Agent-Based Methods for Transportation Network Optimization

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Agents and Their Behaviors

Decision Type	Agents	Time Scale	Influenced By (Major Factors Only)
Driving Behavior	**Driver, Vehicle**	Real-time	Real-time surrounding traffic conditions
En-Route Diversion	**Driver, Vehicle**	Real-time	Real-time congestion, traveler information, traffic management, toll
Pre-Trip Route Choice	**Person**	Daily, Short-term	Network knowledge, experience, information, traffic management, toll
Departure Time	**Person**	Short-term, Fixed for most work trips	Schedule flexibility, dynamic tolls, information
Mode Choice	**Household, Person**	Mid-term	Modal performance, personal attributes, vehicle ownership
Destination Choice	**Household, Person**	Midterm (e.g. shopping) or Long-Term (work)	Spatial knowledge, information, network LOS, HH/personal attributes
Trip Frequency	**Household, Person**	Mid- to long-term, but partially adjustable daily	Activity patterns, household/personal attributes
Vehicle Ownership	**Household**	Mid- to long-term	Household attributes
Location Choice	**Household**	Long-term	Household attributes, land use

Theory and Methodology

Traditional: Rational Behavior Theory

- What agents SHOULD do
- Perfect information and rationality
- Optimizing behavior
- Maximizing utility, profit, welfare, etc.

