Modeling and Simulation Workshop

78th TRB Annual Meeting

Introduction by

David Zavattero

Chicago Area Transportation Study (CATS)

9 January 1999

Workshop Goals

(Mac Lister, ITS-JPO)

- Present a number of approaches that are being developed by the ITS Joint Program Office (JPO) of FHWA to assess the impacts of ITS deployment
- Provide a context for each of these approaches to help the transportation practitioner select the most appropriate approach
- Provide a detailed discussion of each approach
- Gather feedback on how to improve these techniques to best support the needs of the transportation community
- Identify a community of practitioners and experts that have an interest in these techniques to continue this dialogue

Background

- The nature and complexity of the services and associated benefits provided by ITS deployments requires a broad range of approaches for evaluation
- Modeling is a useful tool to deal with these complexities and to address the wide range of variables in the transportation system
- Modeling allows a number of alternative services to be assessed without the cost of actual implementation
- Over the years the regional travel forecast process and a number of operational models have emerged to address planning and operational issues
- Efforts are now underway to provide tools that will enable the estimation of ITS benefits on a corridor and regional scale

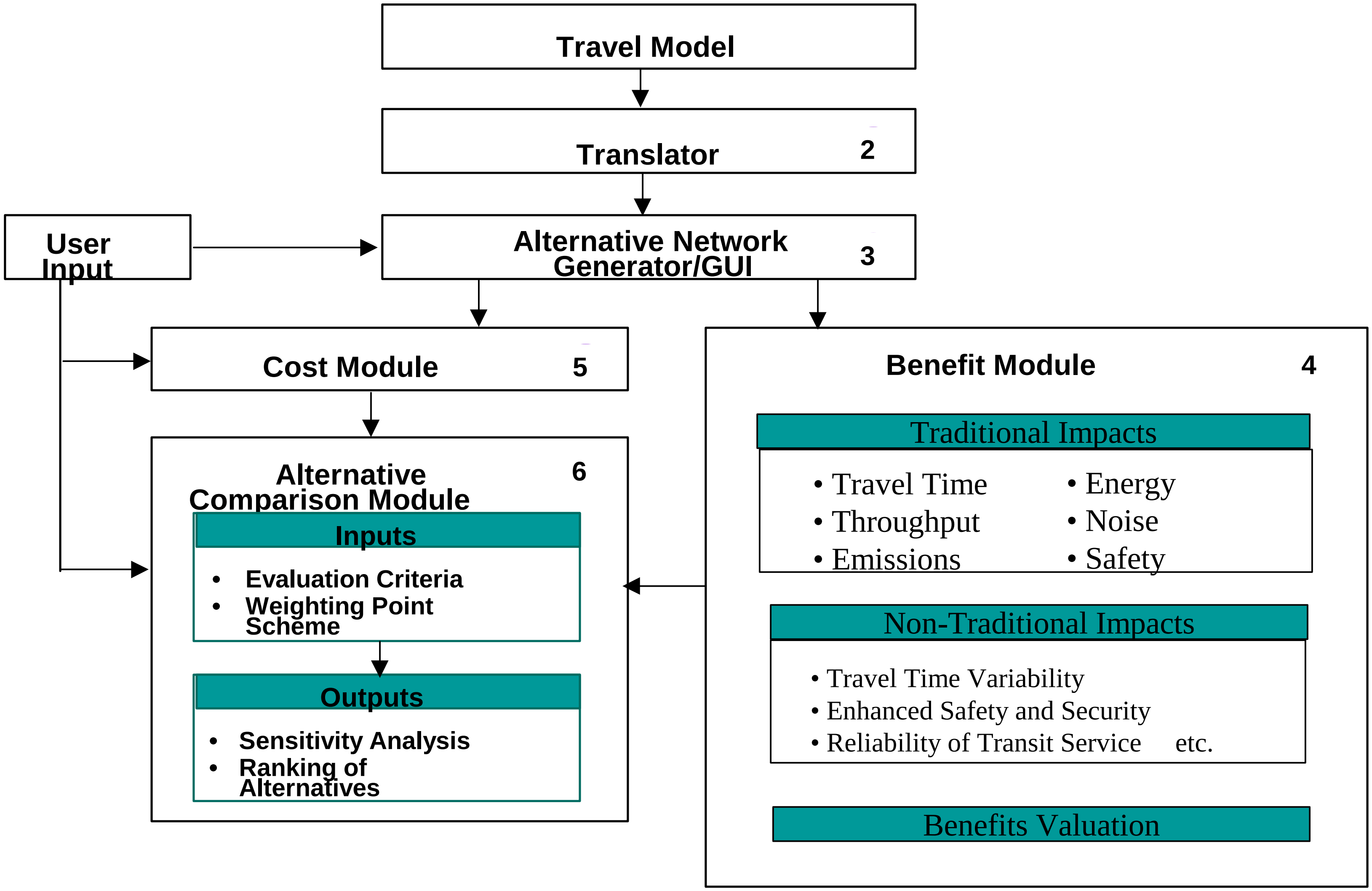
The Suite of ITS Analysis Tools

- The suite of tools under development are:
  - ITS Deployment Assessment System (IDAS); JPO sponsor
  - Process for Regional Understanding and EValuation of Integrated ITS Networks (PRUEVIIN); JPO sponsor
  - The Transportation and Analysis Simulation System (TRANSIMS); DOT, EPA, and JPO (ITS) sponsors
- For the assessment of ITS benefits and costs these tools:
  - operate at different problem scales (ITS sketch planning, macro, micro, etc.)
  - have a number of common elements
  - are programmatically coordinated and interrelated
  - support user development of feedback processes
  - require different levels of expertise and resources
  - provide different levels of results

IDAS

- "Evaluates costs and benefits over a broad range of possible ITS alternatives"
- Key characteristics include
  - near-term ITS sketch planning approach
  - uses an extensive database of ITS technologies and benefit/cost estimates based on:
    - national averages
    - field study results
    - modeling efforts
  - uses the regional forecasting process as input
  - low data requirements
  - lower complexity
- Milestones

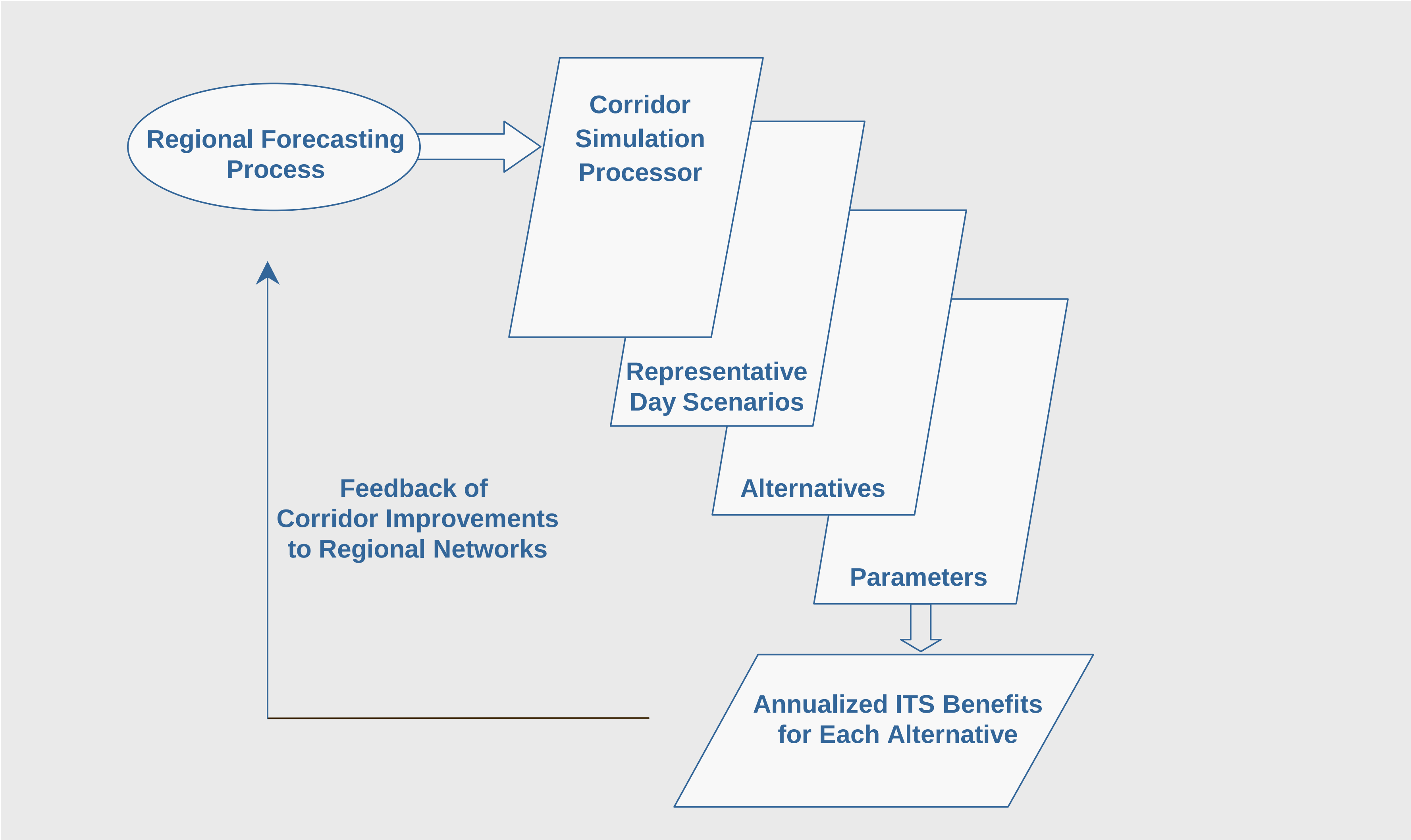
IDAS Overall Structure



PRUEVIIN

- “Assessment of regional and corridor level impacts of ITS improvements in a corridor, along with feedback to the regional planning process”
- Key characteristics include:
  - near-term, large-scale meso, detailed analysis
  - combines the use of the regional forecasting process and simulation modeling to produce a broad range of modal, trip and link based measures of effectiveness
  - uses a set of representative scenarios to address the daily variability in travel demand, weather and incidents
  - modest data requirements
  - moderate complexity
- Milestones

PRUEVIIN Overview



TRANSIMS

- Regionwide Simulation
- Tracks individuals, vehicles, and households
- Needs to represent impacts of integrated ITS systems
- Milestones

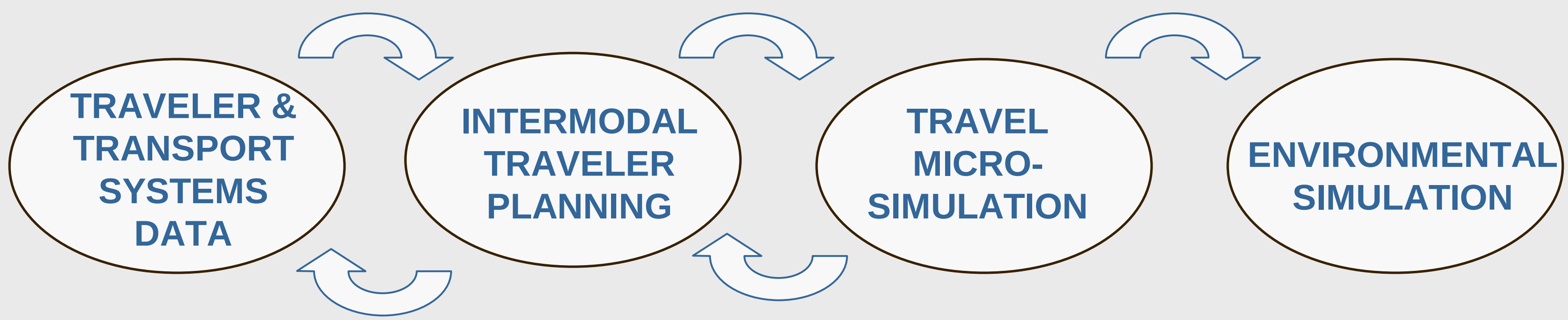
TRANSIMS

FOUR COMPONENTS

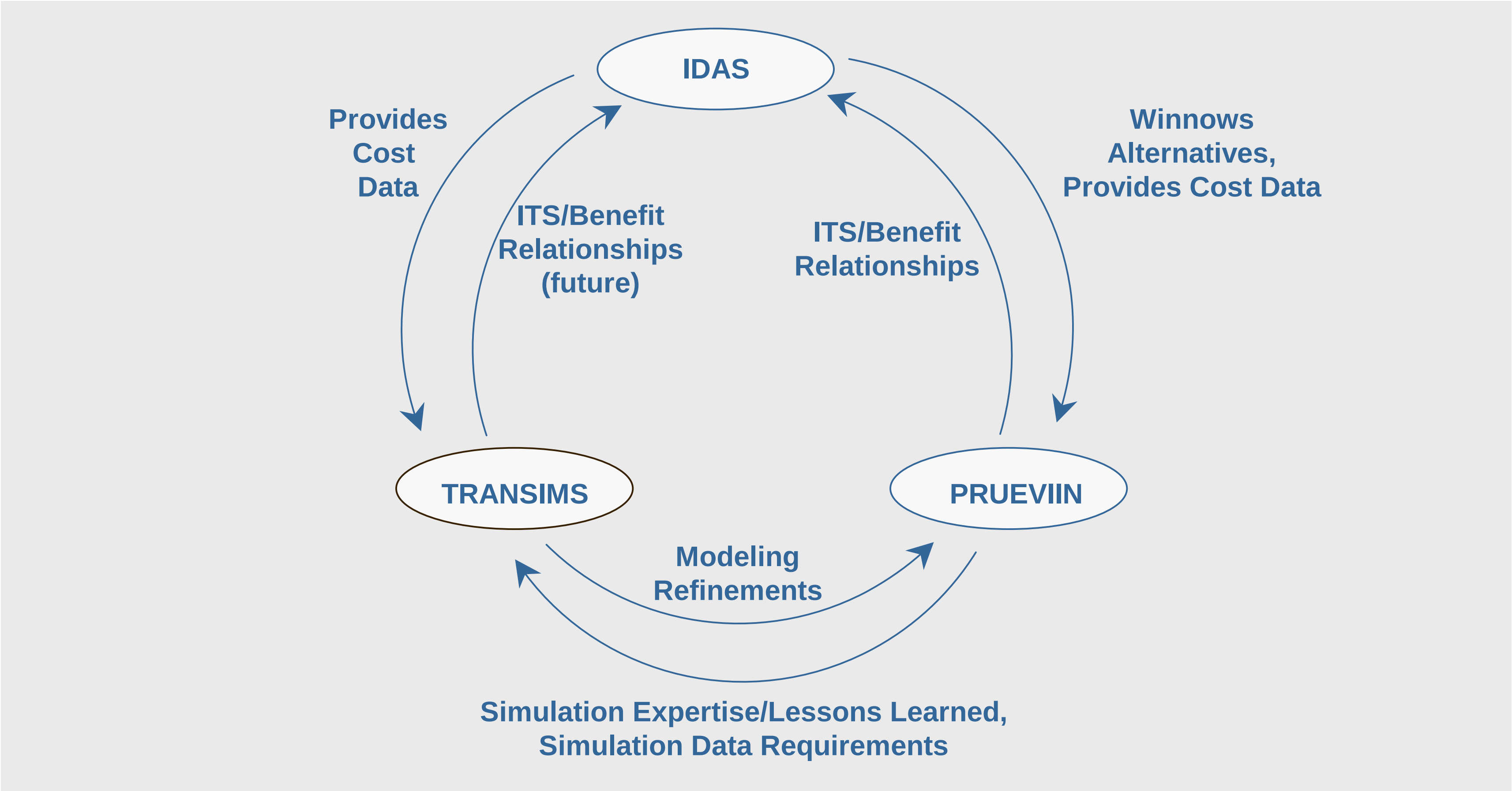
- **Traveler and Transport Systems Data - estimates activity chains to be accomplished by each individual during the course of the day, e.g., home⌫work⌫shop⌫recreation⌫home**
- **Intermodal Travel Planning**
  - **routes individuals and vehicles through the network**
  - **develops methods of accomplishing activities at desired times**
  - **network includes all modes**
- **Travel Microsimulation - Simulates actual network movement**
- **Environmental Simulation - Uses output from microsimulation to estimate emissions**

Feedback between systems data, planning and microsimulation

TRANSIMS


TRAVELER & TRANSPORT SYSTEMS DATA
INTERMODAL TRAVELER PLANNING
TRAVEL MICRO-SIMULATION
ENVIRONMENTAL SIMULATION

Interrelationships



Possible Migration Paths

Today | **Near Term** | ***"Detailed, Least Complex"*** | **Longer-Term**

a. Improve 4-Step

b. 4-Step + IDAS

4-Step +

Ongoing R&D

Operational Simulations

c. 4-Step + PRUEVIIN

d. IDAS + 4-Step + PRUEVIIN

e. IDAS + TRANSIMS (With ITS)

"Detailed, Most Complex"

Process for Regional Understanding and Evaluation of Integrated ITS Networks (PRUEVIIN)

Introduction

9 January 1999

Donald Roberts
Mitretek Systems

Problem Context

- Shifting focus in transportation, with an increasing *emphasis on operations, not just construction*
- Operations, including ITS, provides benefits when conditions differ from the norm
  - *conditions are rarely perfect or average*
- *Traditional assessment tools used by planners can't capture effects of operational enhancements, including ITS*
- Since ITS does not come with an additional source of funding, key question for transportation decision makers is *how ITS compares with other uses of a fixed budget*

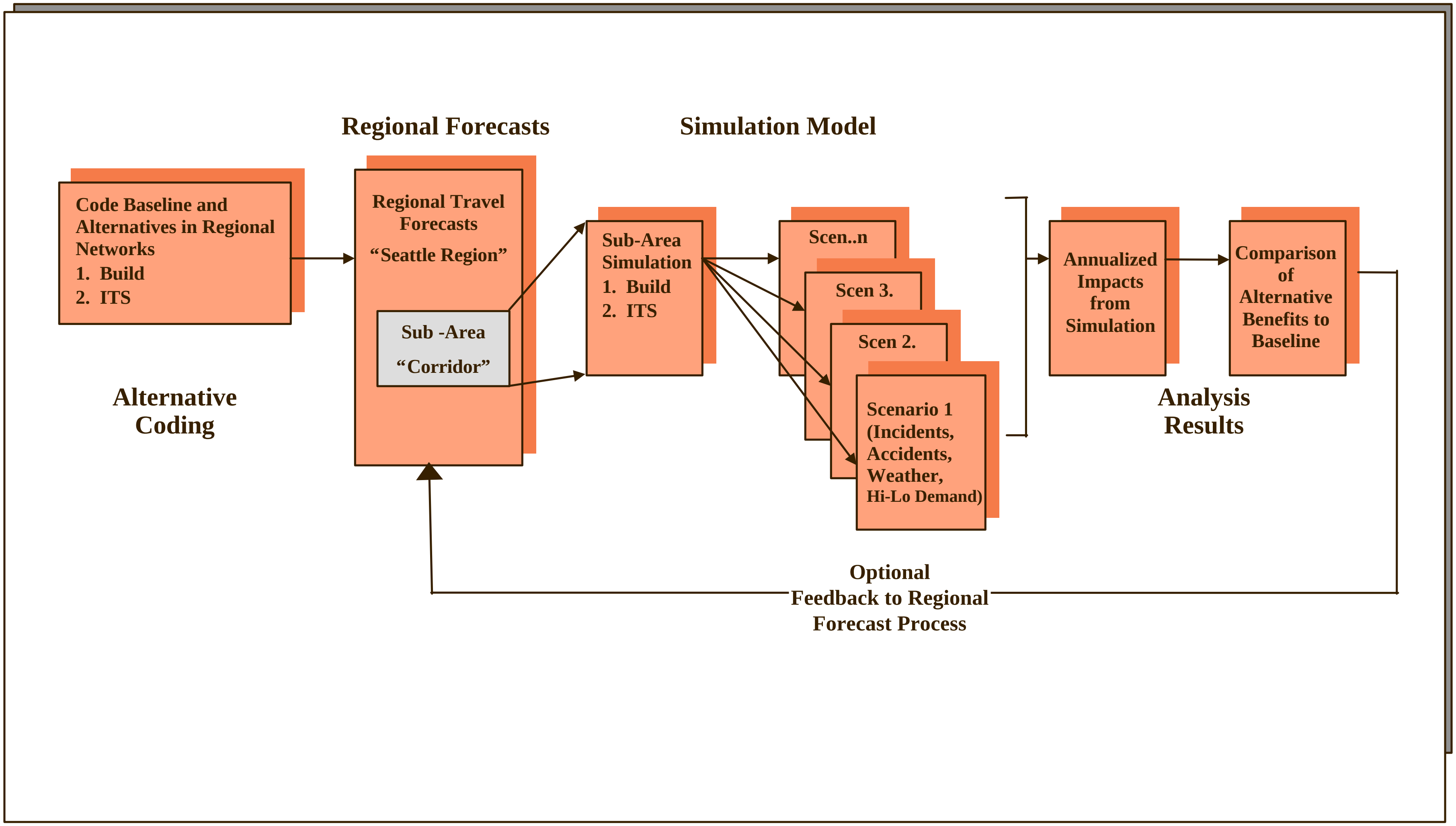
Approach

- Develop a *methodology to assess the benefits of ITS*
  - Conduct a shadow Major Investment Study (MIS) --- scale, real-world alternatives
- Examine benefits of using ITS strategies
  - Alone, in an ITS-rich corridor
  - To enhance other more traditional "modal" alternatives (HOV/Busway, SOV/Expressway, etc.)
- *Produce methods that can be applied today, in the real world, by current transportation professionals*

Description of the Methodology

- ***PRUEVIIN*** **is an analysis methodology containing** ***techniques, programs and data sources designed specifically to assess the benefits of several, integrated ITS services*** **at the corridor level**
- **Provides the ability to add a corridor level simulation to an existing planning model based alternatives assessment at a reasonable costs**
- **Uses** ***existing transportation planning processes, commercial simulation models, and standard windows based PCs*** **combined with Mitretek developed pre- and post processing routines**

PRUEVIIN Methodology Overview



Key Features of the Process

- ***Leverages the existing MPO regional planning model process assets*** **by providing a logical interface to the more detailed simulation model required for ITS evaluation**
- **Ability to *evaluate ITS strategies in combination with traditional transportation improvements at the corridor level* and to assess the *impacts of corridor improvements at the regional level* (feedback to trip distribution in the planning model) for *peak traffic periods***
- **Ability to capture and utilize the day-to-day variation in the transportation system (via *representative-day scenarios*)**
- **New techniques to *calibrate a large-scale simulation model* of the transportation (125 sq. mi., 2,500 links; 350,000 trips in 3.5 hours) system to within-day and between-day variations using actual traffic data**

Key Features (concluded)

