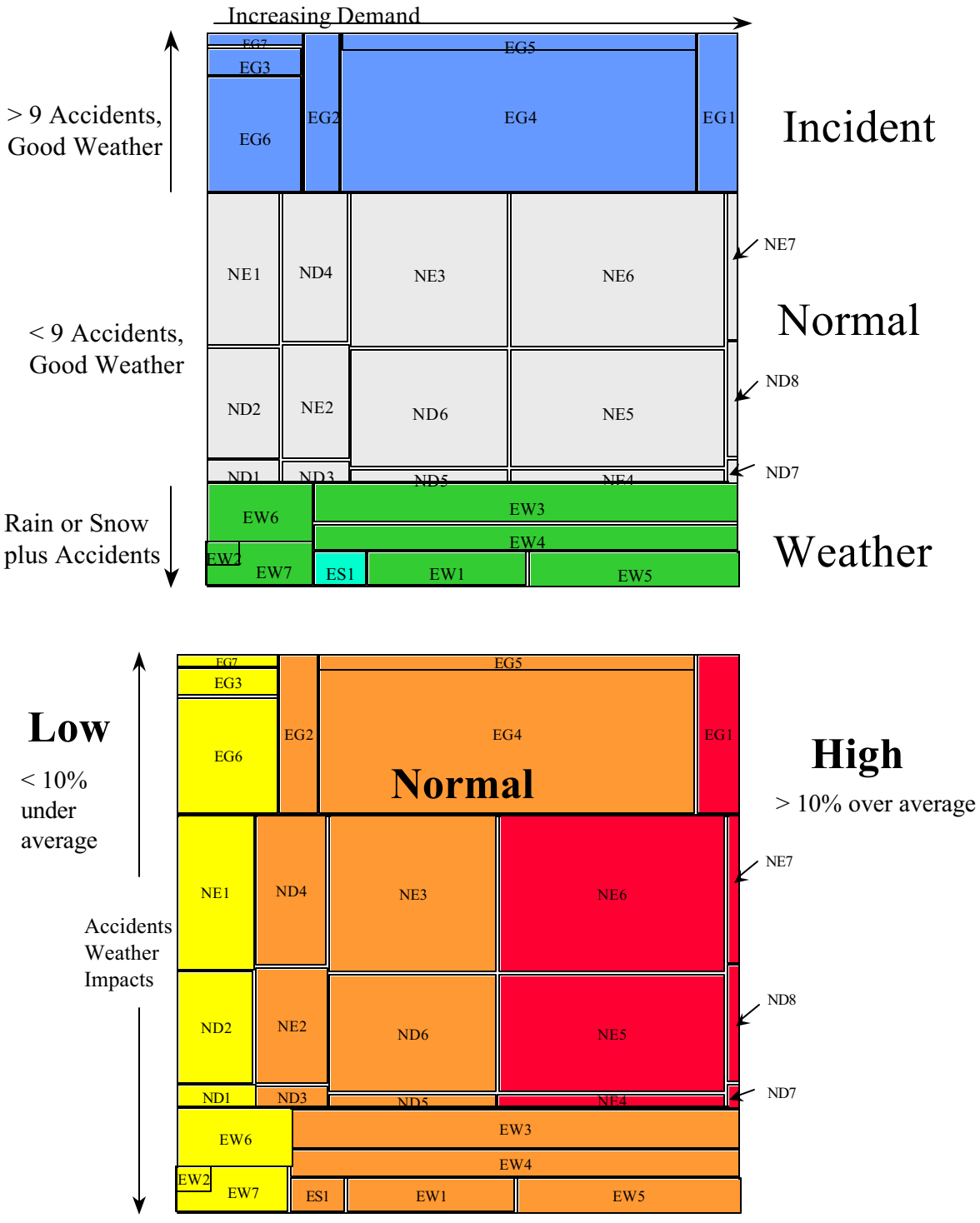
The analysis process starts by building both the planning and simulation networks. In this study the approved Puget Sound Regional Council (PSRC) 1990 travel demand modeling process was used. The simulation model for the corridor/sub-area is generated from this base network. A validation process was then conducted to validate that both models were representative of the 1990 time period. Next each alternative is defined and coded in both models for the horizon year, in this case 2020. Each alternative is first run in the planning model and the appropriate performance measures generated. From this run a demand table is generated for input to the simulation model. The simulation model is then run for each alternative with this demand and the representative-day scenarios. The appropriate performance measures are generated for each scenario and then annualized across all scenarios. Adjustments (feedback) between the two models are then made to ensure that the benefits generated in the corridor are properly reflected in the region.