→ **Econometric Models and Mathematical Optimization**

Equilibrium Analysis

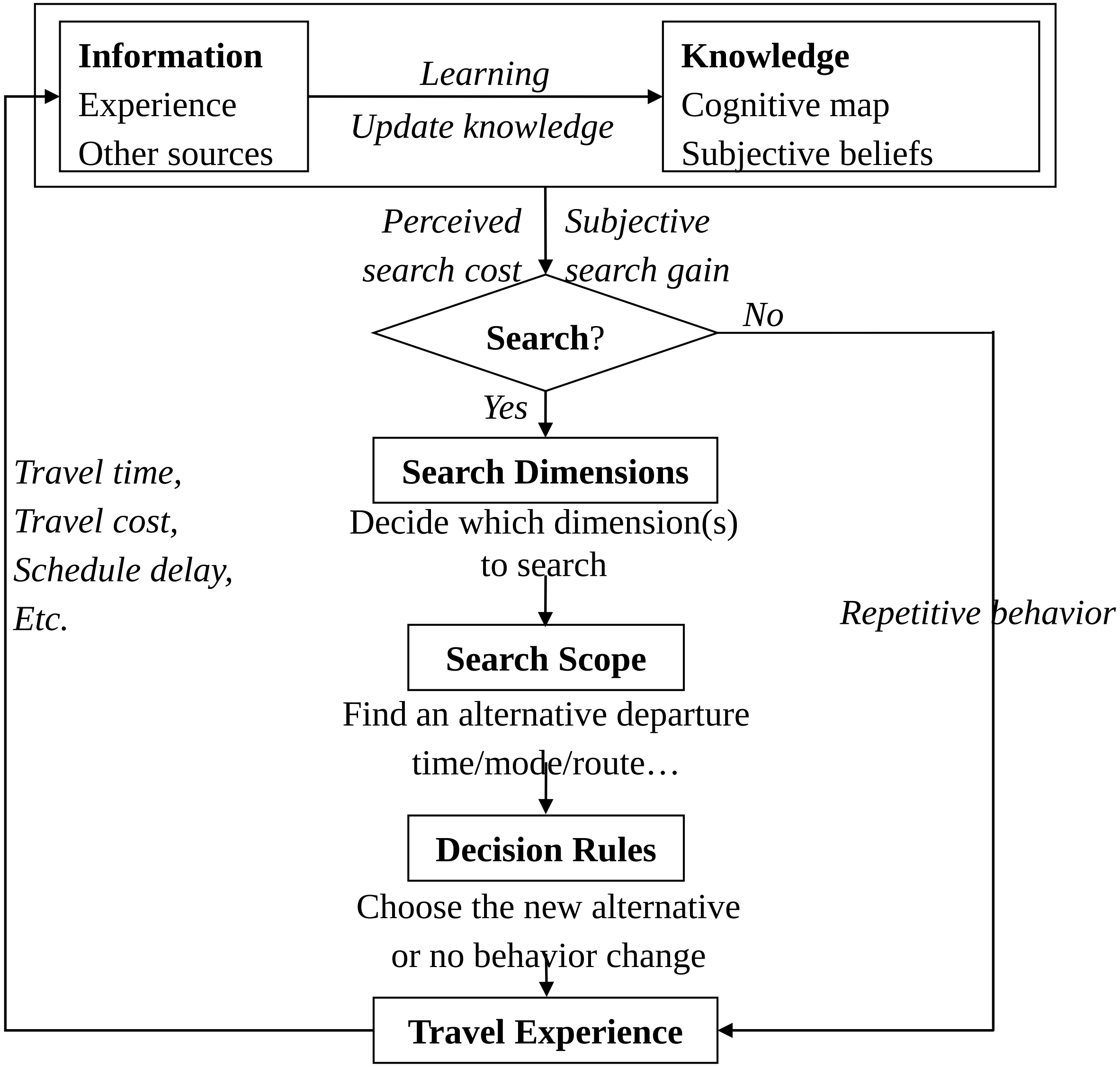
Emerging: Descriptive Behavior Theory

- What agents ACTUALLY do
- Imperfect knowledge and learning
- Time-dependent behavioral dynamics
- Empirically-derived behavioral rules

→ **Artificial Intelligence, Agent-Based Models, and Simulation-Based Optimization**