- Ability to model the *response of different classes of travelers* (commuters, non-commuters) to a wide *range of information of varying quality* (web-based link travel times, traffic radio broadcasts) about the transportation system
- Ability to differentiate and quantify the *impacts of individual as well as fully integrated ITS services (ATMS, ATIS, IMS, Transit priority, etc.)*
- Ability to *fine tune and explore near-term operational changes* (optimize routing around major construction project) to the transportation system --- “what if” studies

PRUEVIIN Development Status

- Developed as part of the Seattle MIS Case Study
  - *methodology development, set of ITS services*
  - evaluated 5 alternatives (traditional major transportation improvements with and w/o ITS)
  - final report May 99
- MMDI Evaluation (Seattle simulation results)
  - *specific ITS sensitivity studies*
  - alternatives: before/after ITS improvements
  - final report April 99
- Washington Metropolitan Traveler Information Showcase --- Partners in Motion
  - *Supporting George Mason University with application of this methodology to evaluate the project*

Cost to Apply PRUEVIIN

- For MIS in general *$350 - $500k for first round of MIS results*, and *$600k to refine and redo alternatives*. Total cost of MIS when done of about $1,000K
- Cost to *add simulation of alternatives to existing MIS analysis is about $250k to $340k*
- Or alternatively, *additional cost is 25% to 34% of a planned MIS (assumes 5 alternatives)*
- Costs vary as a function of the *size of the network, number/complexity of the alternatives, and availability of data for model calibration*

Cost to Apply PRUEVIIN (concl’d)

- Time budget is approximately
  - 10% scenario development
  - 15% build networks
  - 15% code alternatives
  - *30% calibrate model*
  - 15% execute model
  - 15% analyze results

Analysis Framework Overview & Treatment of Recurrent Conditions

Jim Bunch
Lead Staff: ITS & Planning

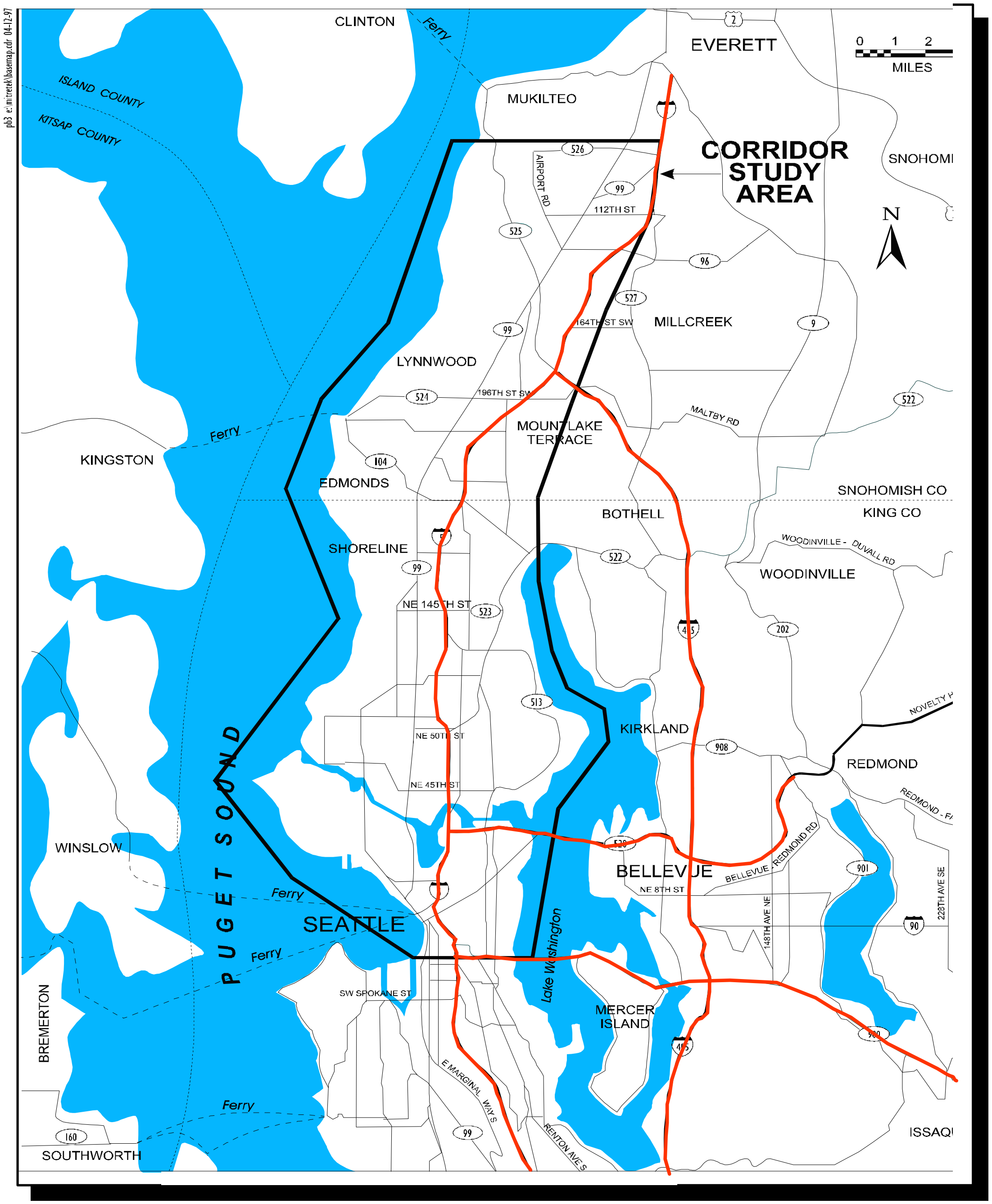
9 January 1999

Analysis Framework Overview & Treatment of Recurrent Conditions

- Seattle Case Study
- PRUEVIIN FRAMEWORK
  - Overview
    - Recurrent Conditions
    - System Variation and Information
  - Regional Model to Subarea Simulation Interface
  - Scenario Development
  - Feedback
  - Measures of Effectiveness
- Treatment of ITS Strategies (Seattle Case Study)
  - ITS Strategies
  - Regional Model Representation

Seattle Case Study
Study Area

- Located Just North of Seattle CBD
- Major Through Commute Corridor to Seattle Activity Centers
- Congestion Problems on I-5 and North-South Arterials
- Availability of Transit and HOV service options
- Good historical and current traffic and incident data availability (esp. I-5)



Seattle Case Study

Detailed Analysis Area

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Case Study Problem Statement

"Develop and evaluate alternatives to alleviate north/south congestion and improve mobility along the North Corridor extending from the Seattle CBD north to SR 526".

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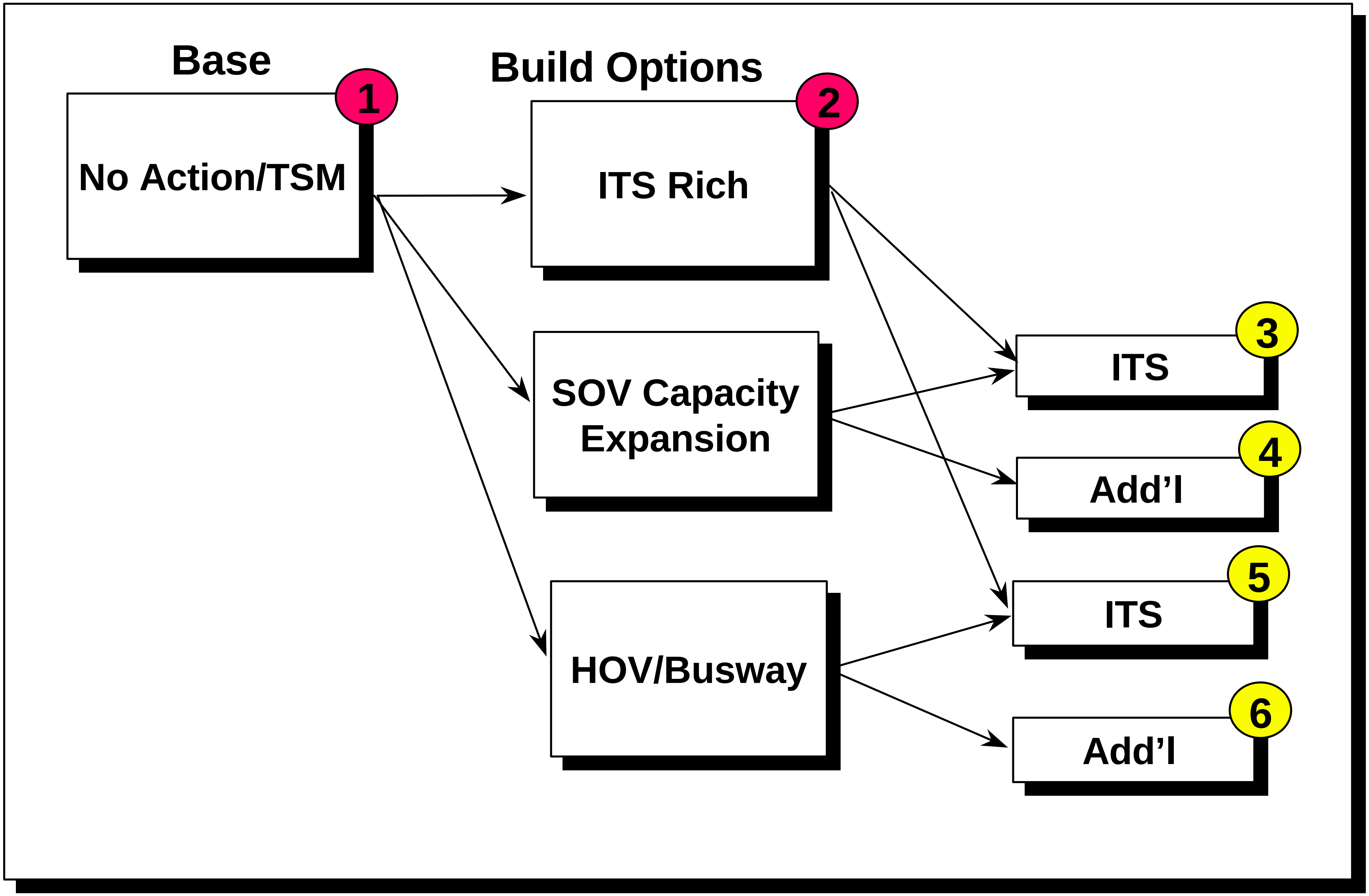
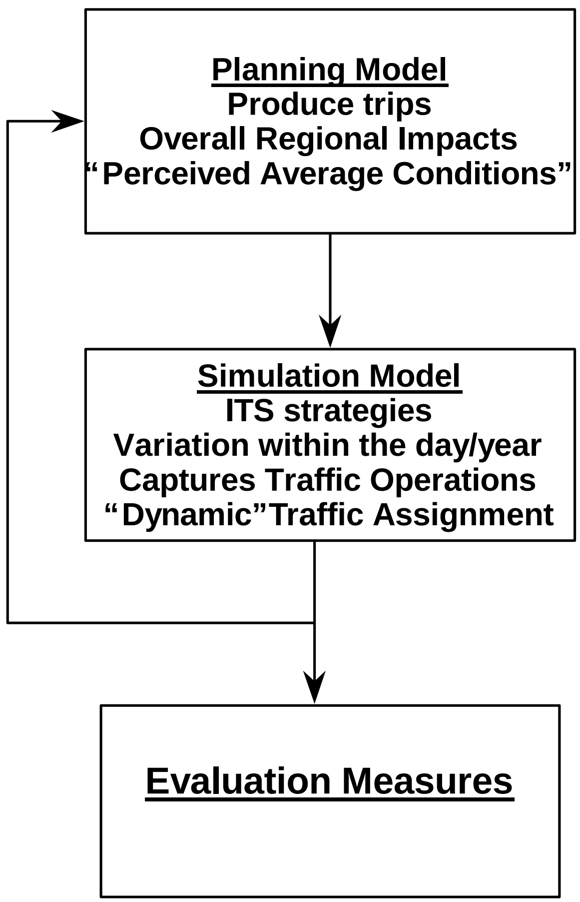
Seattle Case Study Alternatives



PRUEVIIN FRAMEWORK Characteristics of ITS

- ITS strategies use technology, communications, and a “systems” perspective to adjust the system to realized conditions, and are
  - Operations oriented
  - Aimed at events and unusual conditions
  - Information oriented
  - Connected systems

Evaluation Approach



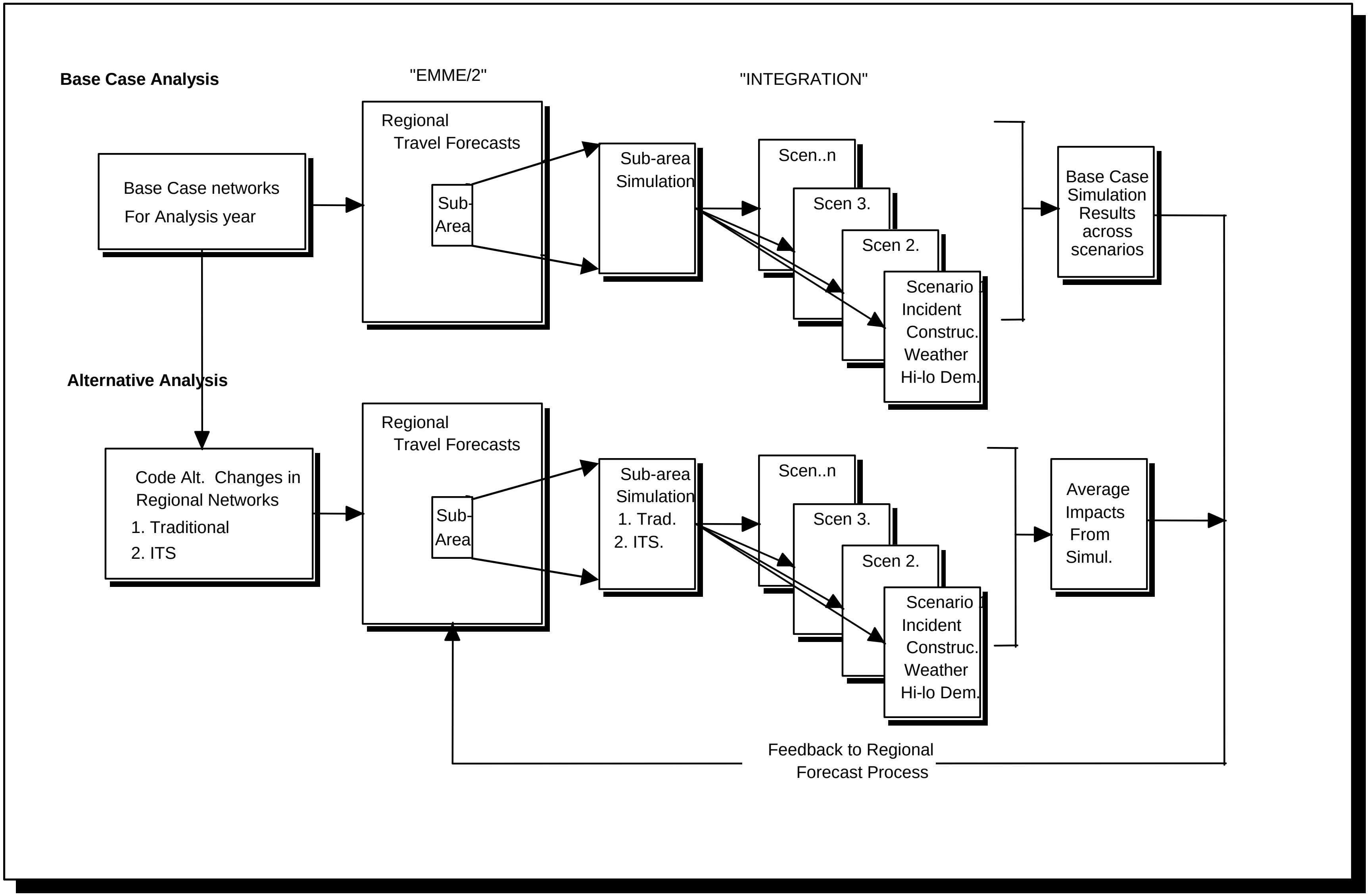
• Trip Generation, Distribution, Mode Split, and Assignment to produce regional travel patterns. Captures "expected" conditions and their impact on travel.

•Travel within the study area.Captures impact of information, variation in travel conditions (within the day, and for incidents, etc) and traffic operations. Will carry out multiple runs to reflect variable conditions. Used to capture effects of ITS strategies.

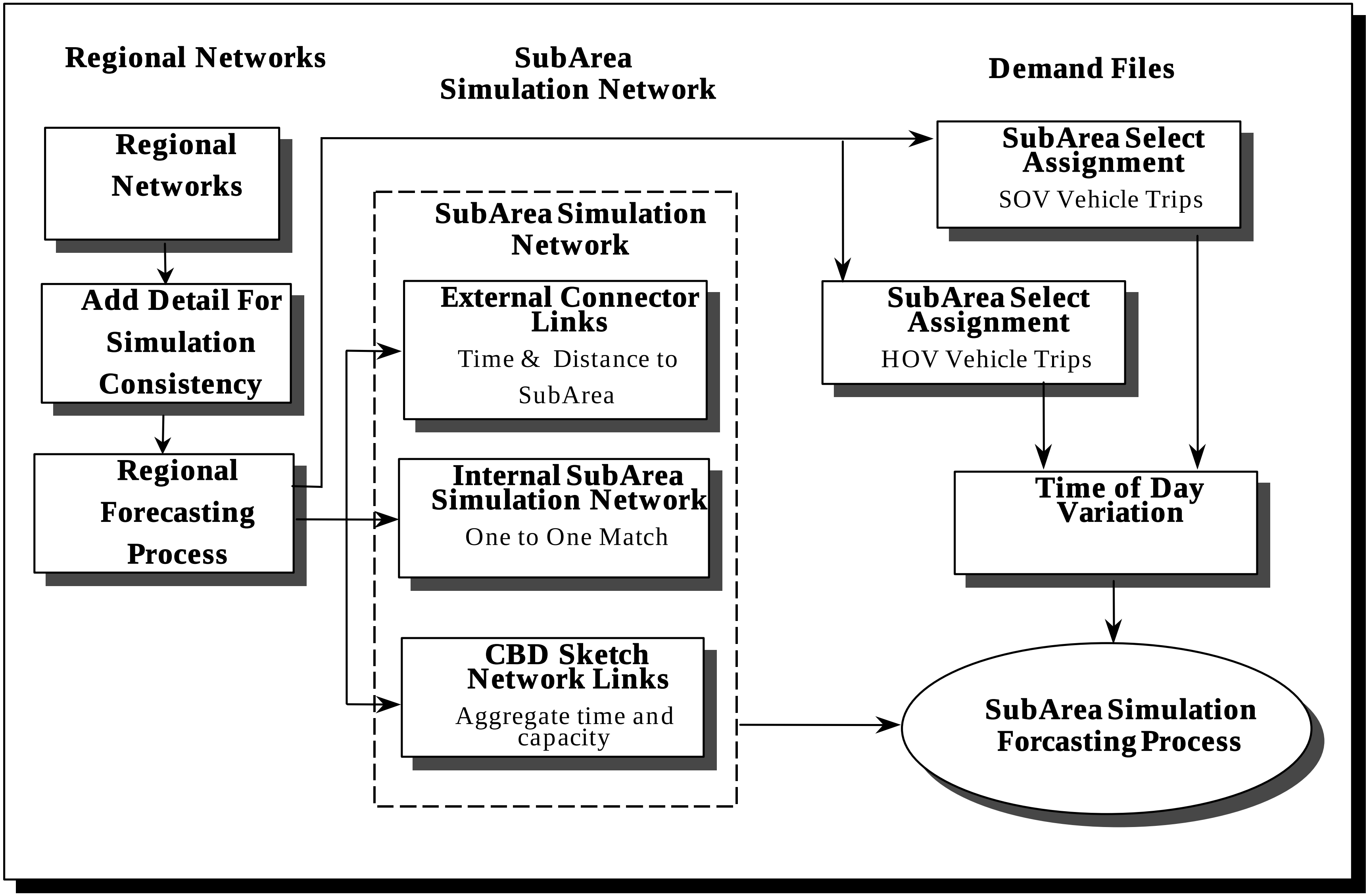
• Feedback to reflect simulation model results in regional travel patterns