Key Alternative Analysis Results

In order to understand the presentation of the results from the alternatives analysis, a further explanation of the concept of representative-day scenarios and the specific measures of effectiveness used in this study is required. Although these two concepts were initially presented in the discussion of key accomplishments, the next two sections provide a broader description, along with a few examples.

Representative-Day Scenario Example

To account for the system variability, two years of travel demand, weather, and accident/incident data in the corridor were analyzed. Using cluster analysis and other statistical techniques, 30 separate representative-day scenarios were developed to reflect these conditions. Figures ES-4 and –5 depict these scenarios. Note that each scenario constitutes a combination of weather, accidents/incidents and travel demand. The size of the box represents the frequency of occurrence of the scenario during the year. For example, using the two figures in combination indicates that scenario NE3 is a non-event (no major incident), normal weather, and normal demand scenario. Scenario EG1 contains a major incident, under good weather with demand 10% greater than average. The scenarios are arranged in such a manner that those with extreme conditions are at the edges of the figure (i.e. top, bottom and right-hand edge).


Increasing Demand
> 9 Accidents, Good Weather
< 9 Accidents, Good Weather
Rain or Snow plus Accidents
Incident
Normal
Weather
EG7
EG3
EG6
EG2
EG5
EG4
EG1
NE1
ND4
NE3
NE6
NE7
ND2
NE2
ND6
NE5
ND8
ND1
ND3
ND5
NE4
ND7
EW6
EW3
EW4
EW2
EW7
ES1
EW1
EW5
Low
< 10% under average
Accidents Weather Impacts
Normal
High
> 10% over average

We use this arrangement of scenarios to present the measures of effectiveness results for each run of the alternative. Our results confirm the hypothesis that ITS is most beneficial when conditions deviate from the norm. (i.e. those scenarios at the edge). The highest levels of benefits occur for a number of measures of effectiveness studied in conditions of above average demand and major incidents. In these cases, the information on alternate routes, and the ability of the signal systems to respond to changing conditions provide the highest level of benefits to the most travelers. This will be further illustrated when the results are presented.

Measures of Effectiveness

During the study we discovered that additional measures of effectiveness were needed to properly represent the impact of ITS. A key phase in any MIS is the development of the measures that are used to evaluate the alternatives under study and that reflect the issues/concerns of those in the community making the decision. Typically, measures of transportation service, costs, mobility and system performance, financial burden, and environmental/community impacts are considered. These measures, however, are usually only calculated based upon the average weekday or expected conditions. Variation in conditions (e.g. travel demand, weather, accidents) and the transportation system's response to them is not part of the analysis and consequently does not enter into the decision process. However, incorporating variation in conditions is key to showing the benefits of ITS and other strategies focused on improving the operation of the system. Accordingly, in the study, several new measures were developed that are more representative of the impacts of ITS. *Delay reduction* is calculated as the difference between the travel time in each scenario and free-flow (30% of average demand, no accidents in the system, good weather) travel times. *Throughput* measures the number trips starting in the time frame that can finish before the end of the peak period at 9:30 AM. Delay reduction and throughput measures are calculated for each scenario. An annualized figure is then calculated by computing a weighted average of across all scenarios. System *coefficient of trip time variation* is calculated by examining the variability of travel for similar trips in the system taken across all scenarios. This statistic is an indicator of the reliability of travel in the corridor. Speed and stops across the network are archived from each run from the whole AM peak period. Speed profiles are then normalized by total vehicle-kilometers of travel in the system to create the statistic *percentage of vehicle-kilometers of travel by speed range.* A similar technique is applied to stops estimated by the simulation at a link level every 15 minutes producing an *expected number of stops per vehicle-kilometer of travel*.

Pair-wise Results

The Alternatives Evaluation section of the report contains a series of summary and detailed tables that provide a pair-wise comparison of alternatives. The summary tables provide descriptive information while the detailed tables provide the full range of both regional and sub-area MOE's. The specific set of comparisons provided in the report are indicated in Table ES-1.