Evolutionary Analysis

Descriptive Travel Behavior Theory

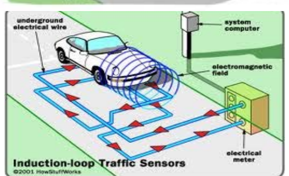


Integrated Agent-Based Model

System Supply and Operations
Agent: Agencies and Controllers

Network, Control, and Policy

Data: Traffic Counts, Speed, Travel Time, and Individual Behavior



Dynamic OD

Agent-Based Behavioral Model
Agent: Individual

Dynamic Routing
En-route diversion

Routing
Departure time
Mode choice

Calibration
Validation

Agent-Based Network Simulator
Agent: Vehicle

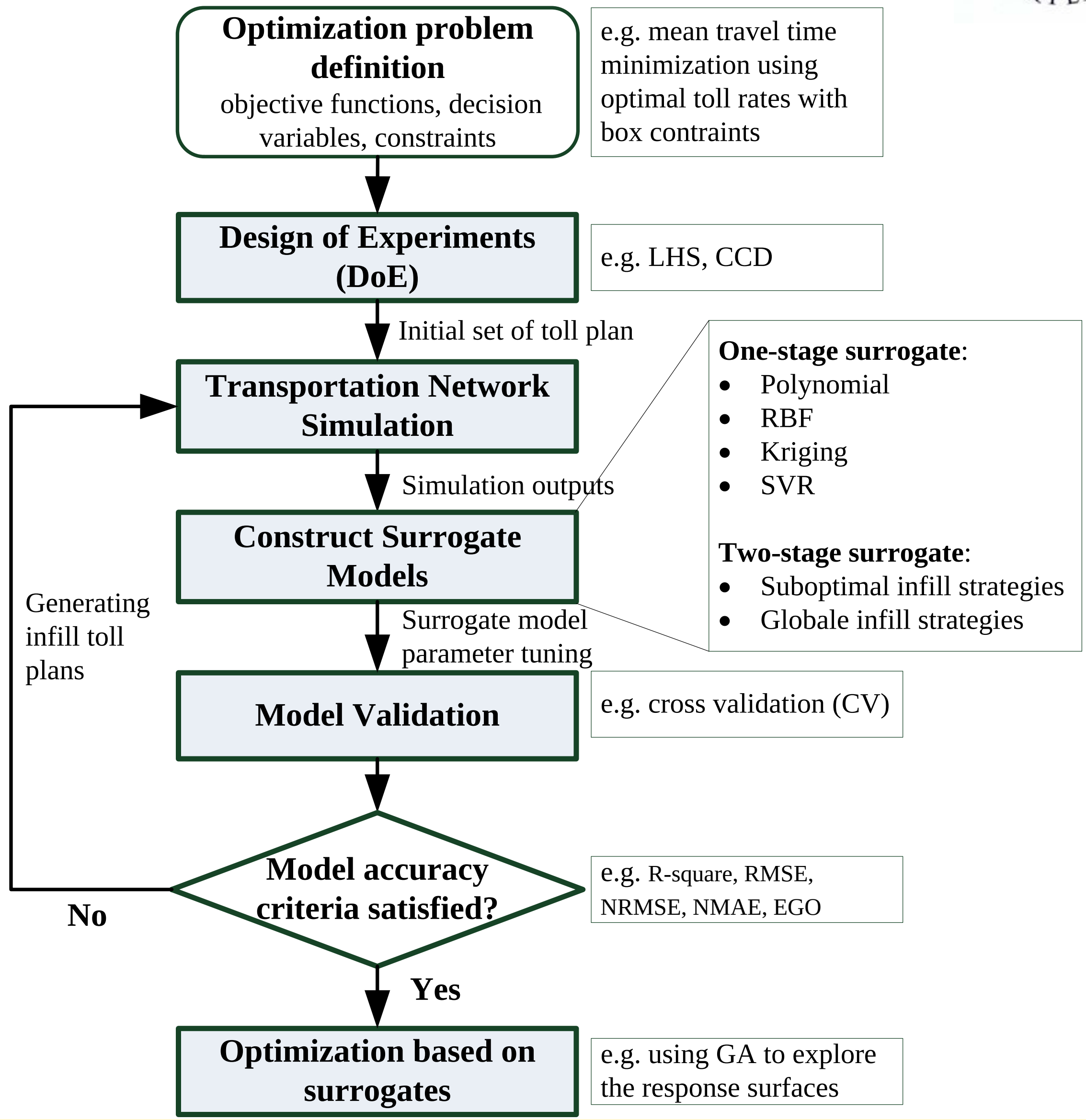
Simulated Network Performance

System Operations, Planning, and Optimization; Energy and Emissions

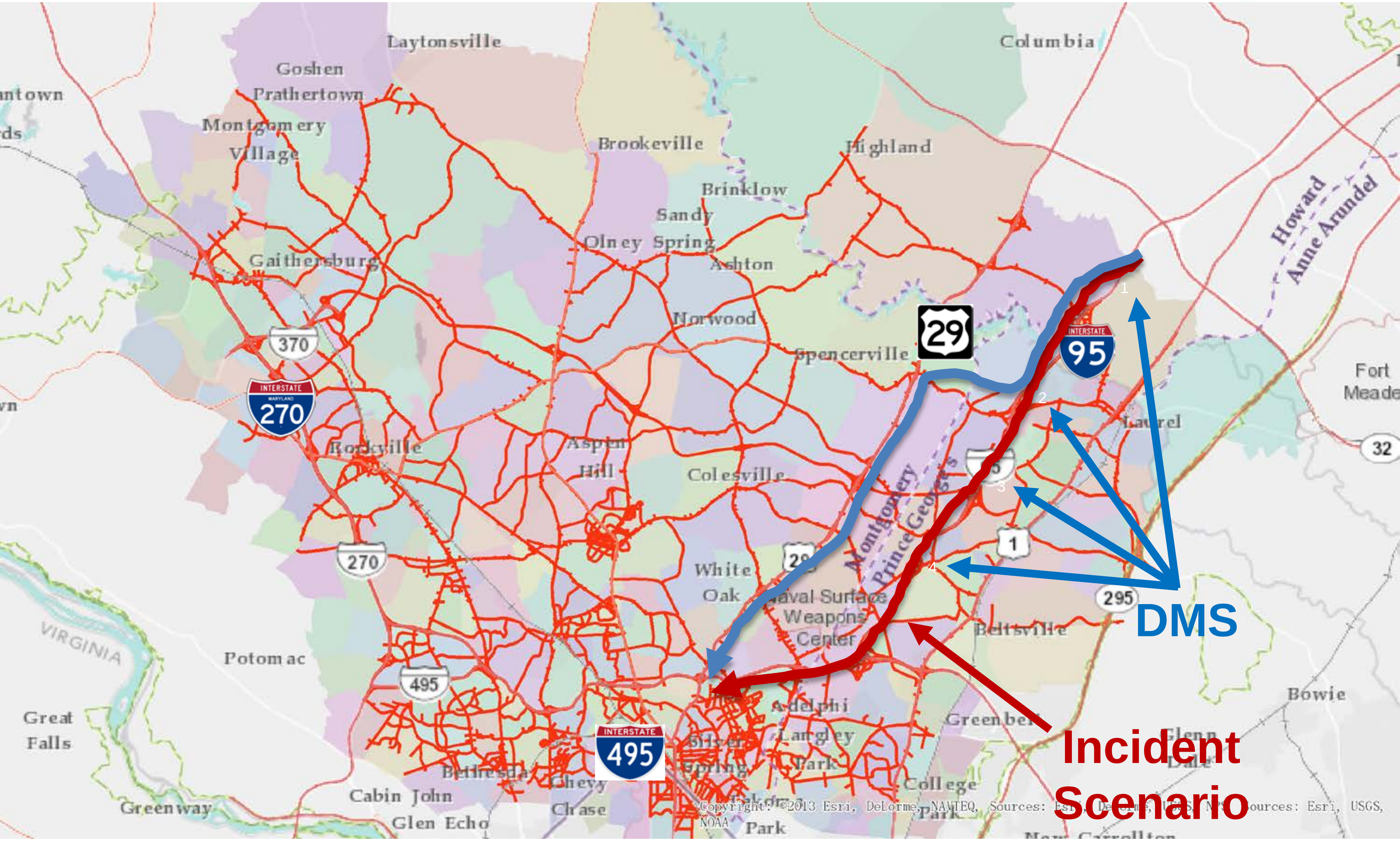
Simulation-Based Optimization

Simulation Based Optimization

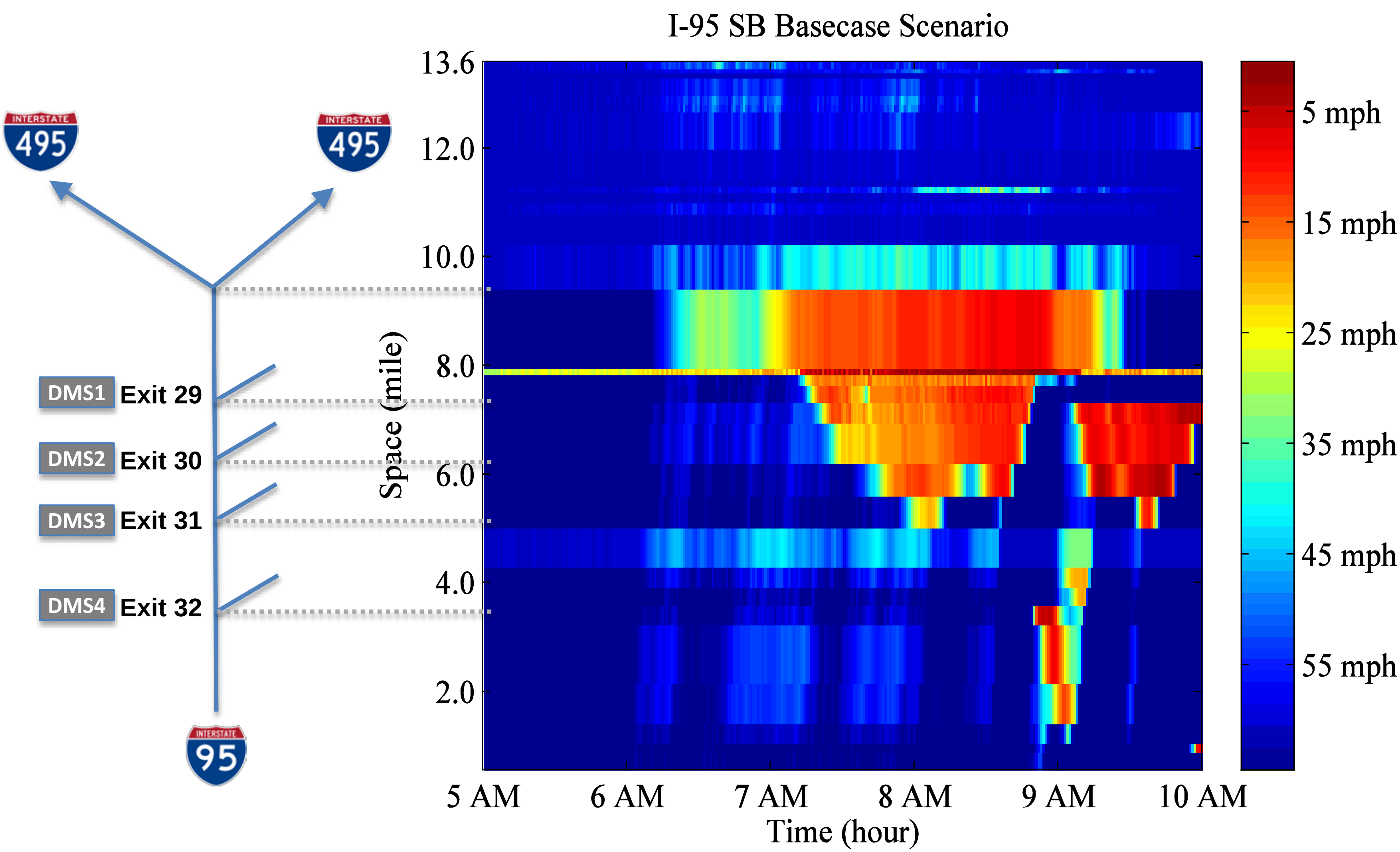
- Jointly optimize multiple operations and planning strategies
- Use simulation models for evaluation and now for optimization too
- Multiple modes can also be jointly optimized with multiple objectives