• Produce output measures to reflect goals and objectives

PRUEVIIN Framework Overview



Regional Model to Subarea Simulation Interface Overview



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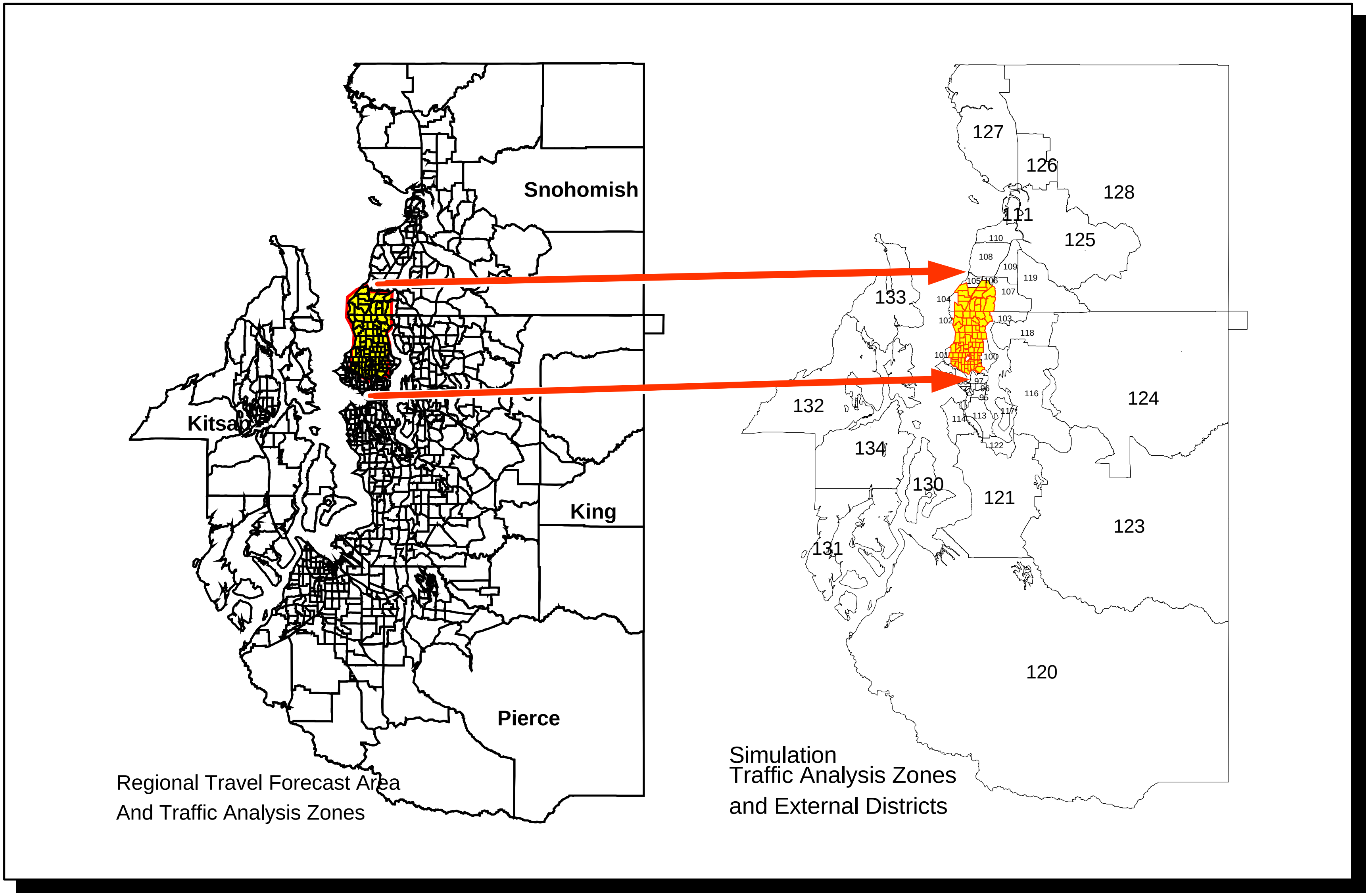
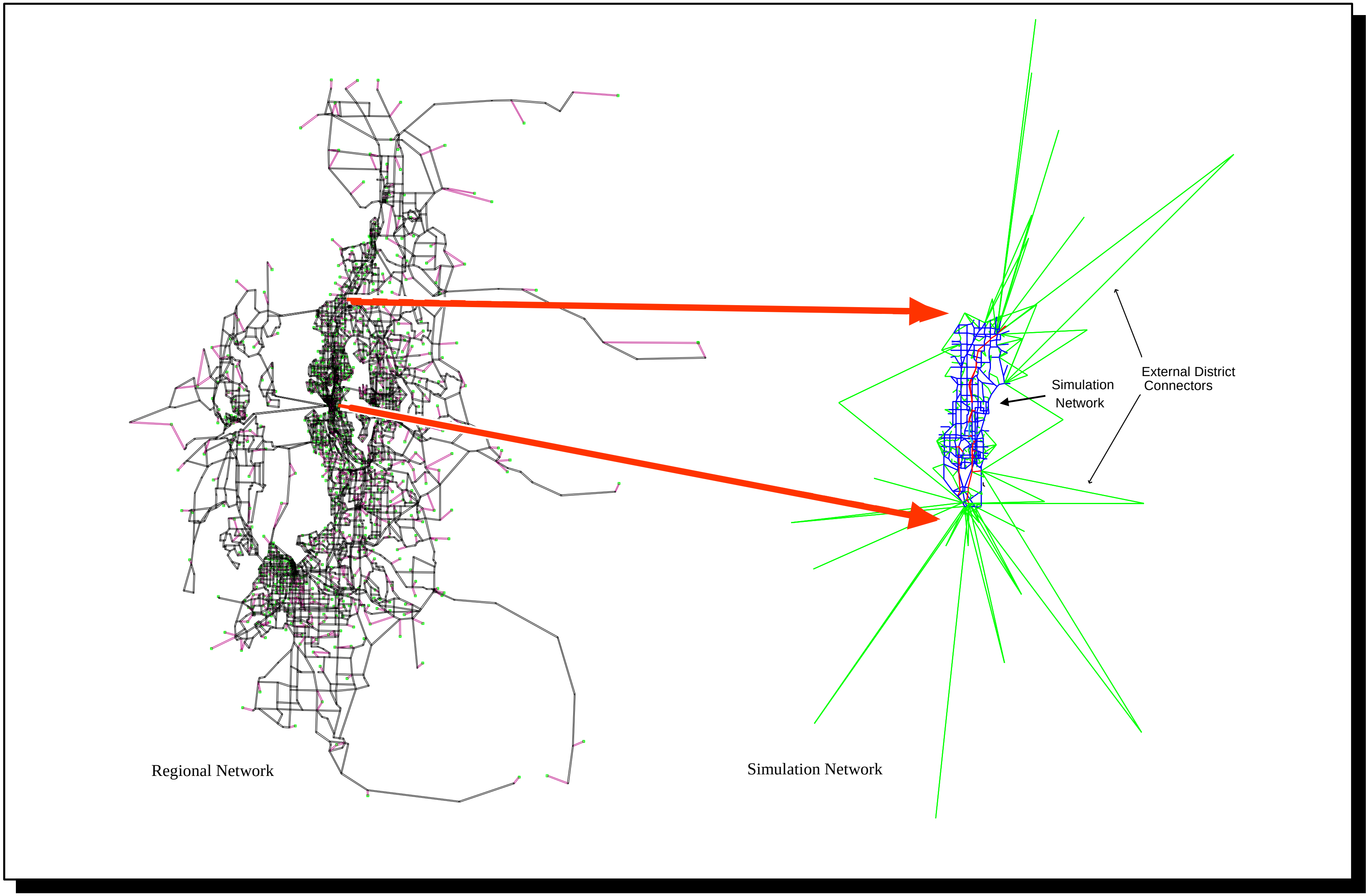
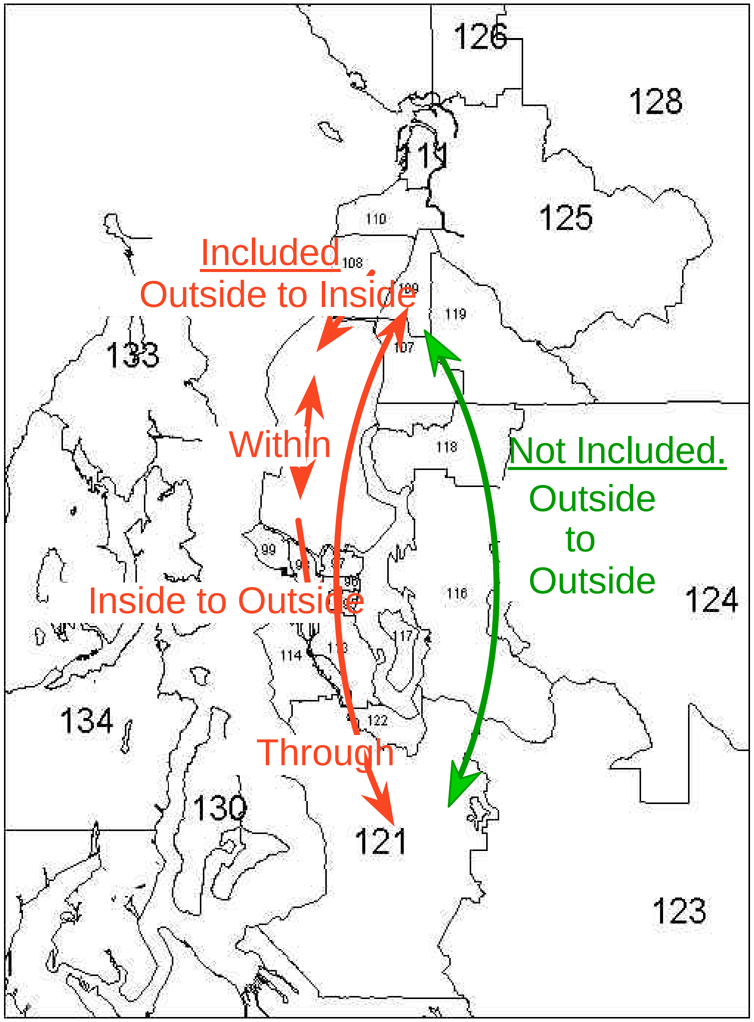
Regional Model to Subarea Simulation Zone Structure



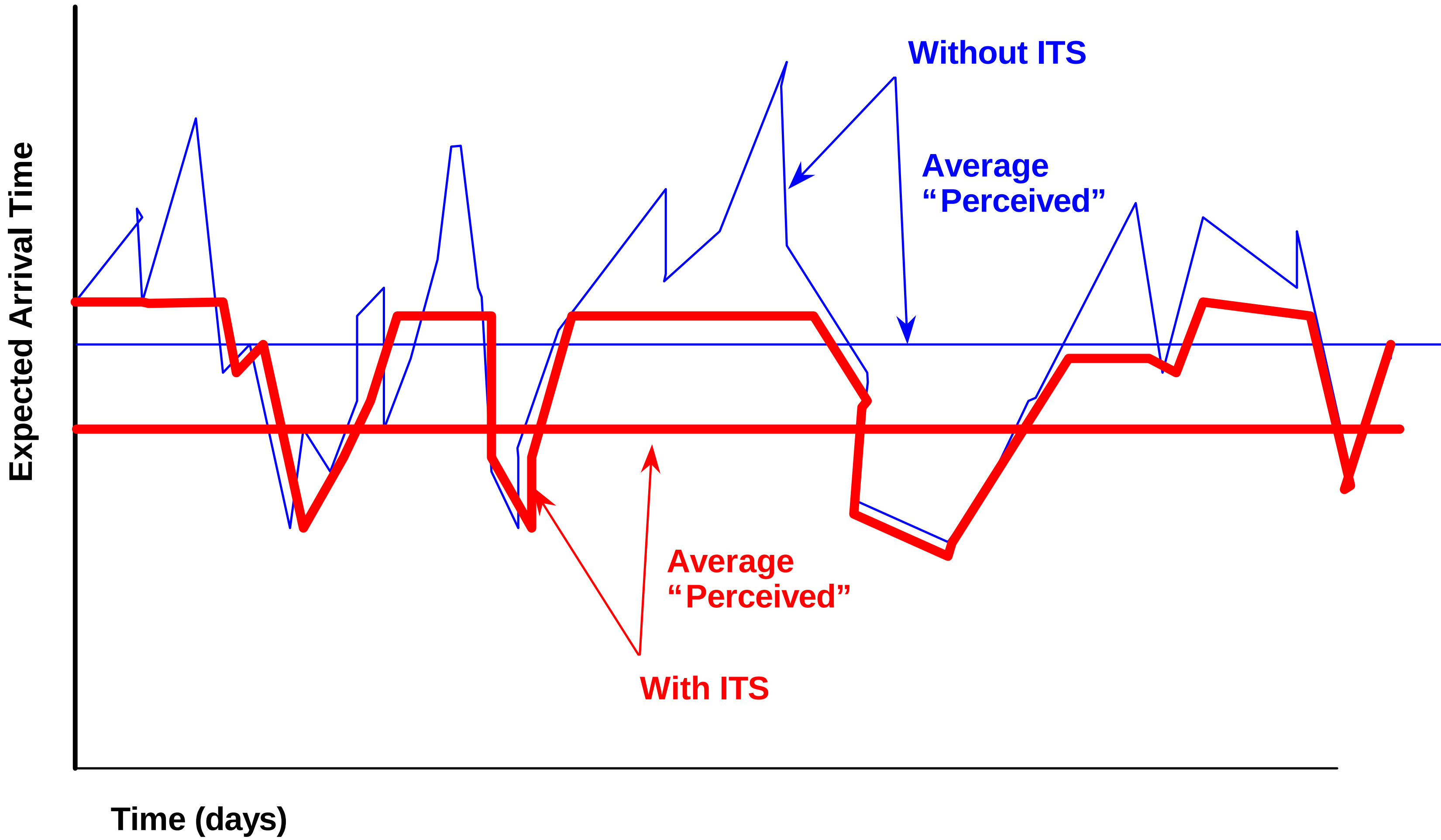
Regional Model to Subarea Simulation Networks



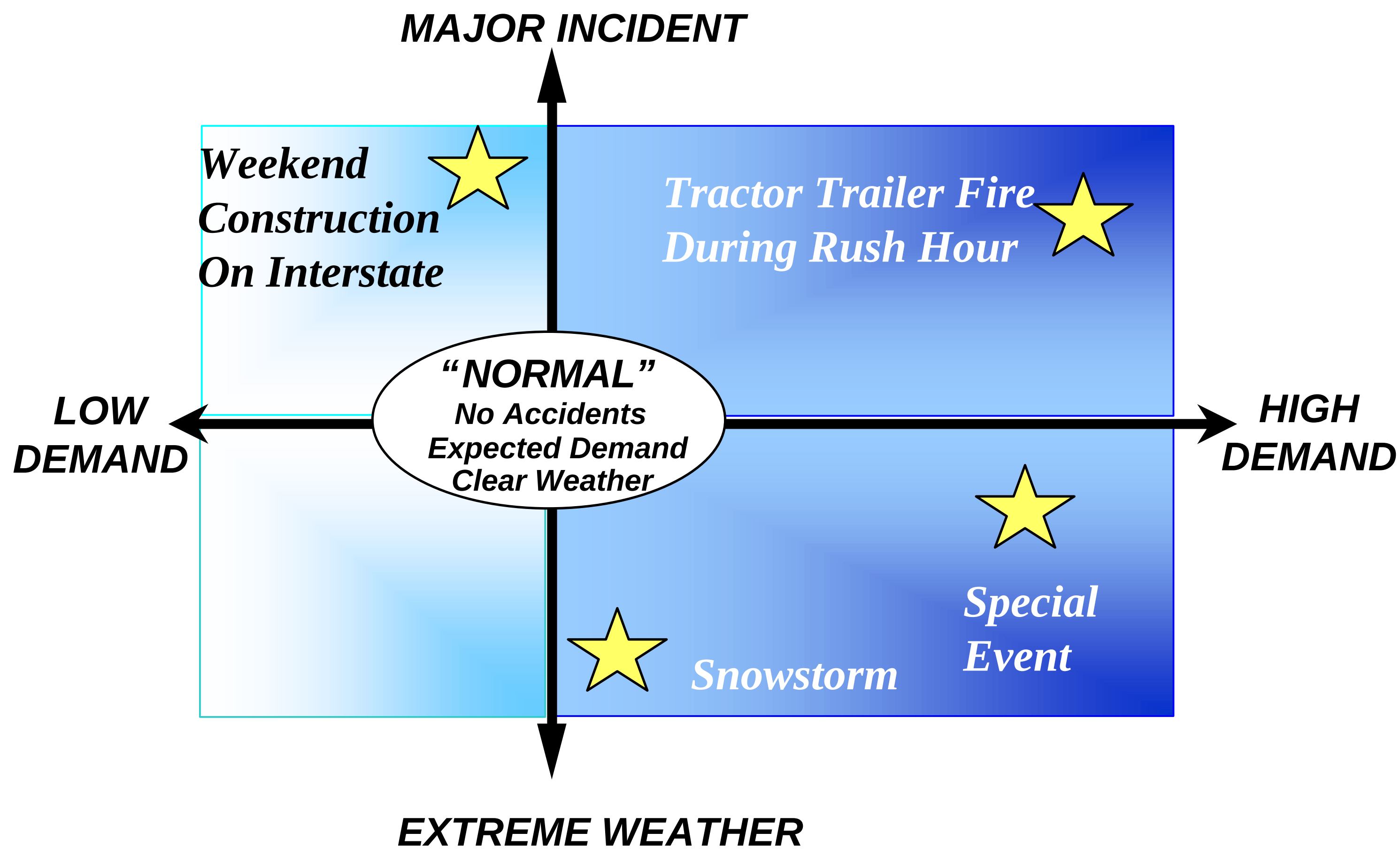
Regional Model to Subarea Simulation Demand



Scenario Development
Planning vs. Simulation:



Hypothesis: Integrated ITS Strategies Most Effective In High-Variability Systems



Scenario Definition Problem Statement.

- Define small set of "Representative Day" simulation scenarios that can be used to capture annual impacts of operational changes.
- Must be mutually exclusive and collectively exhaustive (Probabilities Sum to 1).

$$Annual\_MOE_i = \sum_s MOE_{is} * Weight_s$$

where:

$Annual\_MOE_i$ = MOE i annualized to capture the alternative's performance under varying conditions.

MOE_{is} = MOE i for scenario s

$Weight_s$ = Weight, or probability, of scenario s, Weights must sum to 1.

s = Scenario s

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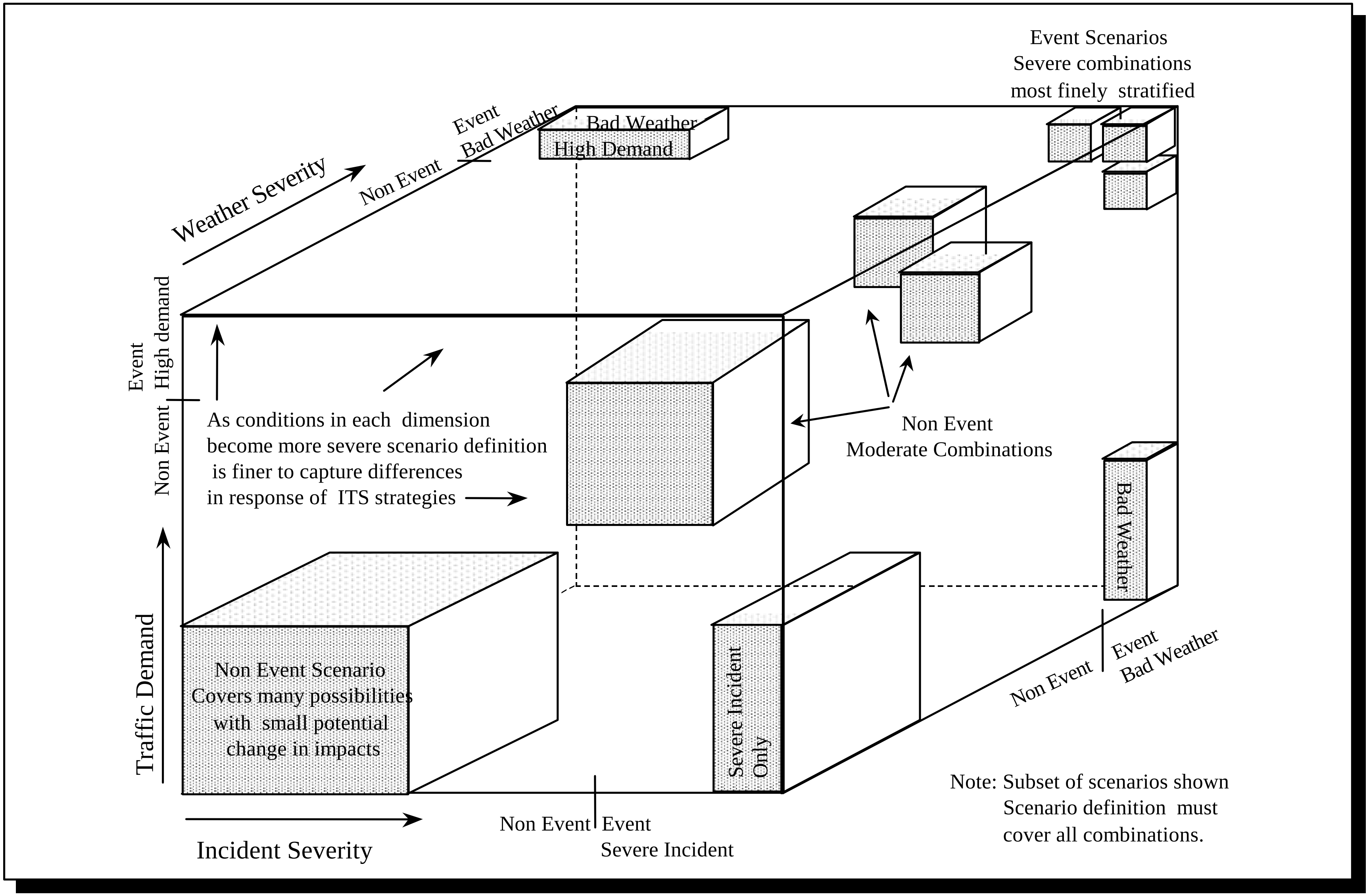
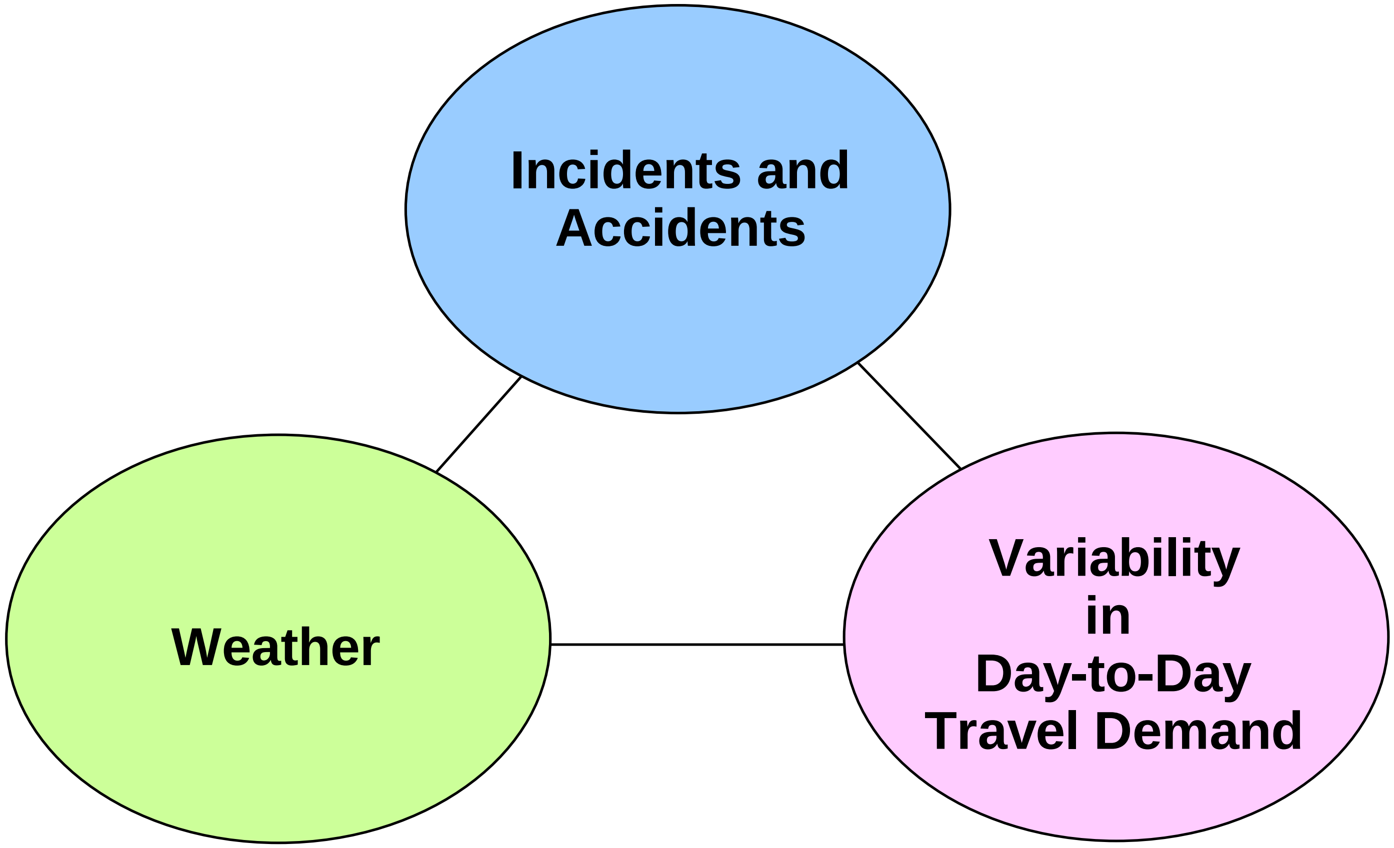
Scenario Definition