Table ES-1. Alternatives Comparison Overview

Section	Pair-wise Comparison	
9.1 and 9.2	Baseline vs. Validation Network	ITS Rich vs. Baseline
9.1 and 9.3	SOV vs. Baseline	SOV vs. SOV + ITS
9.1 and 9.4	HOV vs. Baseline	HOV vs. HOV +ITS

The following paragraphs will discuss some of the results from one of these comparisons, the SOV alternative.

SR99, which parallels I-5, is both an undivided arterial and a limited access freeway. Under the SOV Capacity Enhancement alternative, a significant portion of SR99 near the Seattle CBD is converted into a limited access expressway. Table ES-2 summarizes the SOV Capacity Enhancement alternative without and with ITS improvements. These alternatives are characterized with respect to the 2020 Do-Nothing/TSM (Baseline) alternative. The SOV alternative is characterized at the regional level as providing faster travel times, particularly for trips that utilize the upgraded SR99 facility. At the sub-area level, the upgraded SR99 facility demonstrates susceptibility to congestion under weather or heavy demand cases. The result is that an expected improvement in annualized throughput and travel time is not realized. The SOV + ITS alternative mitigates to some degree the congestion conditions along SR99 under poor weather and heavy demand conditions, and provides a significant increase in annual sub-area throughput. At the regional level, the ITS improvements increase total trip length and bring additional demand into the sub-area.

The predominant trends at the regional level resulting from ITS enhancements to the sub-area, are relatively small in magnitude given that the sub-area where ITS implementation is proposed is a small subset of the region as a whole. Impacts on trips traversing the sub-area, however, are significant. Regional trends from implementing ITS, given the SOV enhancements, include a shift from auto modes to transit (0.73%), an increase in sub-area vehicle trips (0.72%), a decrease in regional vehicle trips (-0.30%), and an overall shift toward longer trips.

Some specific annualized MOE's drawn from the simulation sub-area analysis are provided in Table ES-3. Impacts of the SOV + ITS alternative are illustrated as *delay reductions* with respect to the SOV Capacity Expansion alternative. On an annualized basis, average traveler delay is reduced by 2.2 minutes per traveler per day, from 13.86 to 11.65 minutes per traveler per day. On an annualized basis, *throughput* in the SOV + ITS alternative increases to 185,565 vehicles per AM peak period (6:15 – 8:30 AM trip starts) from 168,338 vehicles. This increase of roughly 13,223 vehicles per peak period represents an increase in throughput of 10.2%. The coefficient of trip-time variation in the SOV alternative is 0.39. Applying this to a trip with an expected duration of

Table ES-2. Alternatives Comparison Summaries: SOV without ITS vs. SOV with ITS

2020 Alternative Comparison Implications SOV Capacity Expansion With ITS versus Without ITS		
Measure of Effectiveness	Impact of SOV WO ITS from NoBuild/TSM (Base)	Impact of SOV W ITS from SOV WO ITS (ITS Alt.)
Alternative Summary		
Regional Travel: Trips, Mode Choice, Times, and Miles Traveled		
Daily Travel		
	Overall daily person trips remain the same Shift to walk to transit trips within/from the corridor, but drop in long distance transit Park&Ride Drop in trips within study area and increase in trips to/from the subarea especially to CBD Increase in Daily V	Overall daily person trips remain the same Increase in transit person trips (slightly less than ITSRICH increase), and concomittant drop in vehicle trips Further reduction in within subarea trips and increase in trips to/from subarea. Additional increase
AM Peak Period Travel		
AM Travel	Similar patterns as found in daily travel Slight shift in overall transit results from higher walk-to-transit and drop in longer drive-to-transit Much faster travel in SR-99 corridor causes overall decrease in travel times	Similar patterns as found in daily travel Increase in transit trips but again slightly less than seen in ITSRICH Overall increase in travel conditions seen by slightly longer trips in transit and vehicle trips, and improved times, speeds
Subarea Trips	Significant increase in vehicle trips to/from/through the subarea due to diversion to SR-99 Improvements in SR-99 cause increase in subarea average speeds	Additional vehicle trips diverted to the corridor are the greatest of any alternattive Slight improvement in congested speeds due to more reliable system
Sub Area Impacts: Delay Reduction, Reliability, and Level of Service		
AM Peak Period Travel		
	Higher system demand Significant increase in travel time variability Throughput increase not concomitant with demand increase	Significant improvements in travel time variability and system throughput Changes particularly signficiant in weather or high demand scenarios
Capital & Operating Costs		
	Cost drivers are: Conversion of 14 miles of urban arterial to urban expressway Construction of nine new urban expressway interchanges Construction of nine new grade separated arterial crossings of the expressway	Capital costs to implement same elements as in ITS Rich slightly higher than for baseline due to increases in communications and traffic management costs.
Environmental Impacts		
	Likely marginally worse: increase in high-speed stops	Likely positive: many fewer high-speed stops