Scenario Definition: Dimensions

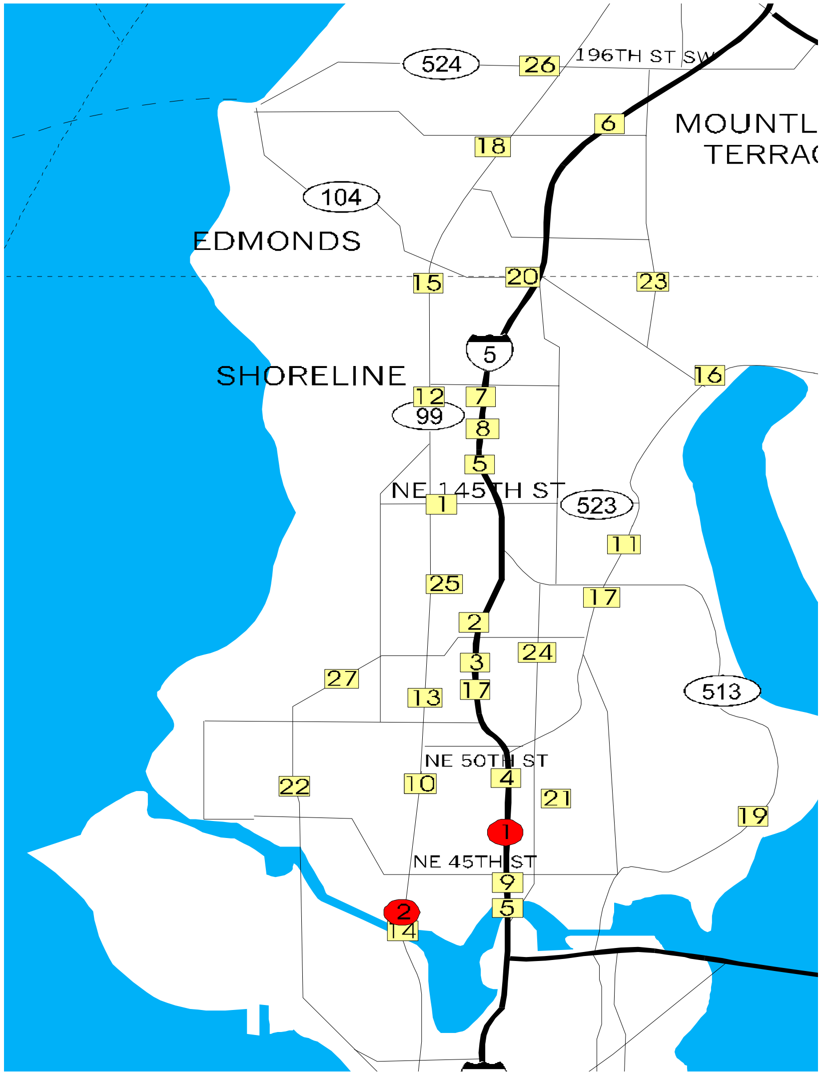


Scenario Definition Dimensions:

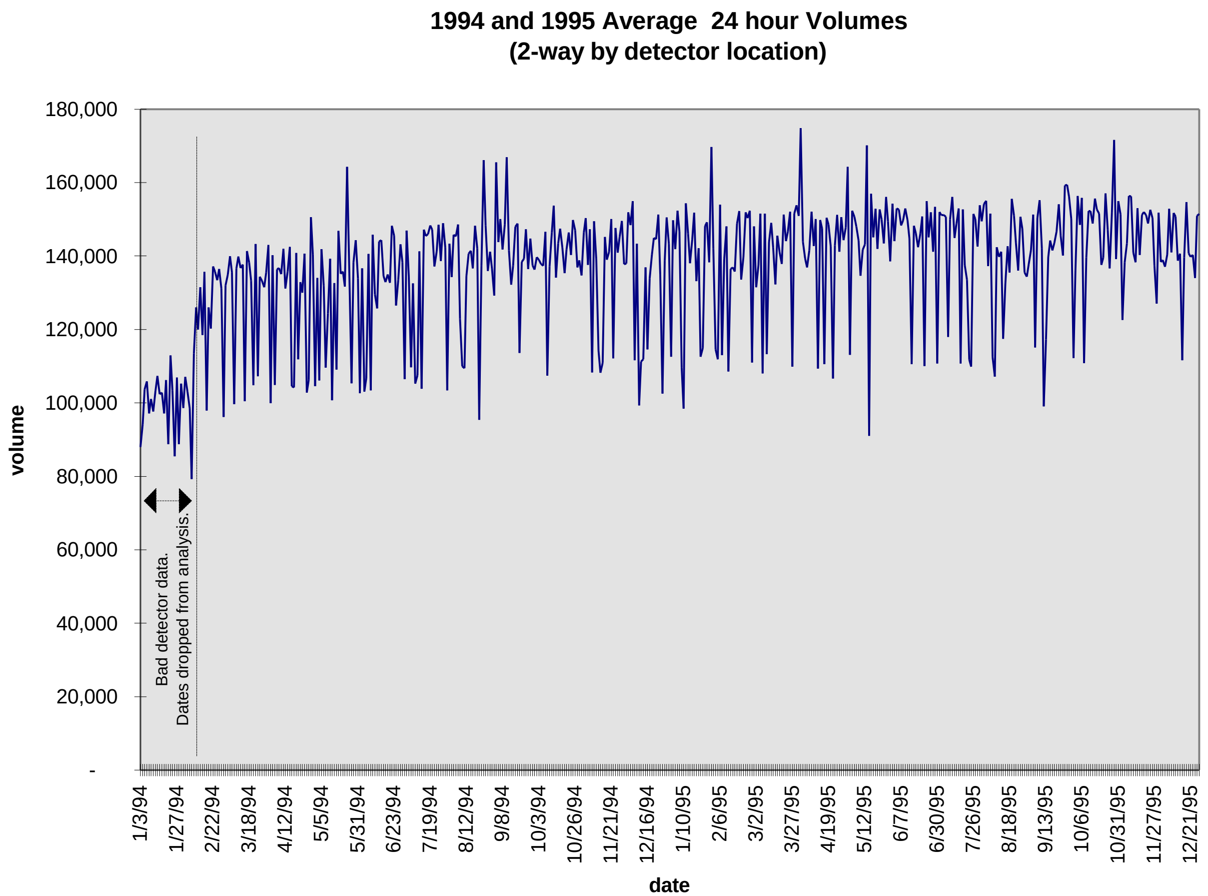
- Event
  - Weather (6 dimensions)
  - Major Incident (Lnminutes of delay > 30)
  - Number of Accidents in the Major Arterial File (>=6)
  - Volume (Demand variation within Event Days)
- Non-Event
  - Number of Accidents in the Major Arterial file (<=6)
  - Volume (Demand variation within Non-Event Days)

Scenario Definition
Incidents and Accidents

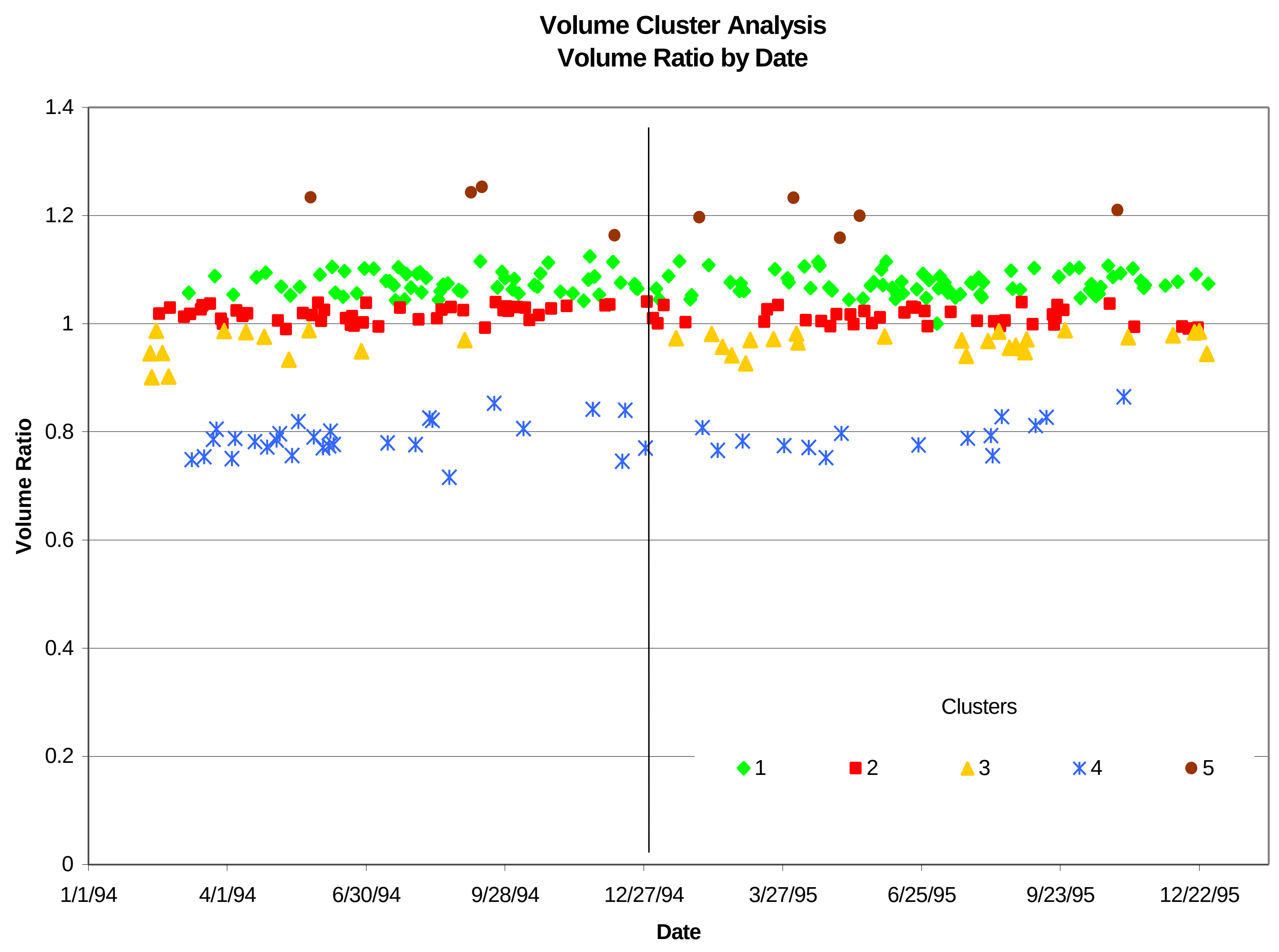
- INCIDENTS (red)
  (Major disruptions)
  - long duration
  - multi-lane blockages
- ACCIDENTS (yellow)
  (Minor disruptions)
  - shorter durations
  - shoulder or single-lane events



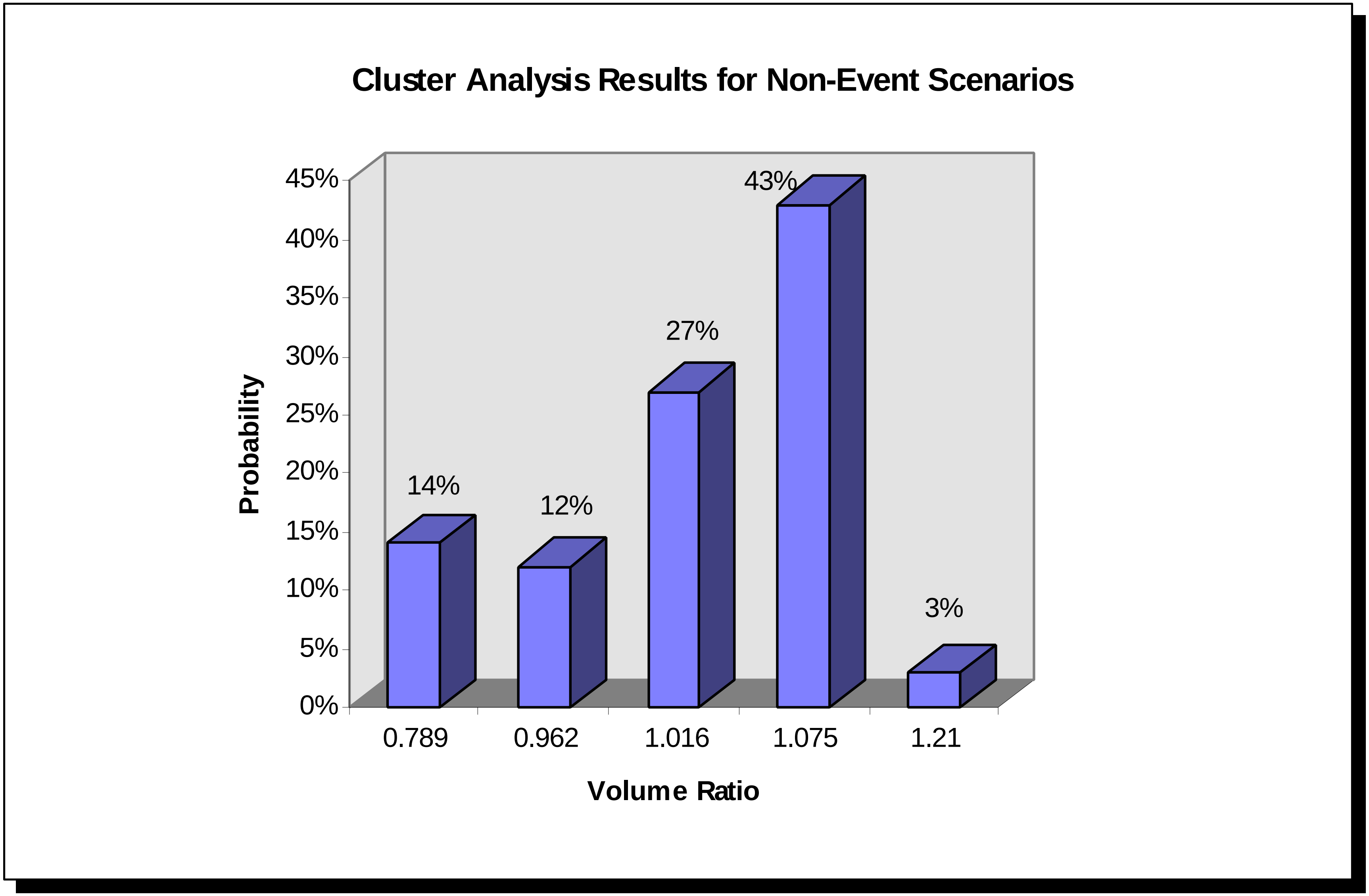
Scenario Development
Volume (Demand Variation)



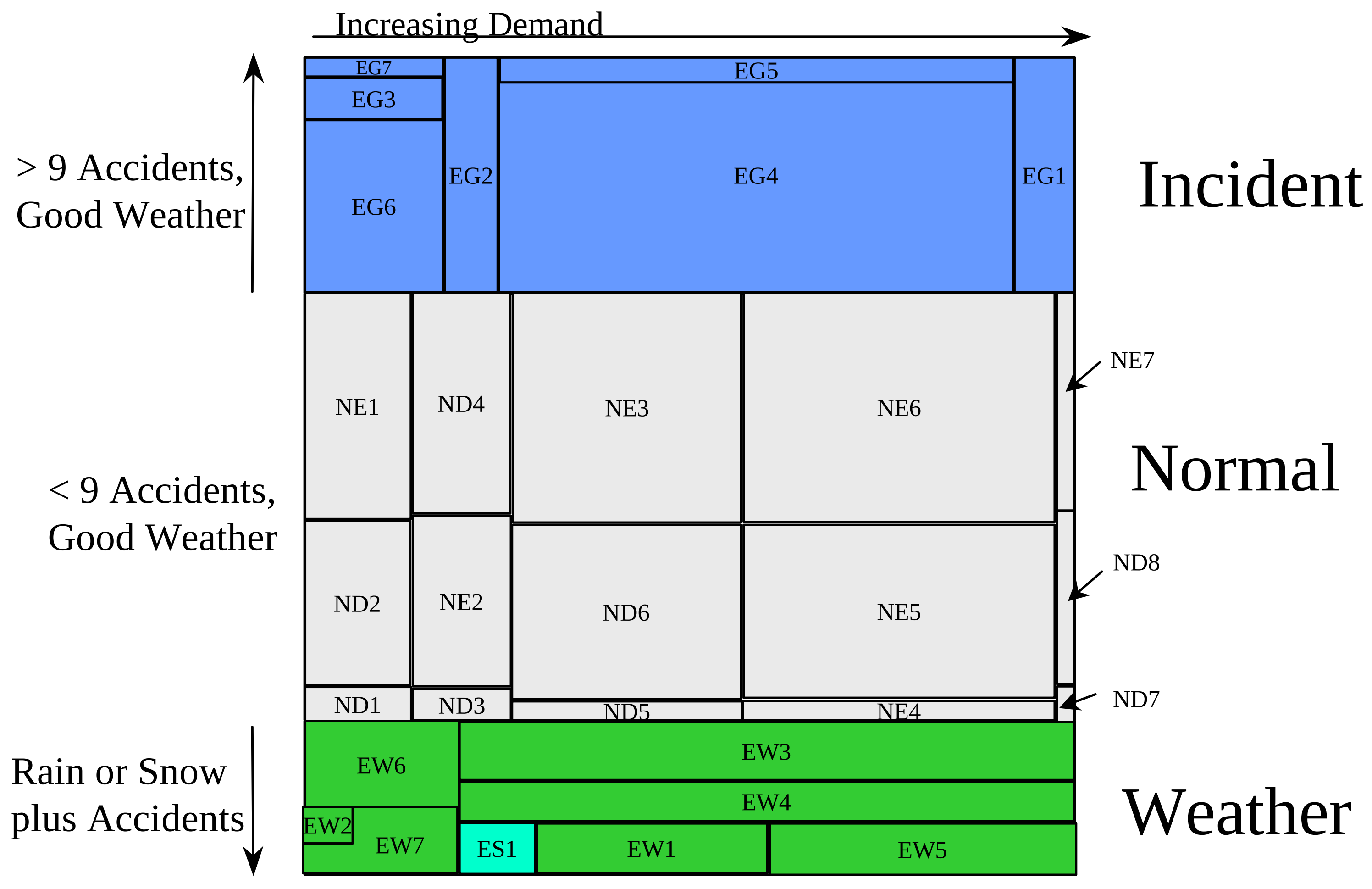
Scenario Development
Volume Cluster Analysis For Non-Event Days



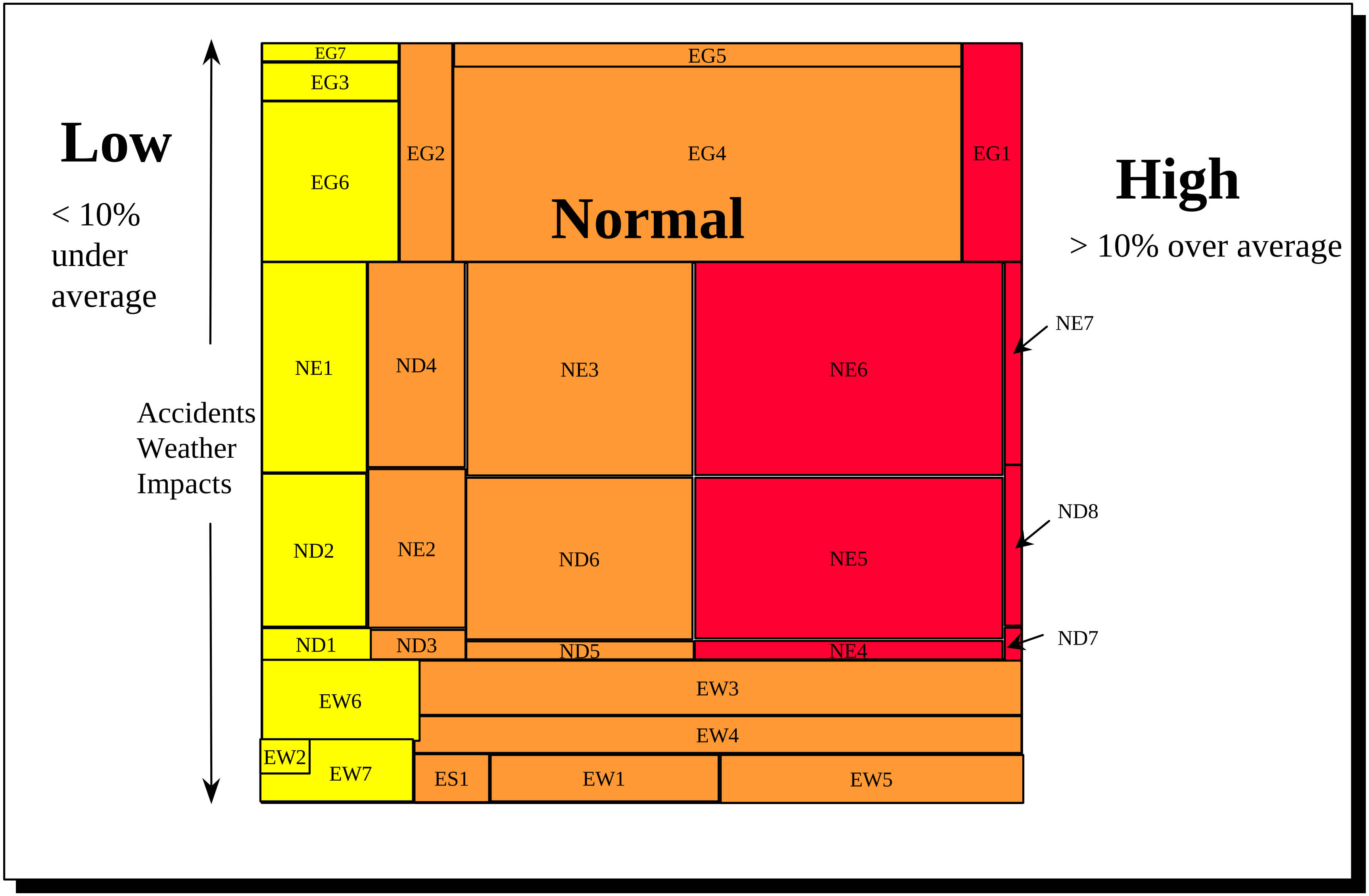
Scenario Development
Volume *Cluster Analysis Example*



Scenario Development
System Perturbations (Supply-Side)



Scenario Development
System Perturbations (Demand-Side)



Feedback Assumptions

- Purpose of Feedback is to capture change in travel patterns caused by ITS response to system variability and information provision seen in subarea simulation.
- Assumptions
  - Each model measures different phenomena.
    Regional model: average peak period flows (recurrent)
    Subarea simulation: discrete travelers and time (system variation and information)
  - Each model calibrated/validated to meet its own assumptions
- Do Not Force Consistency between two models
- Do Adjust % change in subarea simulation impedance to Regional Model units and feedback to trip distribution
- Adjust for percent of trips within Subarea simulation

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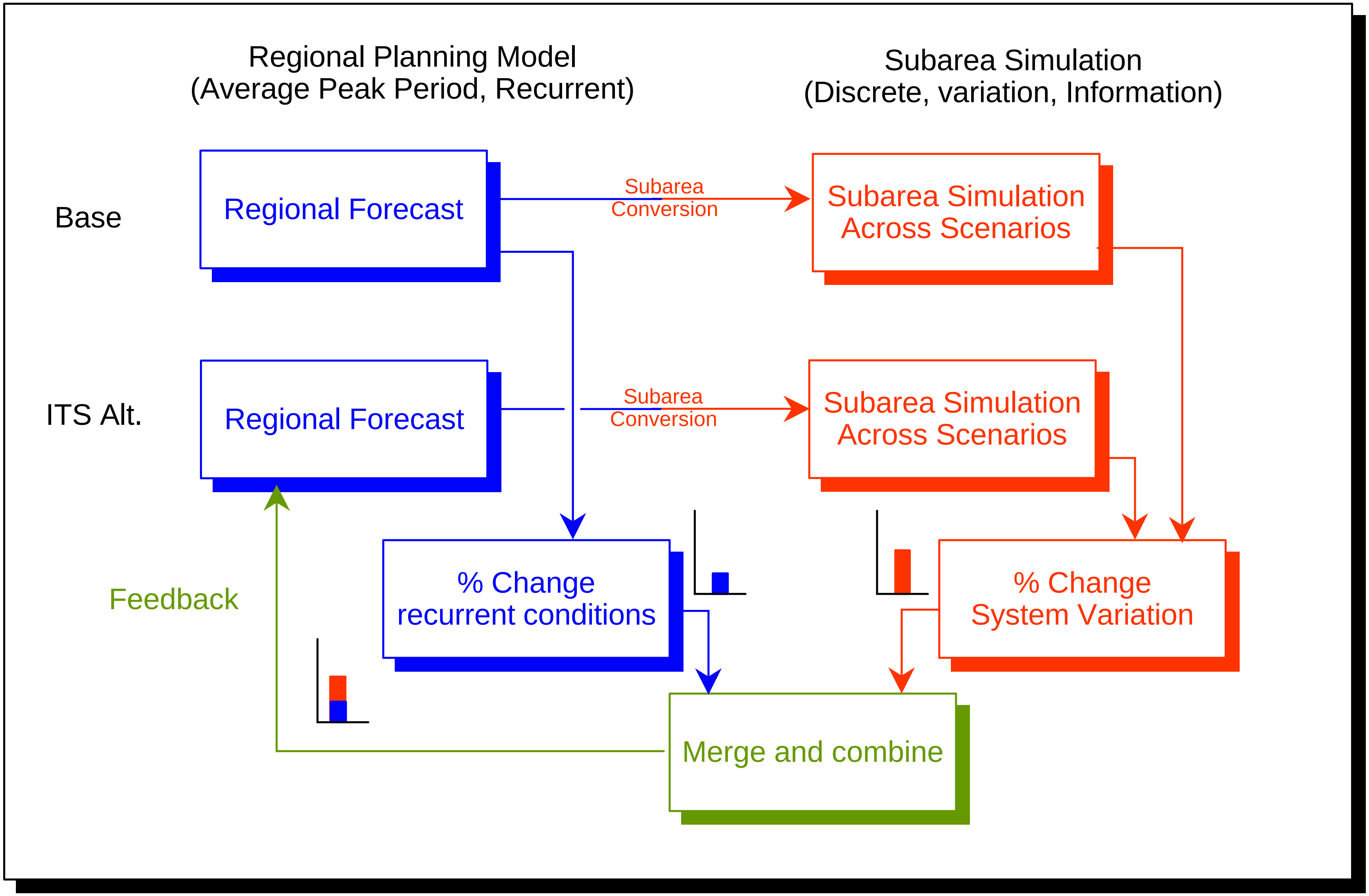
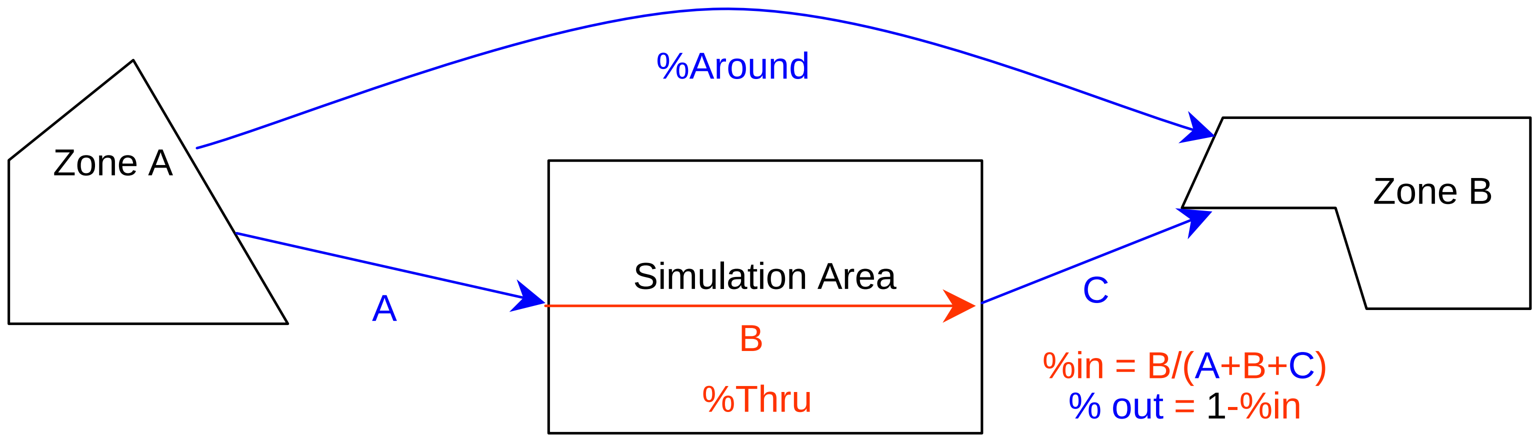
Feedback
Process Overview



Feedback
Origin Destination Impedance Adjustment



	Regional Model	SubArea Simulation
Base Impedance	$RegIMP_0$	$SimIMP_0$
ITS Alt. Impedance	$RegIMP_1$	$SimIMP_1$

Adusted Impedance =

%Around * $RegIMP_1$ +

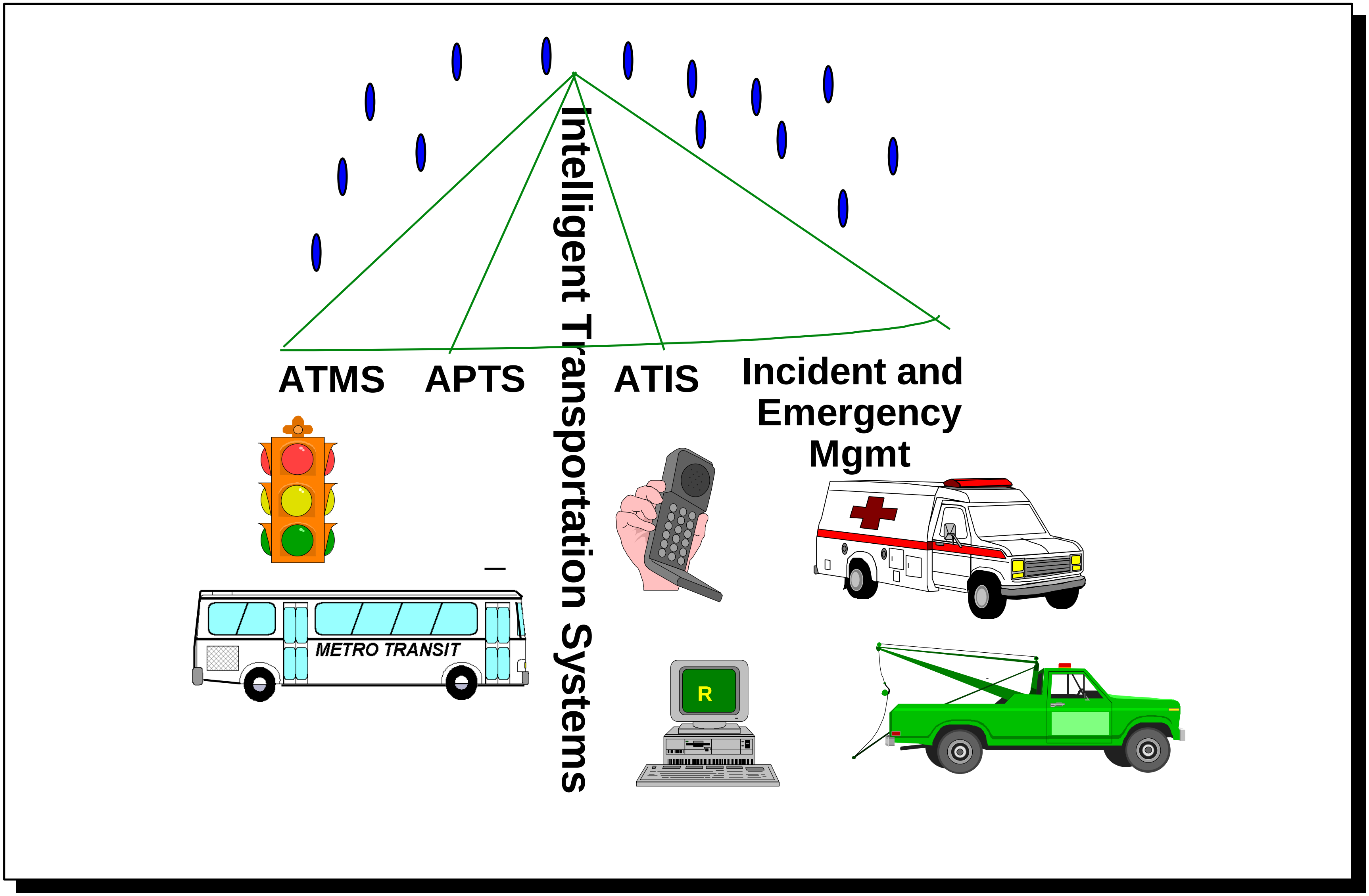
%Thru * %out * $RegIMP_1$ +

%Thru * %in *($RegIMP_0$* $SimIMP_1$/$SimIMP_0$)

Measures of Effectiveness

Primary outputs/ measures		
	Travel time by mode (HOV,SOV,Transit)	
	Throughput (person, vehicle)	
	Mode choice , Trips by mode	
	VMT by mode (HOV, SOV, Transit)	
	PMT by mode (HOV,SOV,Transit)	
	Peak Period Vehicle stops/starts	
	Deferred Trips	
	Capital costs	
	O&M costs	
Derived measures		
	Delay reduction (recurrent and incident)	
	Risk of Significant Delay	
	Mode shift from SOV	
	LOS by link	
	Reliabilitiy and Variance reduction (Standard dev. of arrival times, travel times)	
	Accessibility	
Other Impacts (Accidents, Emissions, Energy) *		
	* Produced by post processor tools outside of scope	

Treatment of ITS Strategies
Range of ITS Services Considered



Model Representation For *ITS Strategies*

ITS Elements	Model Representation: Regional Planning Model (EMME/2)	Combination	Subarea Travel Simulation Model (INTEGRATION)
ATMS			
Traffic Management Centers		X	
North Seattle ATMS (Comm. Infra)		X	
TOD/existing signal systems		X	
Ramp meters (I-5)		X	
Freeway surveillance			X
Coordinated/adaptive signal system (arterial plus freeway ramps)		X	
Support for EMS priority			
Expanded surveillance system (CCTV, loops, probes, etc.)			X
TMC/ comm. system upgrade		X	
EMS/ IMS Improvements			X
ATIS			X
APTS		X	

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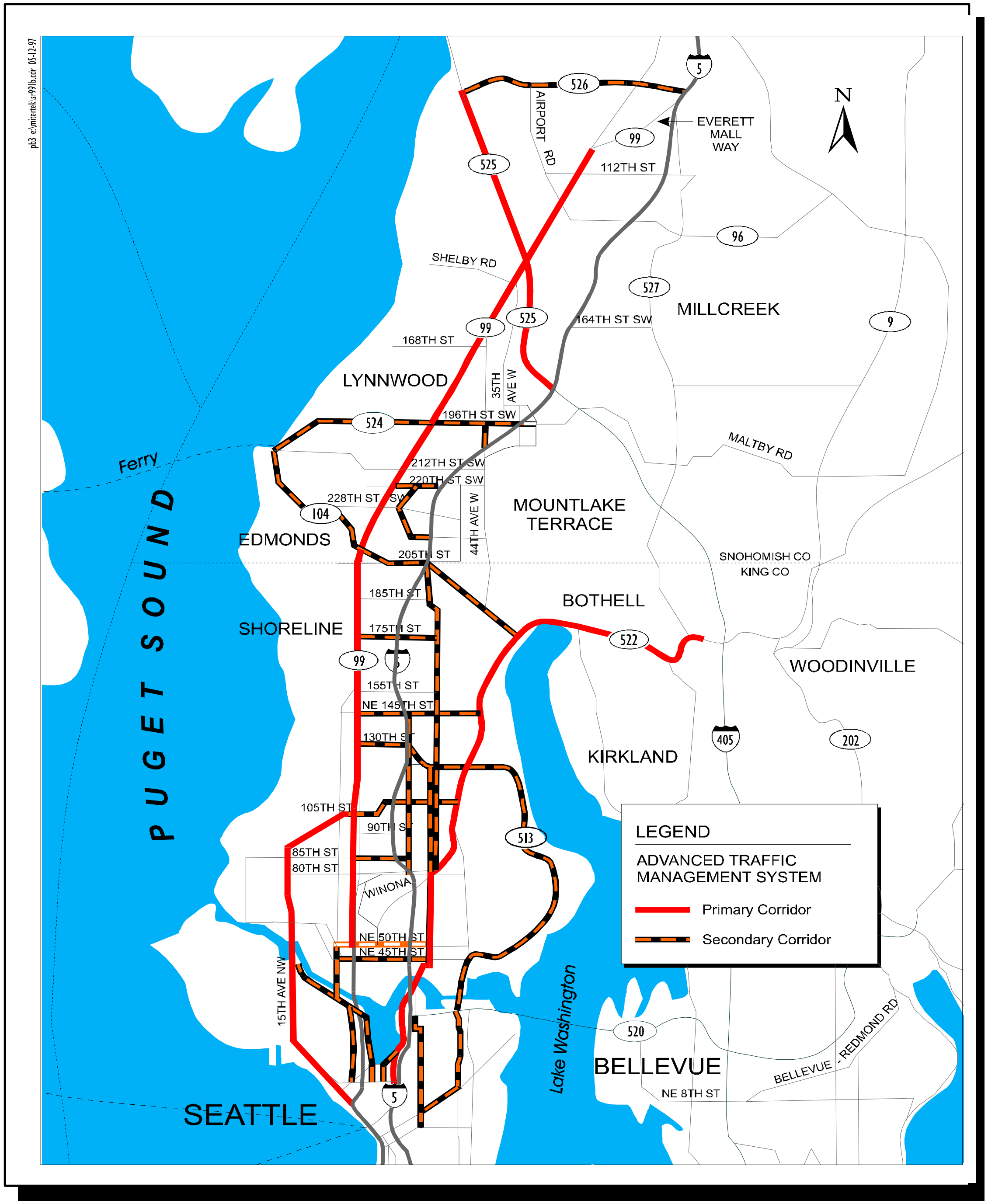
ITS Rich
ATMS Plan (Part A)



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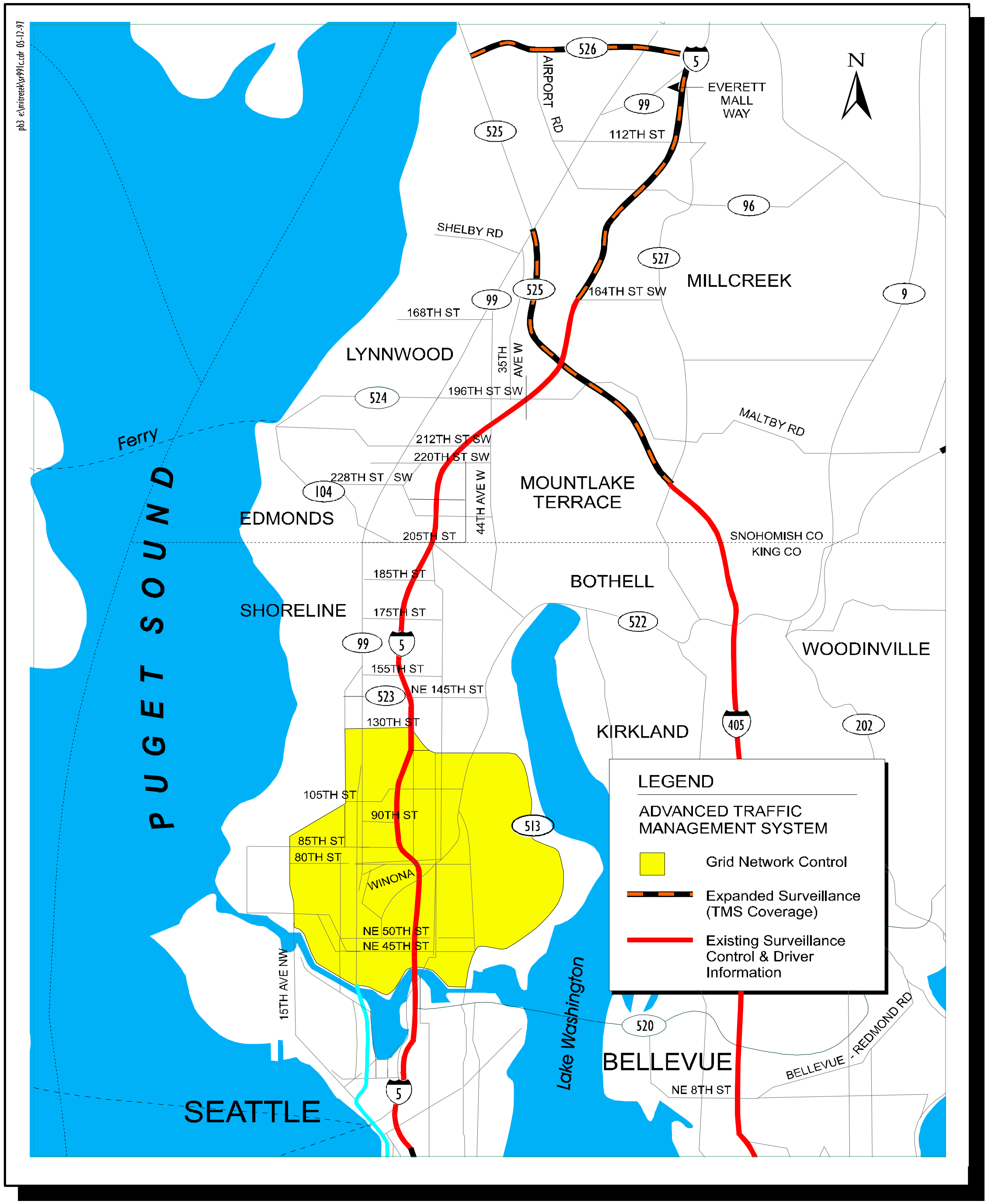
ITS Rich
ATMS Plan (Part B)



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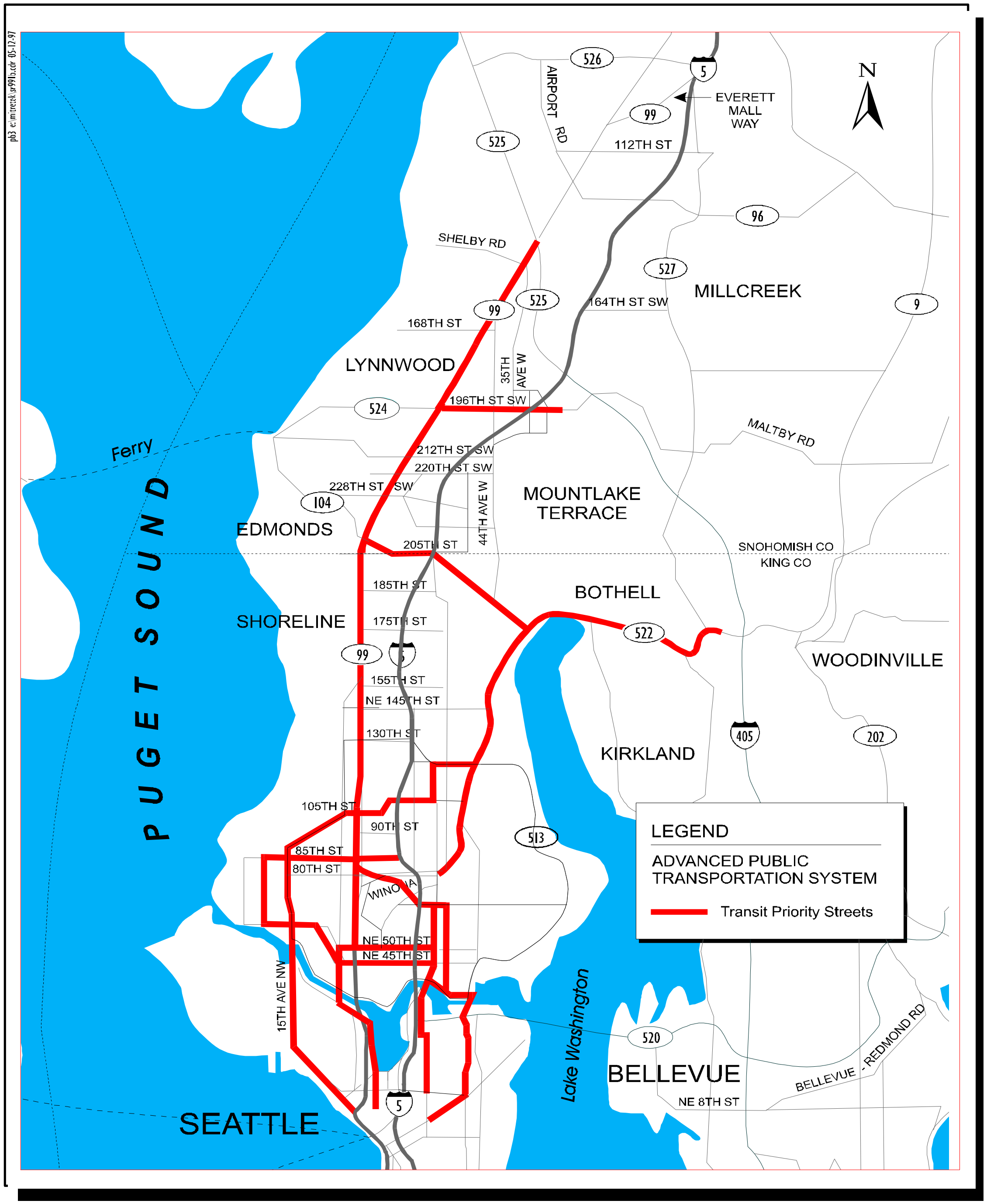
ITS Rich Transit Priority



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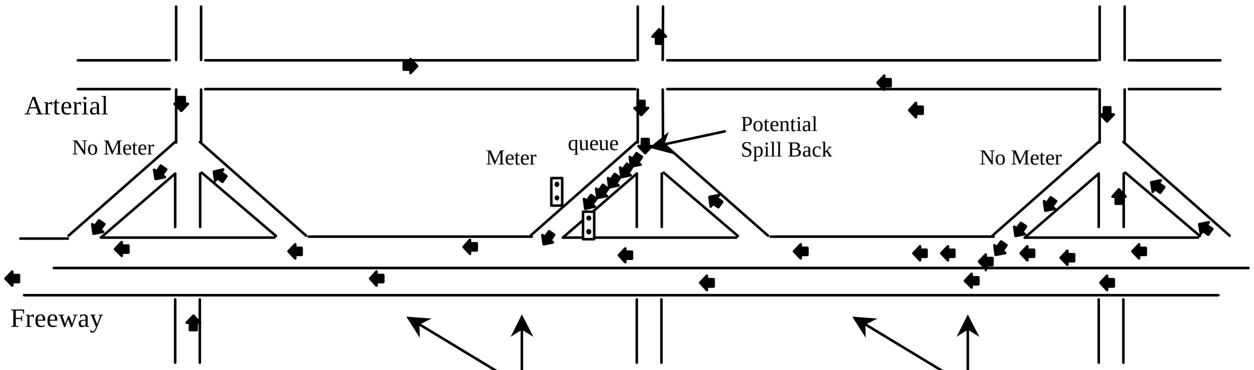
ATMS
Ramp Meter Representation



For Ramp Meter:

$$time_{ramp} = time_{flow} + time_{queue} + time_{accel/decel}$$

where:

$time_{ramp}$ = total time for ramp meter link

$time_{flow}$ = time from normal volume delay calculation

$time_{queue}$ = time spent in queue

$time_{accel/decel}$ = time difference due to acceleration / deceleration vs. traversing the link at a constant speed.