Table ES-3. Selected Sub-area Impacts: SOV vs. SOV + ITS

Measure per Average AM Peak Period, North Corridor Sub-area	SOV	SOV + ITS	Change	% Change
Delay Per Vehicle Trip (min)	13.86	11.65	-2.21	-15.9%
Vehicle Throughput (finished trips)	168,336	185,565	+17,227	+10.2%
Coefficient of Trip Time Variation	.39	.30	-0.10	-24.5%

60 minutes (normally distributed), a traveler would have to budget just over 99 minutes to arrive at the trip destination on-time 95% of the time. In the SOV + ITS case, the coefficient of trip-time variation is reduced to 0.30. Under the constraints of our example one-hour trip, the same traveler would have to budget 89 minutes to arrive at the trip destination on-time 95% of the time.

Figure ES-6 illustrates the conditions where the addition of ITS was most effective in terms of absolute minutes of delay saved per traveler. The largest delay reduction occurs in scenarios with incidents on SR99 (EG2) or I-5 (EG1), heavy demand scenarios (NE4, NE5, NE7, ND7, ND8), and weather/accident combination scenarios (ES1 and EW4).

The reason for ITS having a large impact in this case is that the SOV Capacity expansion alternative and the upgrade SR99 expressway facility can each be characterized as having "brittle" performance. When travel demand is close to average conditions or lighter than average and weather conditions are clear, the new SR99 expressway facility efficiently handles traffic along its length, both in terms of through movements and traffic exiting at grade-separated interchanges with the adjacent arterial grid. Travel times in these cases are improved for trips that typically use SR99. When the travel demand is high or capacity is reduced from weather impact, the upgraded SR99 facility's performance breaks down to a point that travel times actually exceed those associated with the pre-upgrade signalized arterial facility.

SR99 Expressway breakdown is a function of the narrow right-of-way accorded the new facility. The number of opportunities to exit the upgraded SR99 expressway facility and access the adjacent arterial grid are reduced since only a subset of the signalized intersections along its length have been converted to grade-separated interchanges. This results in high off-ramp utilization along SR99. Reliance on these off-ramps becomes problematic because they are relatively short and end with signals. These short ramps cannot hold many vehicles attempting to exit SR99, and if signal controllers at their terminus are set to relative long cycles, then we see periodic queue spillback into the expressway facility. The simulation model accurately reacts by severely crimping expressway carrying capacity when this condition occurs, resulting in backups in the SR99 expressway mainline. These periodic breakdown become persistent breakdown conditions when travel demand is high or under poor weather scenarios.