ATMS and APTS (Transit Priority)
Network Parameters

	EMME/2		INTEGRATION			
Designation	Free Flow Speed	Capacity	Free Flow Speed	Speed at Capacity	Capacity	Signal Strategy
Priority Corridor (SR 99)	5%	4%	5%	2%	3%	DCO Level 1 Corridor
Priority Corridor (other)	10%	9%	10%	5%	6%	DCO Level 1 Corridor
Secondary Corridor	7%	6%	7%	3%	3%	DCO Level 2 Corridor
Grid Control Area	5%	3%	5%	2%	0	Isolated Adaptive
Perpendicular to Transit Priority	0	-5%	0	0	-5%	---

APTS (Transit Priority)
Transit Line Coding

- Reflects Speed and Capacity Changes due to ATMS
- 30% Reduction in intersection delay for mixed flow operation
- 40% Reduction in intersection delay for HOV or operation with bus bypass

Treatment of System Variability and Results from the 2020 Seattle Case Study

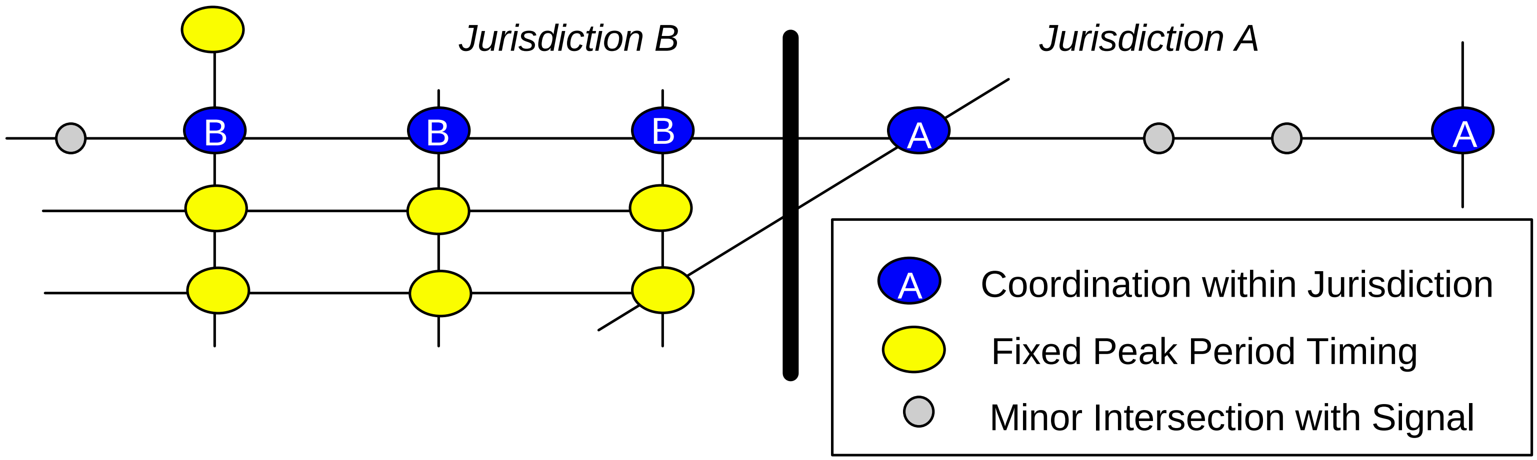
Dr. Karl Wunderlich
Lead Research Engineer

9 January 1999

Overview

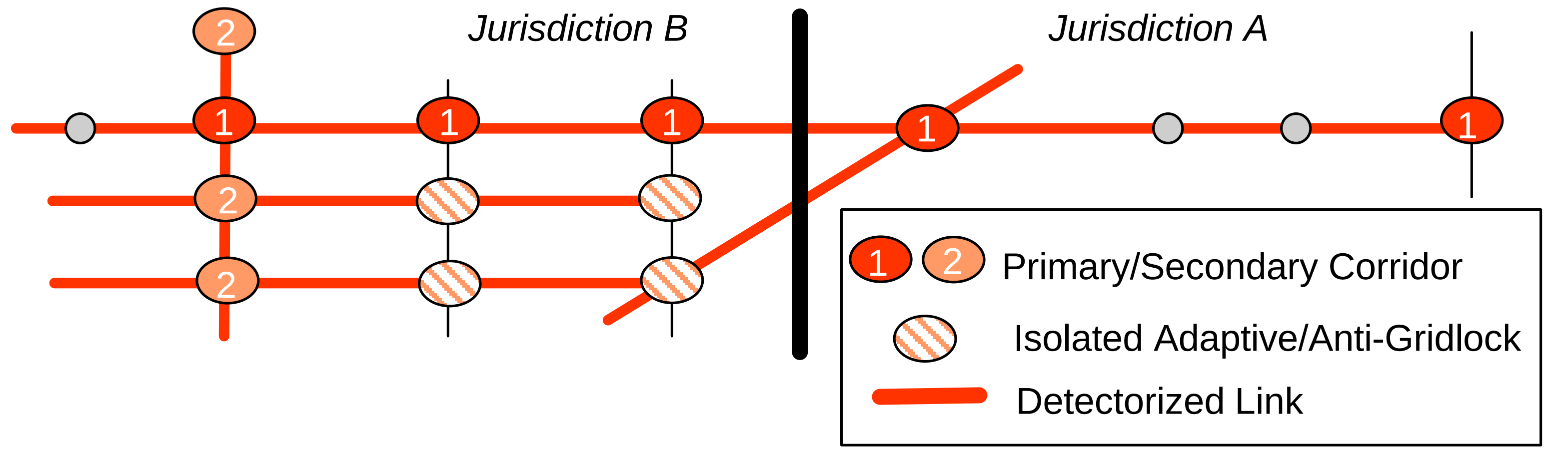
- Modeling Methodology and Networks
  - Advanced Traffic Management Systems (ATMS)
  - Advanced Traveler Information Services (ATIS)
  - Incident Management
  - Traveler Expectation Modeling
- System Variability: Sources and Scenarios
- Calibrating PRUEVIIN
  - Within-Day Variation
  - Between-Day Variation
- MOEs and Results

ATMS Modeling
2020 Baseline Alternative



- **135 major signalized intersections modeled**
- **Baseline timing plans:**
  - **optimized for average peak flow**
  - **fixed plans for entire period**
- **North Seattle ATMS documents used to find cycle lengths and coordinated corridors (e.g., piece-wise coordination along SR99)**

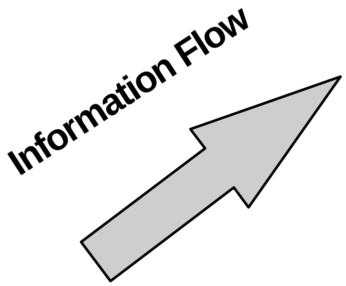
ATMS Modeling
2020 ITS Rich Alternative



- Primary corridors are dynamically optimized for cycle length, coordination, and phase split
- Secondary corridors are optimized as above, except where they conflict with Primary corridors
- Gridlock control identifies blocked downstream links and allows vehicles to enter only when space opens up

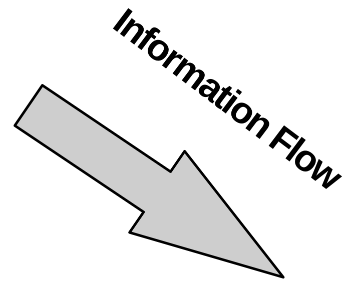
ATIS Modeling:
2020 Baseline Alternative

Distribution Media

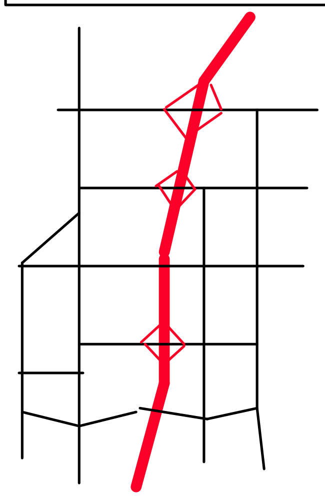


VMS, HAR
gross delay estimates

Internet
real-time freeway speeds



Network Surveillance



Detectors
I-5 freeway and ramps

Traveler Classes

Experienced Commuters
know expected (average) conditions
know of diversion alternatives

Unfamiliar Drivers
estimate uncongested travel times
know of few alternatives (less likely to divert)

Pre-Trip Planners
check internet for freeway conditions before trip start

ATIS Modeling:
2020 ITS Rich Alternative

Information Flow

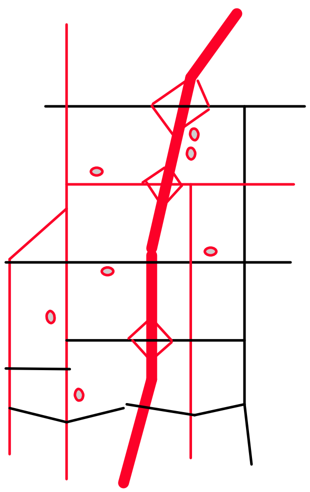
Distribution Media

VMS,
HAR
Internet
travel times by mode

Information Flow

Route Guidance Service Provider
broadcasts to 10% of vehicles

Network Surveillance



Detectors
I-5 + ramps
ATMS corridors

Probe Vehicles
(5% of vehicles)

Traveler Classes

Experienced Commuters

Unfamiliar Drivers

Multi-Modal Pre-Trip Planners
pick fastest path from bus, SOV

Route Guidance Users
updated fastest roadway path
computed en route

Incident Management/ Emergency Management Systems

- **INCIDENT FREQUENCY**
  (number and location of incidents)
  - **unchanged between baseline and ITS Rich**

- **INCIDENT SEVERITY**
  (number of lanes blocked in each incident)
  - **unchanged between baseline and ITS Rich**

- **INCIDENT DURATION**
  (duration of lane blockage)
  - **reduced 25% from baseline to ITS Rich (source: Houston Transtar study)**

♦

Motivation for Perception Models and "Expectation-Setting"

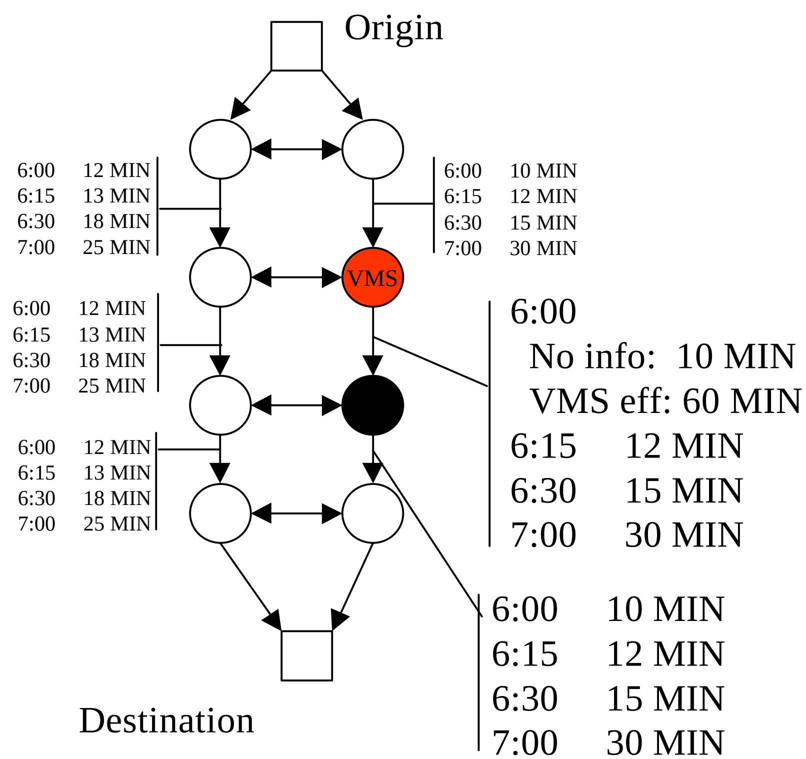
- Objectives of Expectation-Setting:
  - differentiate impacts of providing more accurate and timely real-time delay information to travelers
  - explicitly model experiential knowledge of network conditions (familiar and unfamiliar drives)
  - facilitate large-scale impact estimation

- Approach
  - develop data model to explicitly represent traveler expectation for the AM peak period
  - develop training process to populate data model in a way that could be calibrated against real-world data
  - utilized calibrated perception models to evaluate range of existing and proposed ATIS services

♦

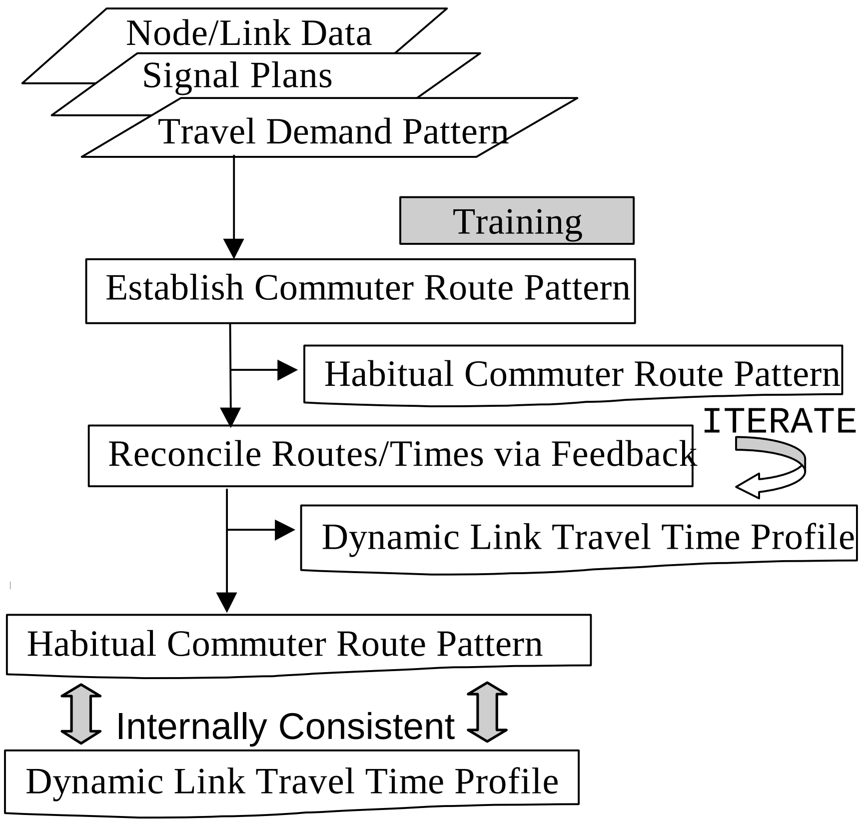
Traveler Perception Data Model

- Experienced travelers have rough estimates of average conditions on routes they habitually traverse
- Radio reports or VMS provide exception data that on specific points in the network
- Knowledge of system conditions is stored as estimates of link travel time by 15 minute increments + ERROR

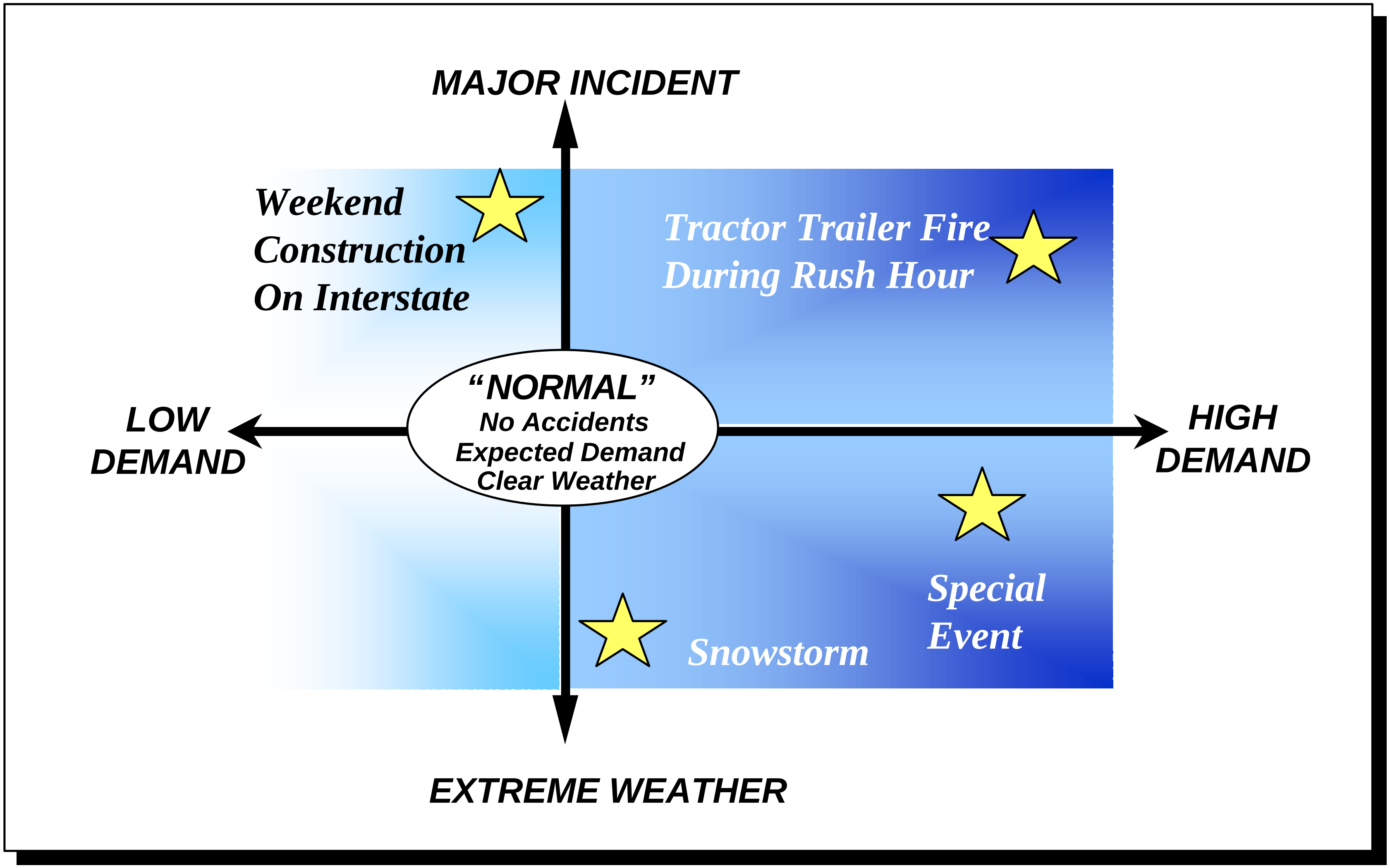


Training Process

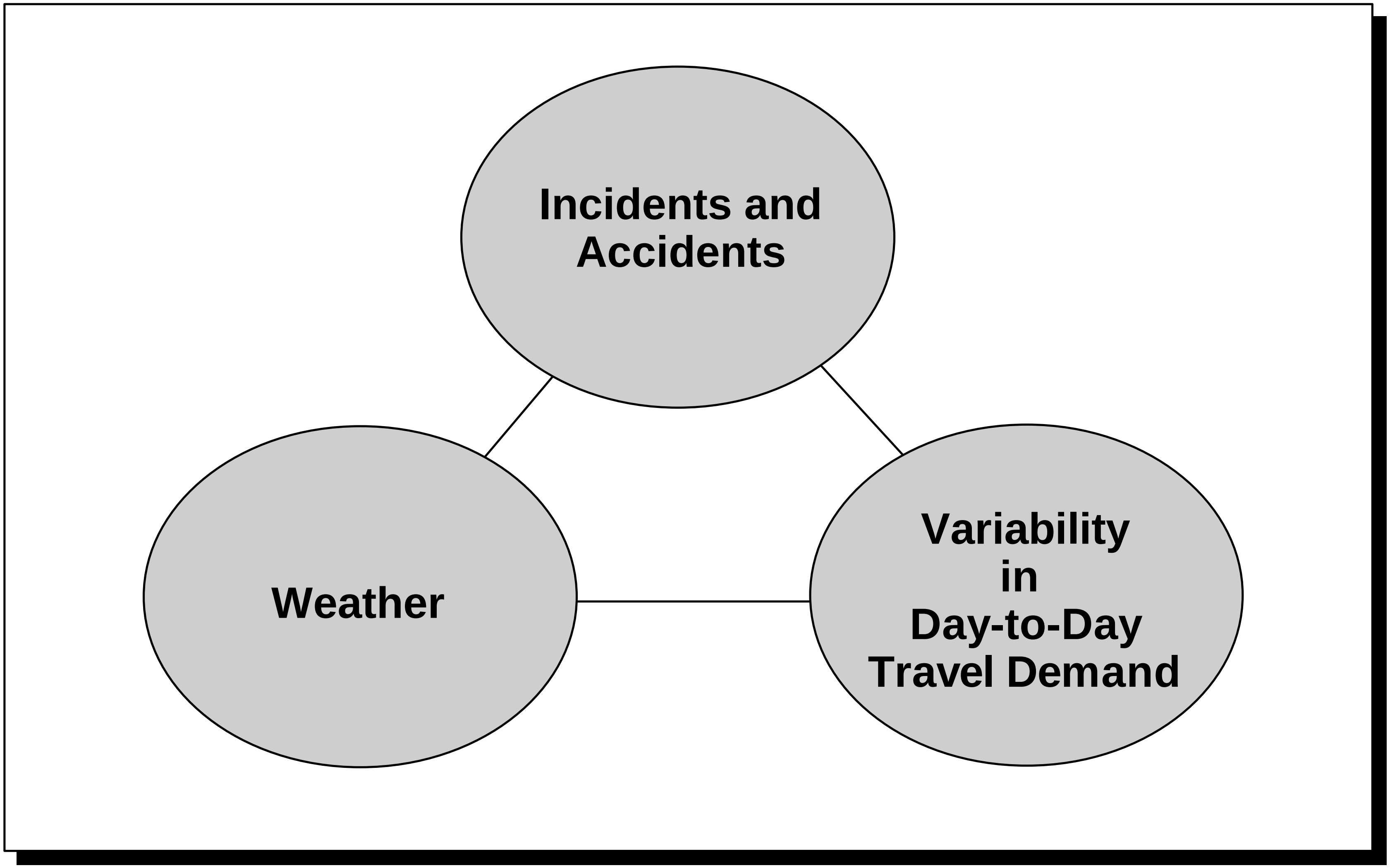
- Dynamic assignment technique draws on time-varying congestion in the system
- Travelers are "trained" under assumption that commuters know travel times throughout system
- Iterative process converges to form time profile consistent with habituated routes