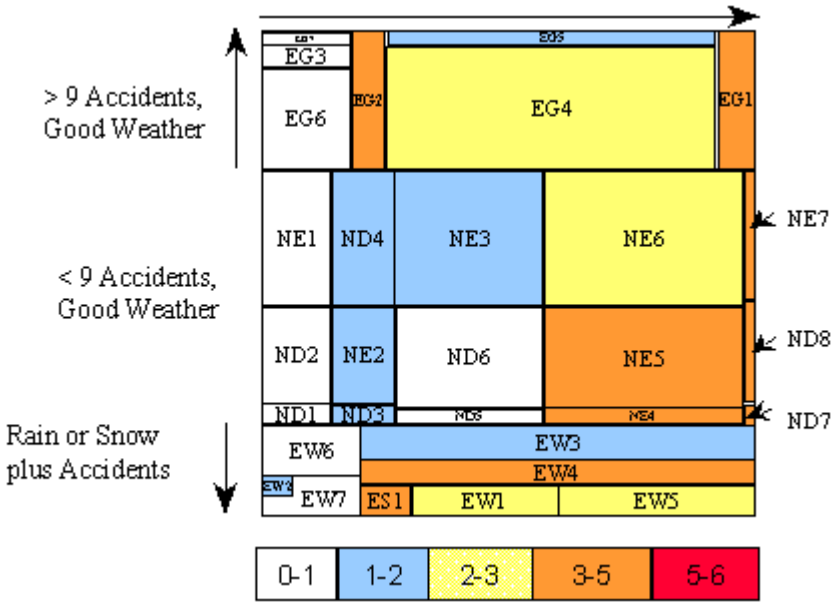


Figure ES-6. Minutes of Delay Reduction: SOV + ITS vs. SOV

ATMS control as implemented in the SOV + ITS alternative helps to mitigate the impact of SR99 breakdown. In these cases the adaptive signal control system senses the queue buildup on the off-ramp and extends the ramp's green phase to flush vehicles off of the ramp/mainline and onto the arterial grid. The minor arterials see worsened service as the green phase for the off-ramp is progressively extended, but from a system perspective, keeping the SR99 mainline from breaking down is the most critical factor in reducing overall delay.

Similar results are provided in section 9.0 of the report for the comparison of the ITS Rich alternative to the Baseline, and the comparison of the HOV/Busway alternative with and without ITS to the Baseline. Also, in this section detailed results for all the MOE's are provided.

Observations on Alternatives Analysis Results

Key attributes of how an alternative might perform under expected travel conditions (such as the brittleness of the SOV alternative) could not have been predicted using only the regional model. Under normal conditions, the SOV alternative appears to have ample capacity at the SR99 interchanges. Since the regional model does not consider the periodic queue growth from traffic signals or spillback, a breakdown along SR99 does not occur. Clearly there are non-ITS solutions to the off-ramp problem: wider right of way at interchanges, revised interchange design, more interchanges, etc. However, it is likely that *these issues would not have been addressed until the engineering design phase of the alternative*. Knowing at the planning phase that the new SOV facility had this performance characteristic is a critical element to either tailoring the alternative definition or in the comparison of alternatives.

Potential Next Steps

The goal of the study was to develop and demonstrate the use of a new methodology for incorporating ITS into the transportation planning process. We feel that the methodology developed (PRUEVIIN) and the alternatives-analysis results contained in this report met this goal. The ITS cost and benefit results provided herein are a significant addition to the store of ITS knowledge. The PRUEVIIN methodology and the study results have been presented at several conferences and at the *Workshop on Methods to Model ITS Impacts* during the 78th Annual Transportation Research Board (TRB) Meeting.

There are several next steps for further use of this report and analyses using this methodology, each of which is discussed below. These include conversion of this report into more of a user-guidance document, development of a training course to teach the methodology, and the direct application of the methodology to an ongoing MIS.

This report documents a three-year analytical effort. It provides richly detailed documentation on methodology, and ITS cost and benefit results. However, it has some limitations. The document is written as a report on the results of a study effort. It is not written in the form of a users manual, providing comprehensive, ordered, guidance to a transportation planner who is interested in the implementation of this methodology to achieve similar results in his/her region. In addition this process was implemented in only one location (Seattle, Washington), and with only one planning model (EMME/2) and one simulation model (INTEGRATION 1.5). The set of ITS Rich technologies was also fixed for the study. In addition, this study was done with the knowledge of and cooperation of PSRC, the local Metropolitan Planning Organization (MPO). They participated at the front-end of the study and reviewed the results at the end of the study. However, they were not involved in the actual execution of the study or in the refinement of the alternatives as the study progressed. The study is for a "shadow MIS," not an actual MIS. We followed the MIS approach in terms of alternatives development, definition and impact measures, but were not constrained by the need for public hearings and review of alternatives.

With these facts in mind, Mitretek recommends that the best way for transportation professionals to learn this methodology would be for them to receive some hands-on training. This could be achieved by having an organization that is knowledgeable in the PRUEVIIN methodology to act as technical advisor to actually add a sub-area simulation as described in this study to an ongoing MIS. This would accomplish several objectives including: the individual staff at the transportation agency would have first-hand experience with using the process, the process would be left in-place at the agency for further studies, and the training organization would then be in a good position to write a user-guidance document for the methodology. In addition, additional knowledge would be gained by applying this process in a new environment, i.e. different problem set, alternatives, and models.

An additional approach would be for Mitretek to work with the ITS JPO to develop one or more training courses for the process. Mitretek would develop and give the course for the first several iterations. This will allow us to refine and tailor the presentation material to the transportation professionals in the various transportation agencies. Afterwards the course would be turned over to a professional training organization for wider audience presentation.