Hypothesis: Integrated ITS Strategies Most Effective In High-Variability Systems

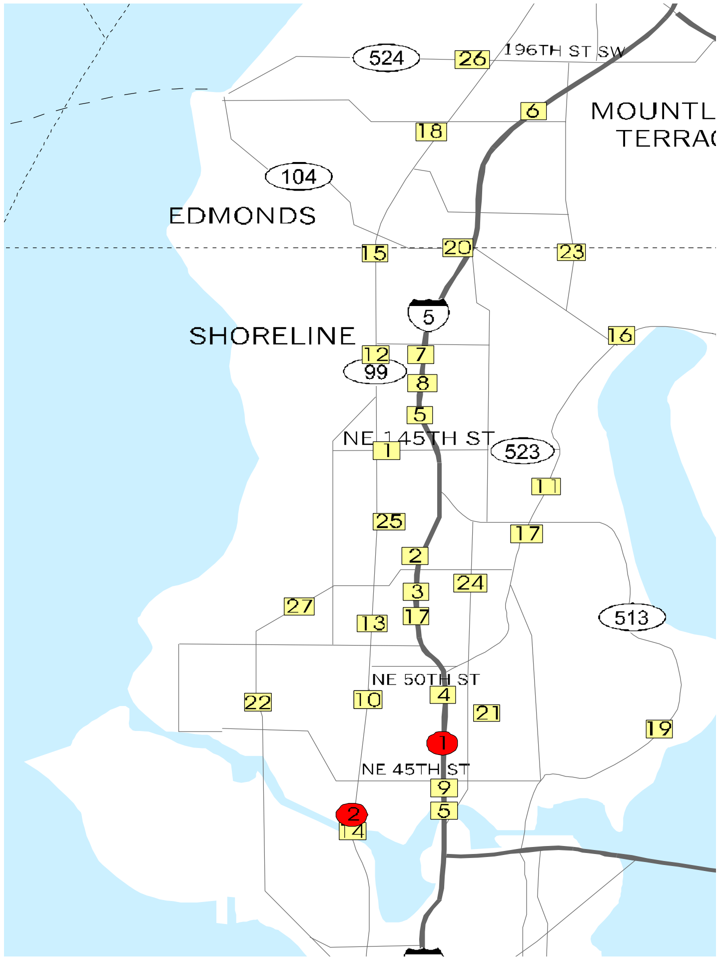


Evaluation Scenarios: Changes to System, Travel Demand



Modeling Incidents in Simulation: Localized, Temporal Reduction in Capacity

- INCIDENTS (red) (Major disruptions)
  - long duration
  - multi-lane blockages
- ACCIDENTS (yellow) (Minor disruptions)
  - shorter durations
  - shoulder or single-lane events
- modeled as temporal reduction in capacity

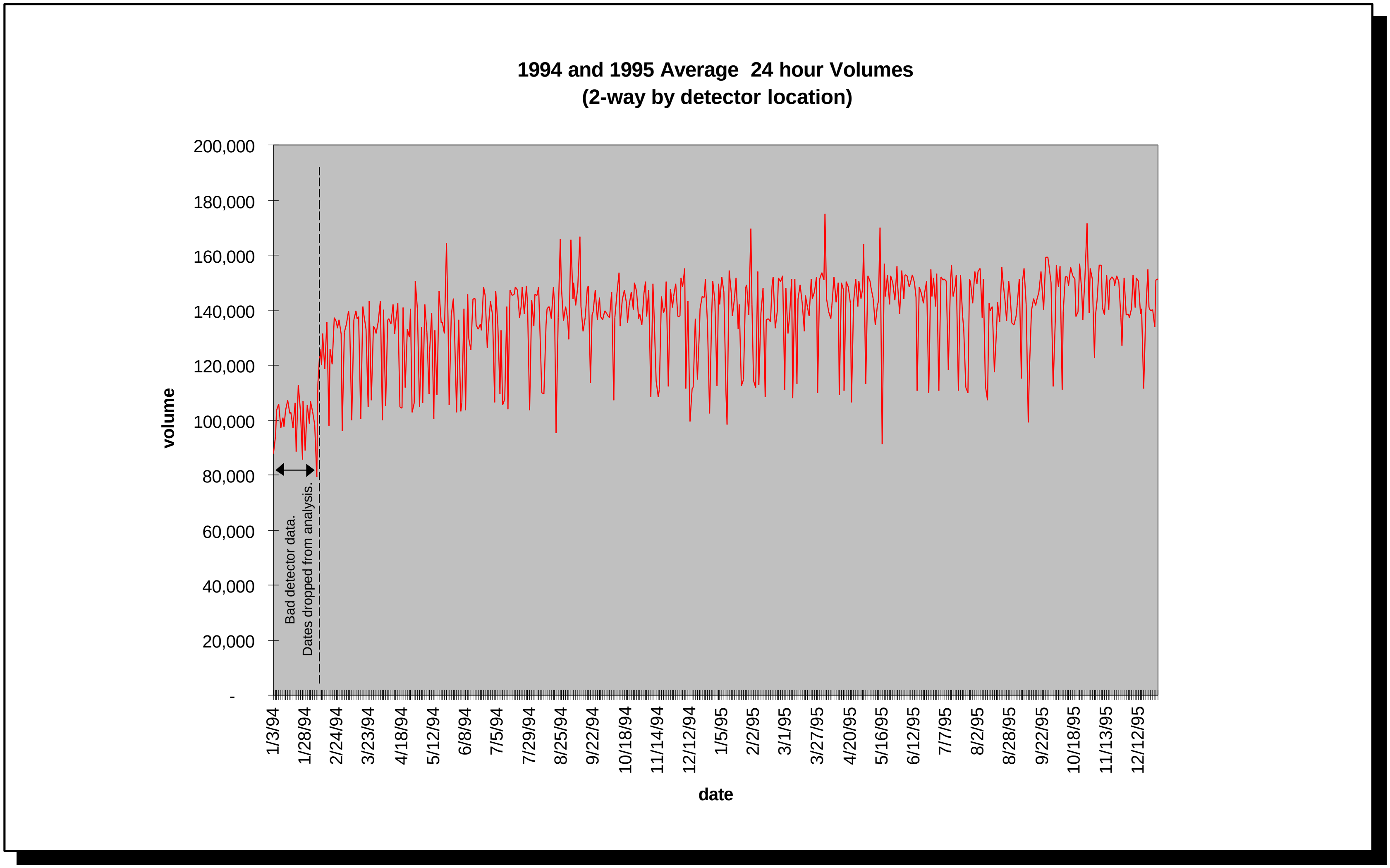


Modeling Weather in Simulation: Global Reduction in Capacity

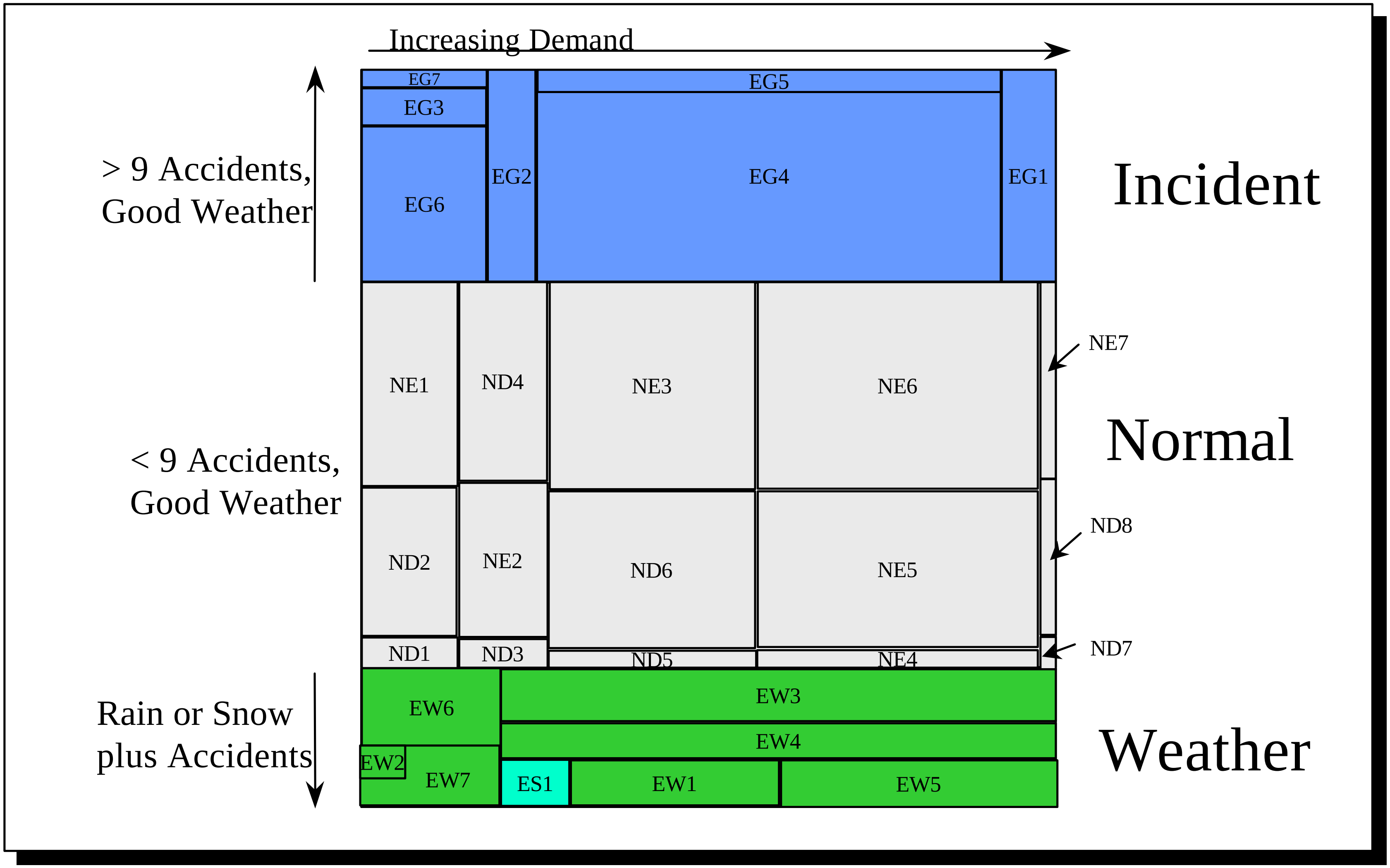
Condition	Capacity Percent Change	Speed at Capacity Percent Change	Free Flow Speed Percent Change
Wet/Rain	-12%	-20%	-10%
Frozen/Snow	-20%	-35%	-20%

Source: Highway Capacity Manual, 1994,
Hall and Barrow,1988, Ibrahim and Hall, 1994 ,
Hanbali and Kuemmel, 1993, Gillam, 1992

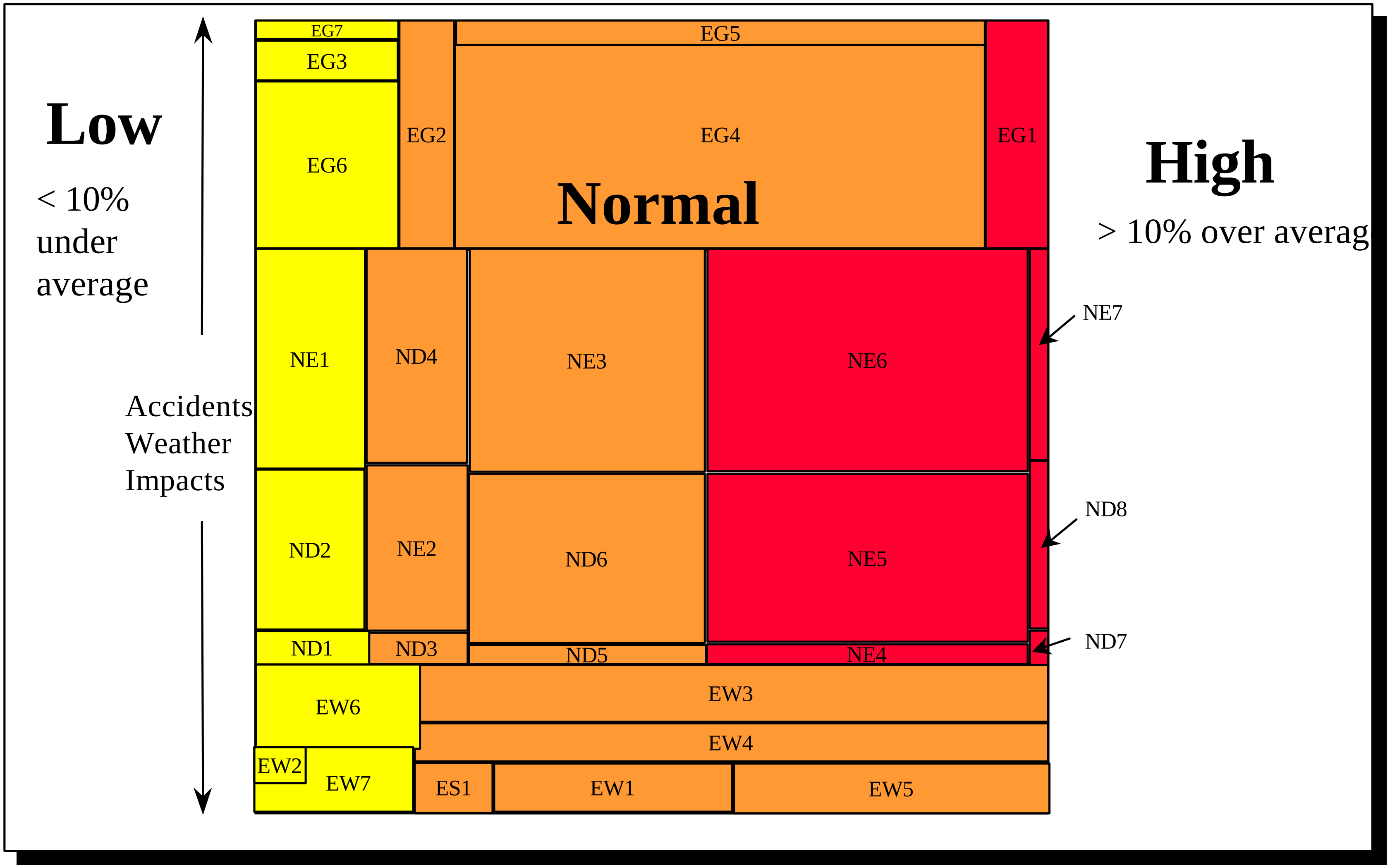
Modeling Day-to-Day Variation in Demand



Classifying Intensity/Frequency of System Perturbations (Supply-Side)



Classifying Intensity/Frequency of System Perturbations (Demand-Side)

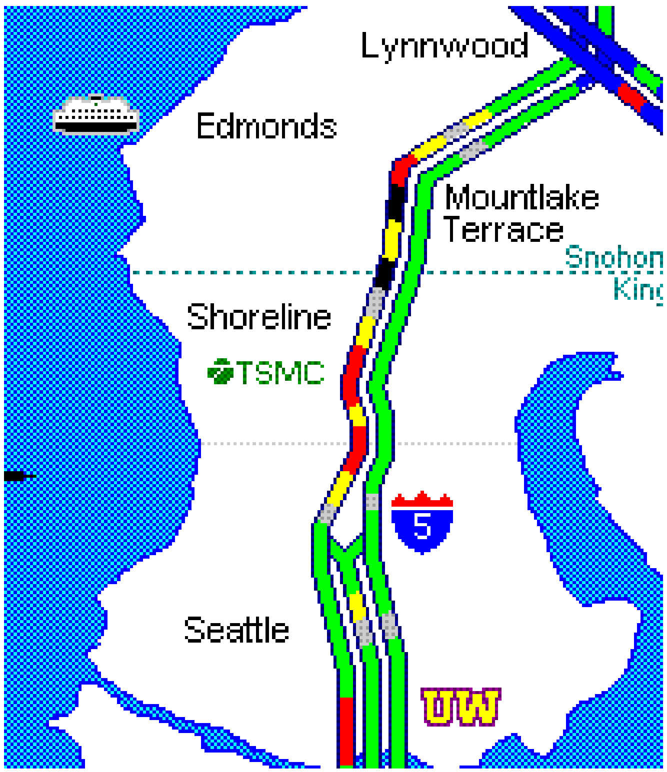


Role of Scenarios

- Acts as the bridge between the two modeling scales
- Highlights performance of ITS strategies under varied conditions
- Allows for annualized benefits calculation
- Facilitates the calibration of both within-day and between-day system variation
  - if system variability overstated, then ITS benefits likely to be overstated
  - if system variability understated, then ITS benefits likely to be understated

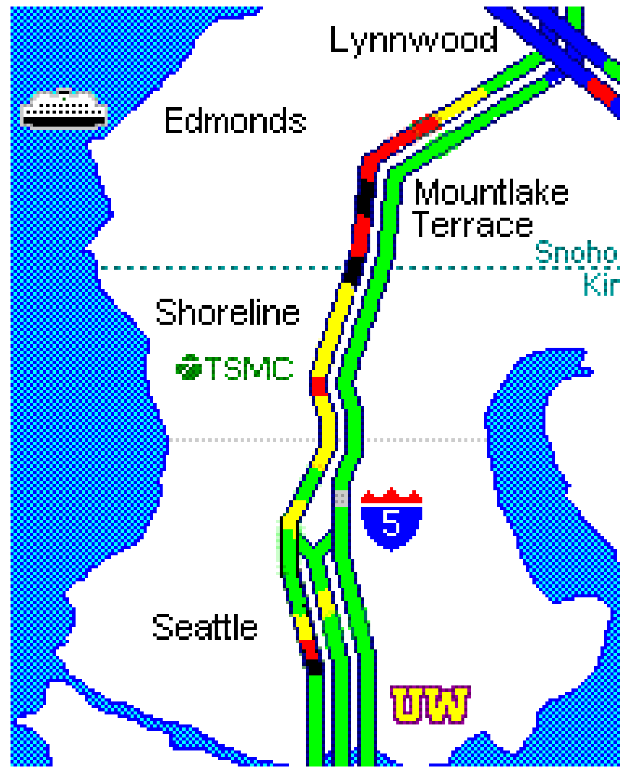
Simulation Calibration: Location of Recurrent Bottlenecks

OBSERVED



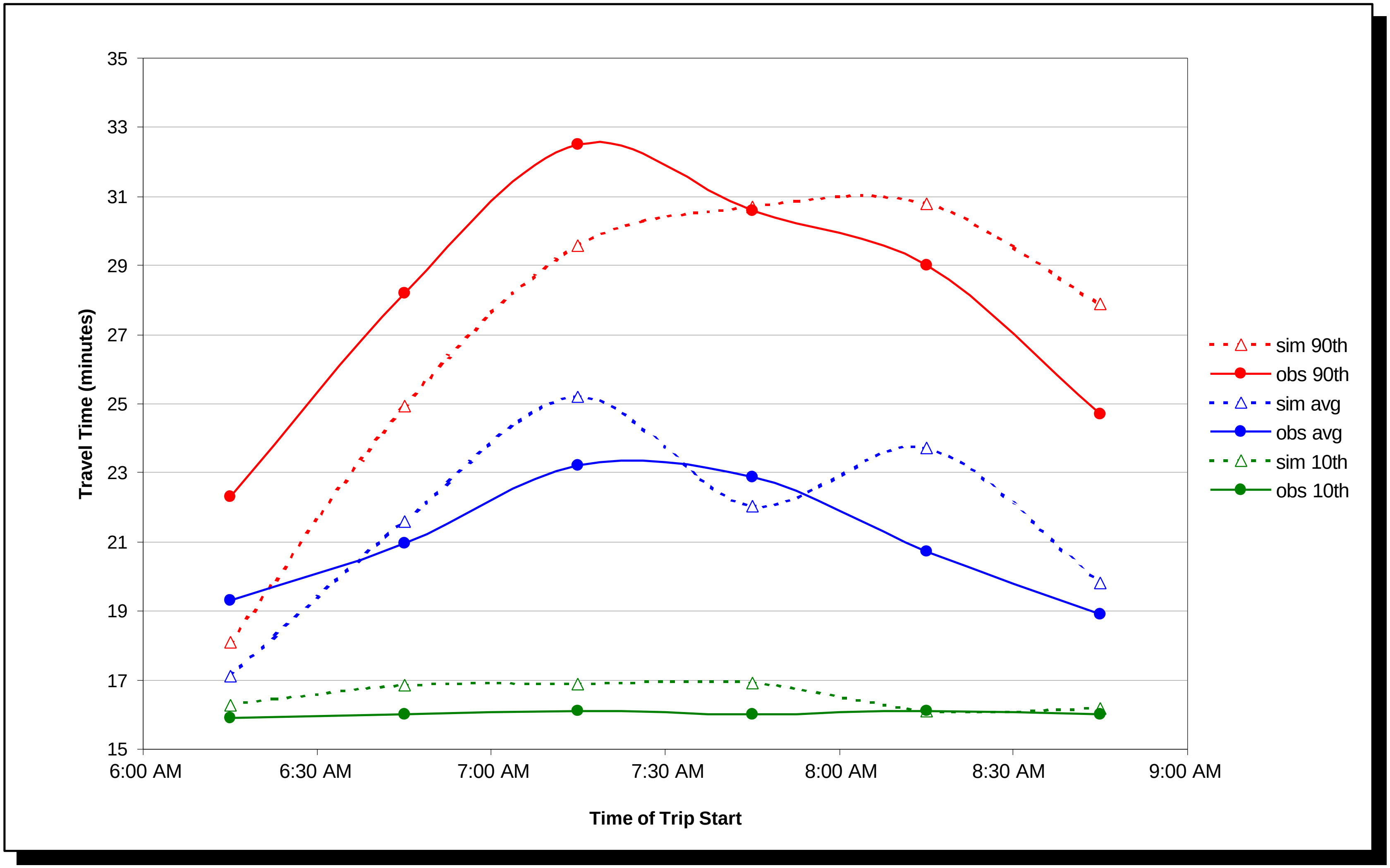
7:03 AM 3/11/97

SIMULATED



7:00 - 7:15 AM

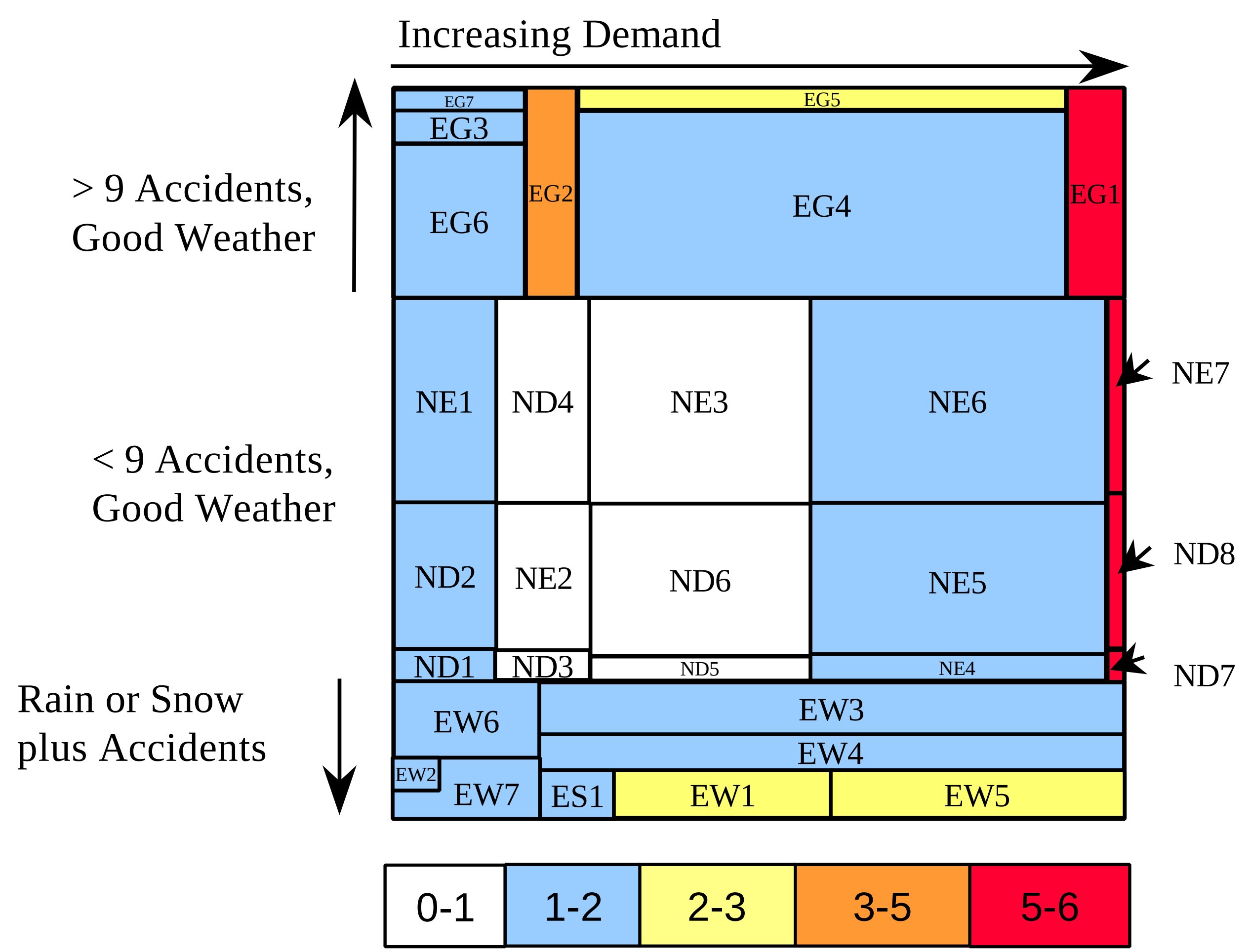
System Variability Calibration: Southbound I-5, Alderwood Mall to Mercer



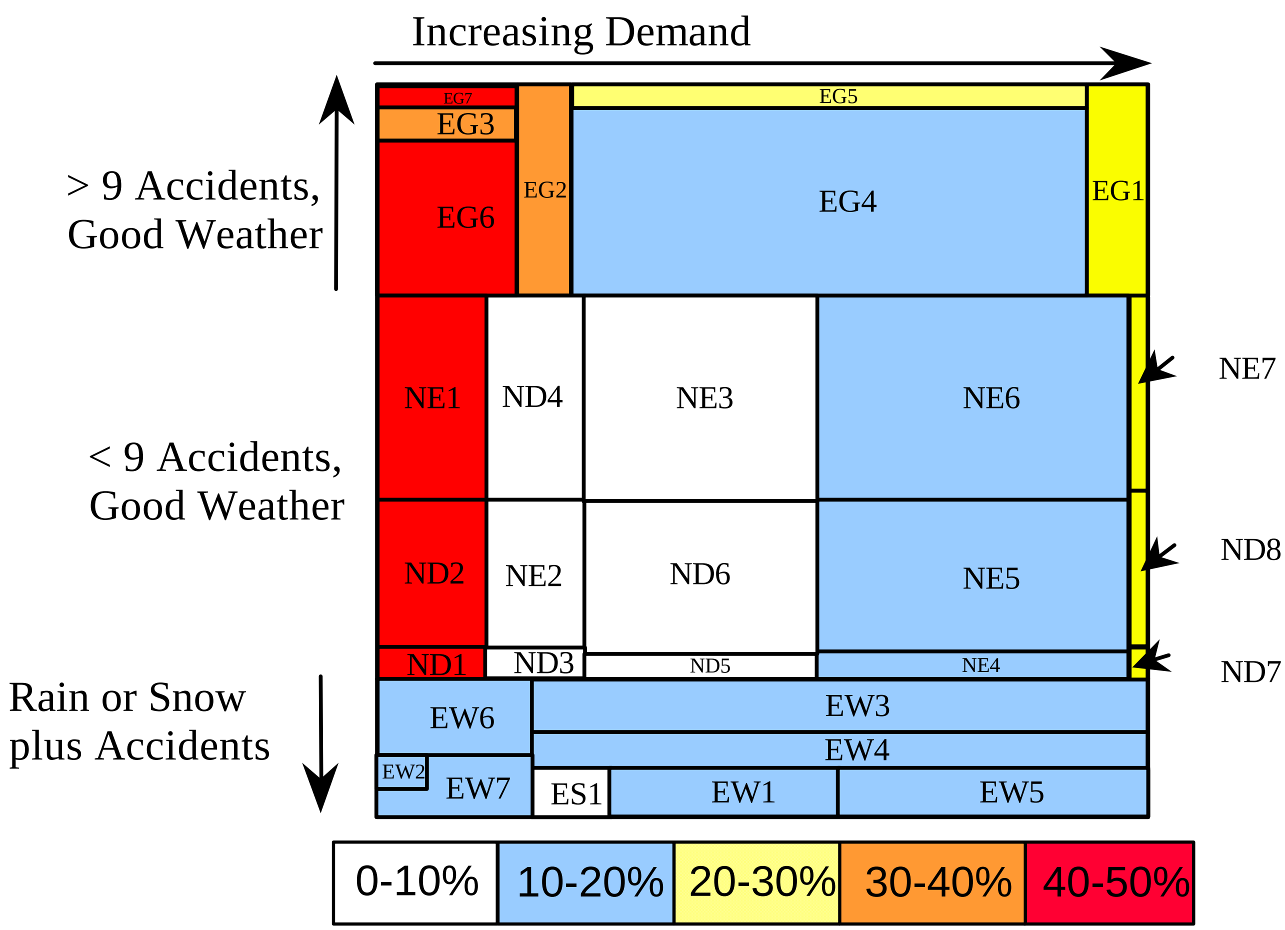
2020 Case Study
Measures of Effectiveness

- Measures from the Planning Model
  - Travel Times
  - Travel Patterns and Mode Shift
  - VMT/PMT
- Measures from the Simulation Model
  - Delay Reduction
  - Vehicle Throughput
  - Travel Time Variability
  - Risk of a Significant Delay
  - Travel by Speed Range
  - Stops per Veh-Km of Travel

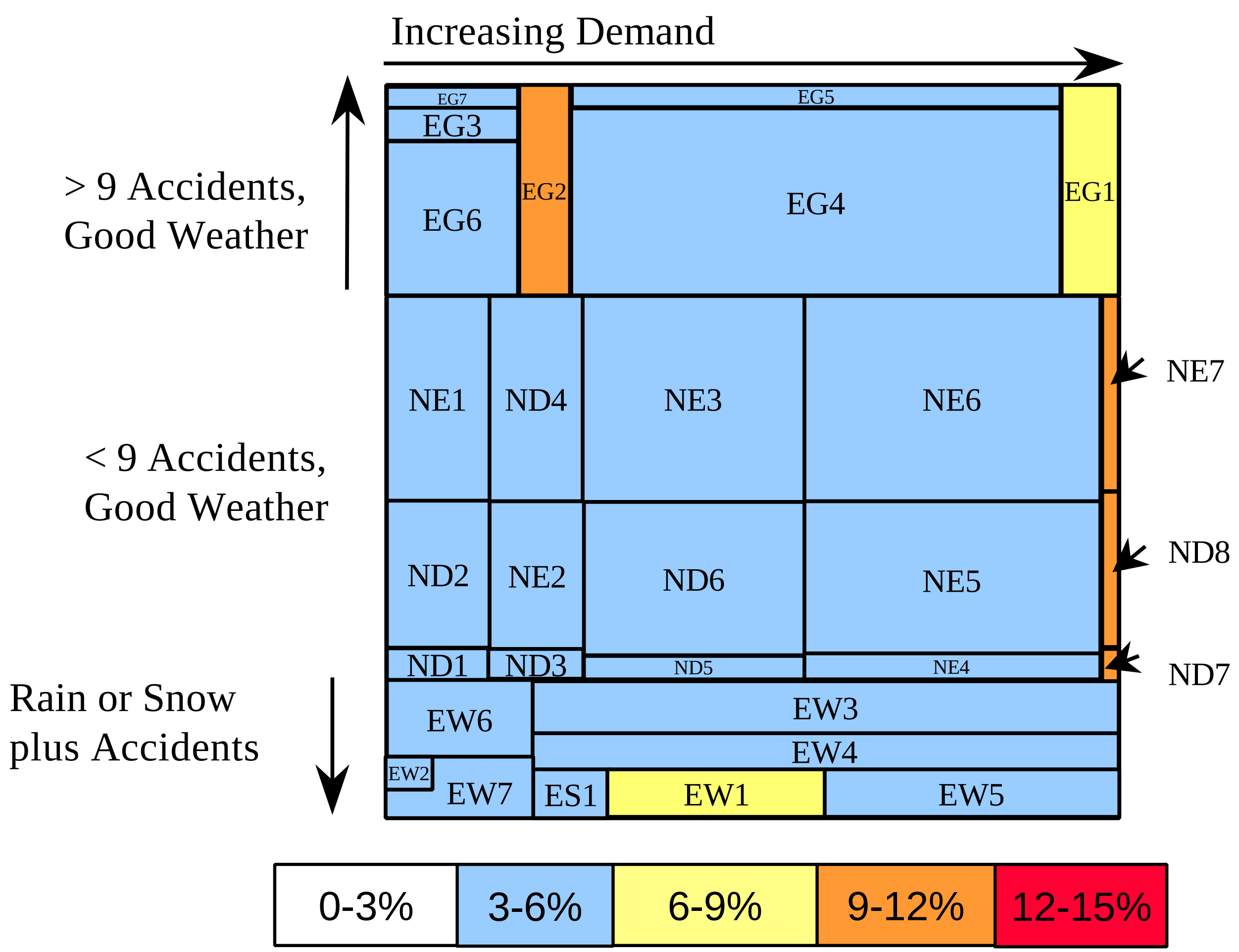
Delay Reduction (Minutes)
ITS Rich vs. Baseline Alternative



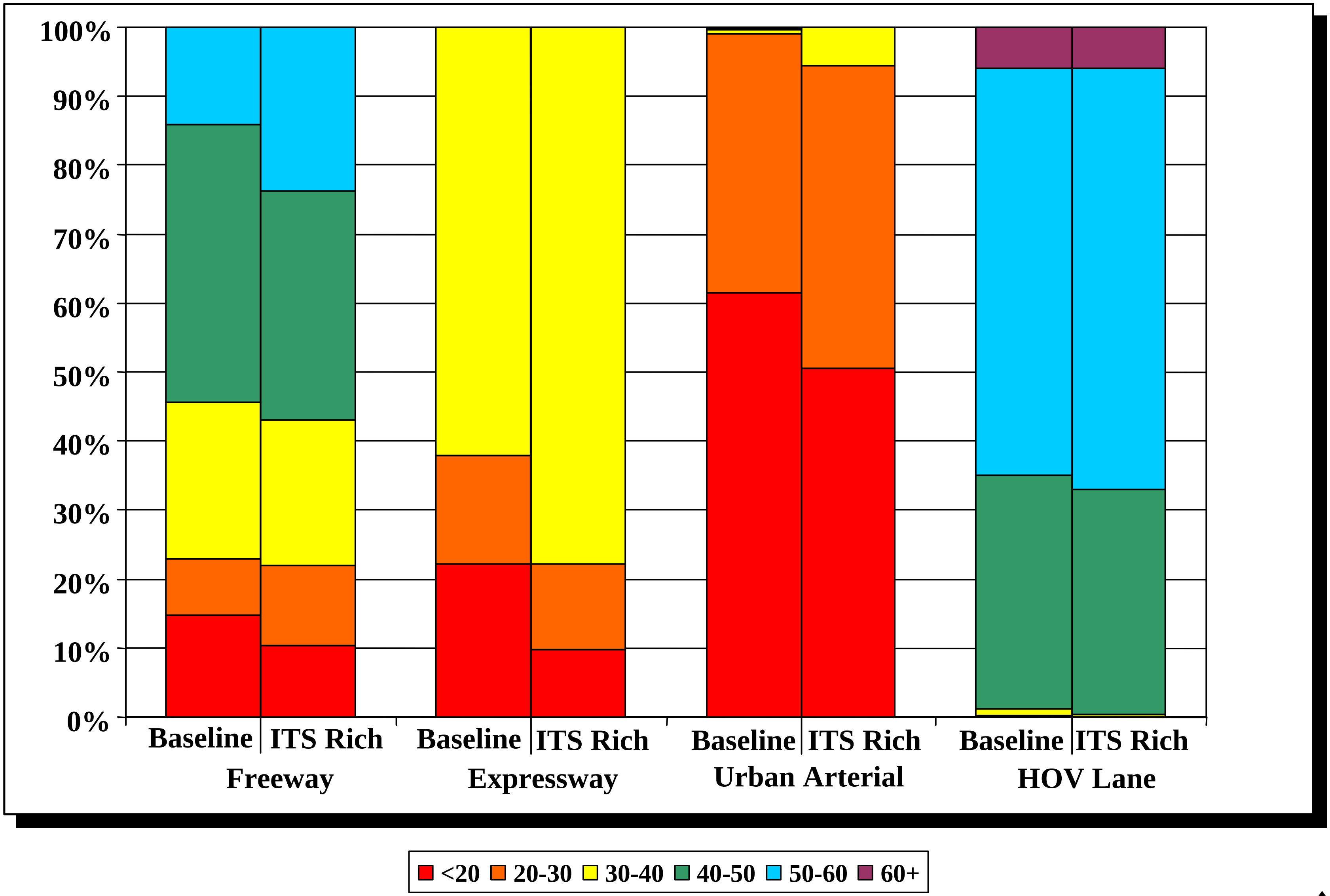
Percent Delay Reduction
ITS Rich vs. Baseline Alternative



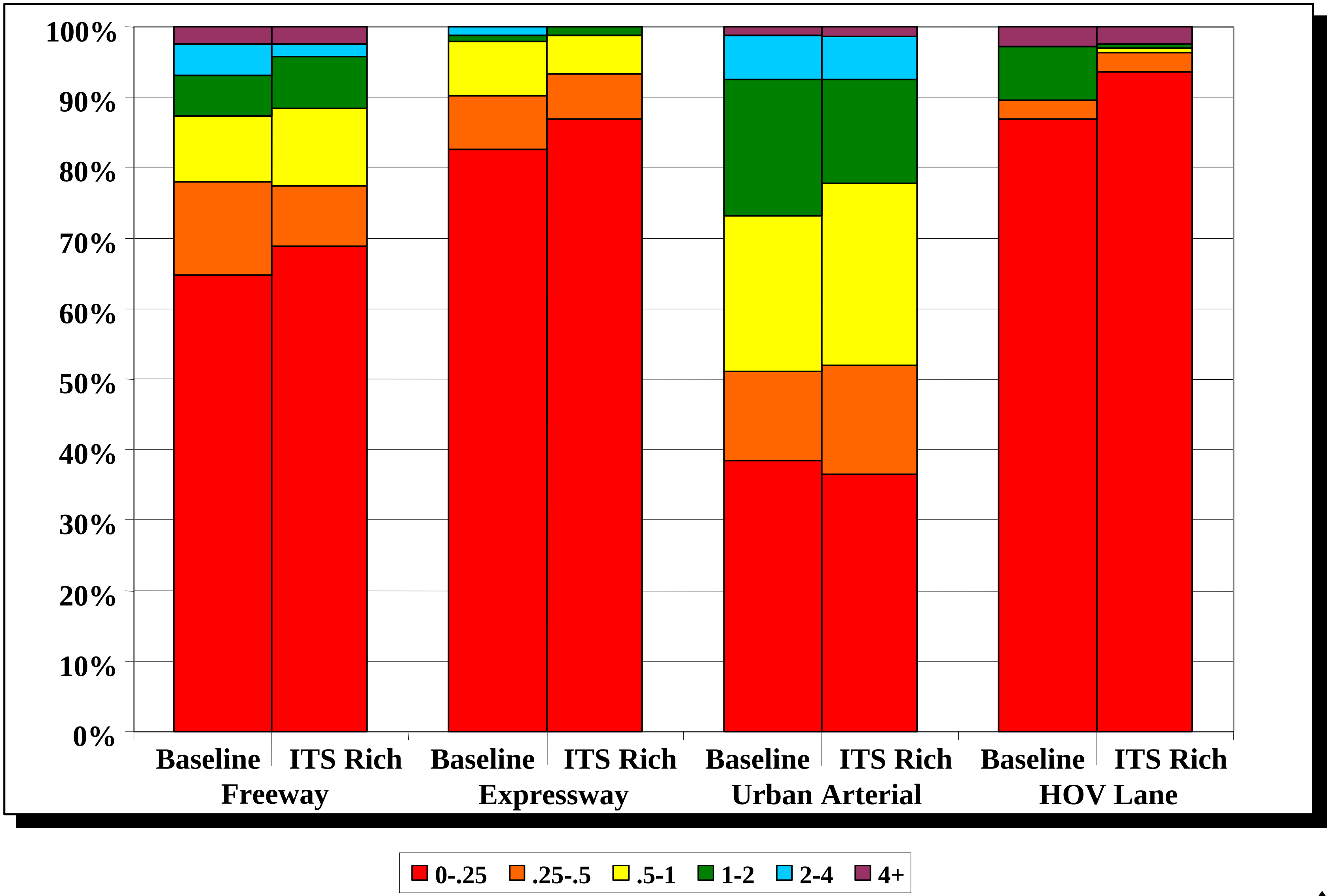
Percent Increase in Corridor Throughput ITS Rich vs. Baseline Alternative



Percentage of Vehicle-Km By Speed Range ITS Rich Vs. Baseline Alternative



Expected Number of Stops Per Vehicle-Km
ITS Rich Vs. Baseline Alternative



Annualized Impacts: ITS Rich vs. Baseline

- **Average AM Peak Period Throughput (completed trips)**
  - **baseline: 172,000 trips complete in peak period**
  - **ITS Rich: 180,000 trips (4.3% increase over base)**
- **Average AM Peak Period Delay**
  - **baseline: 10.88 minutes per traveler**
  - **ITS Rich: 9.28 minutes (14.7% reduction from base)**
- **Trip Time Variability (Coeff. Of Variation for Travel)**
  - **baseline: 0.31**
  - **ITS Rich: 0.22 (reduction by 1/3 from base)**

to be on-time 67% of the time for an average 30-minute commute:
a traveler in the baseline case must budget 39 minutes,
in the ITS rich case 36 minutes

Summary

- Need new approaches to capture the impacts of ITS
- The PRUEVIIN methodology is *an evolutionary extension of current tools and can be applied in today's environment*
- Provides assessment of ITS alone and in combination with traditional transportation improvements
- Provides a tool that *can be used repeatedly by both planners and operations personnel to optimize and tune* the transportation system
- For more information on PRUEVIIN contact, Don Roberts a 202-863-2976 or dlrobert@mitretek.org