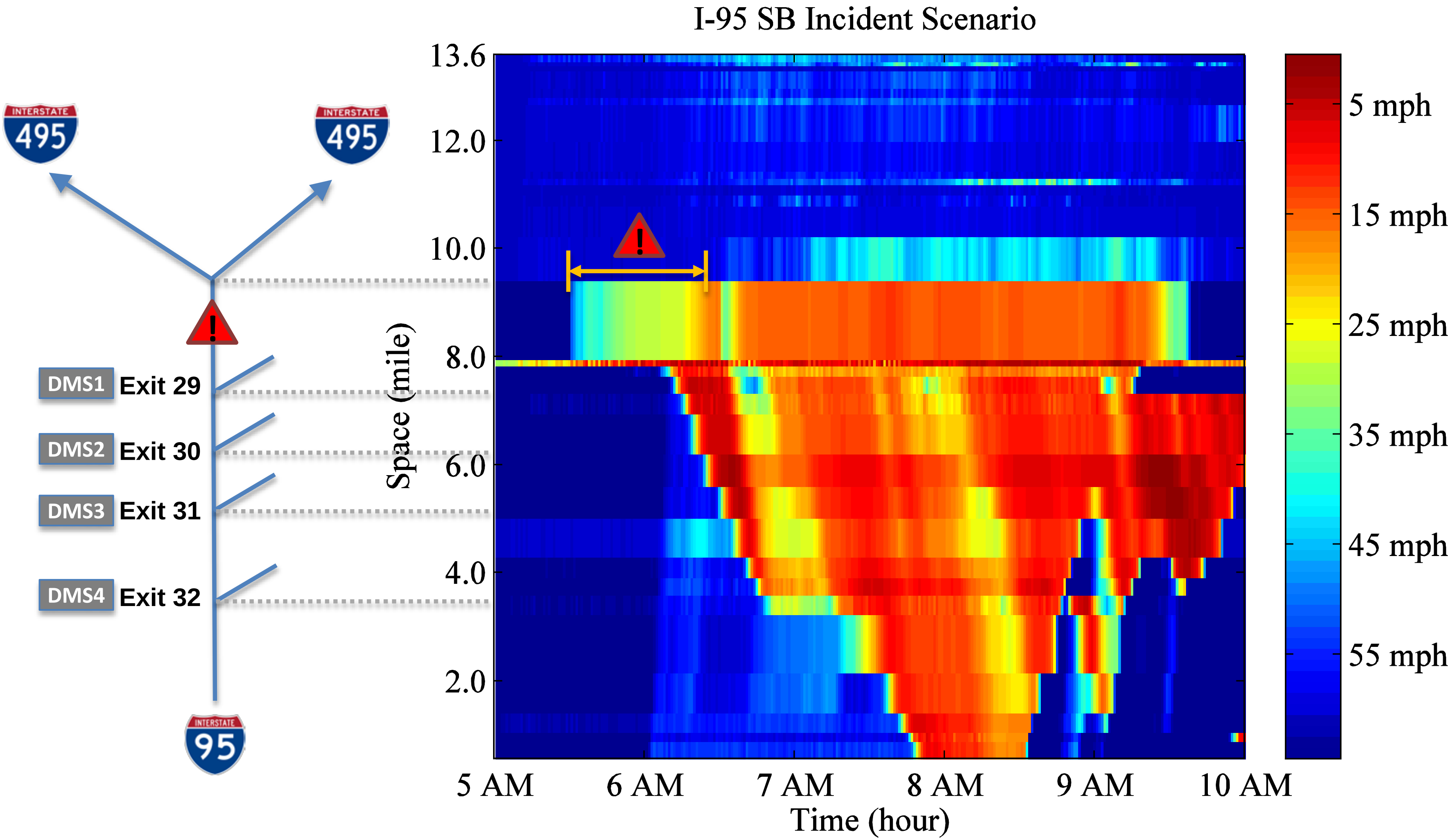
Active Corridor Traffic Management



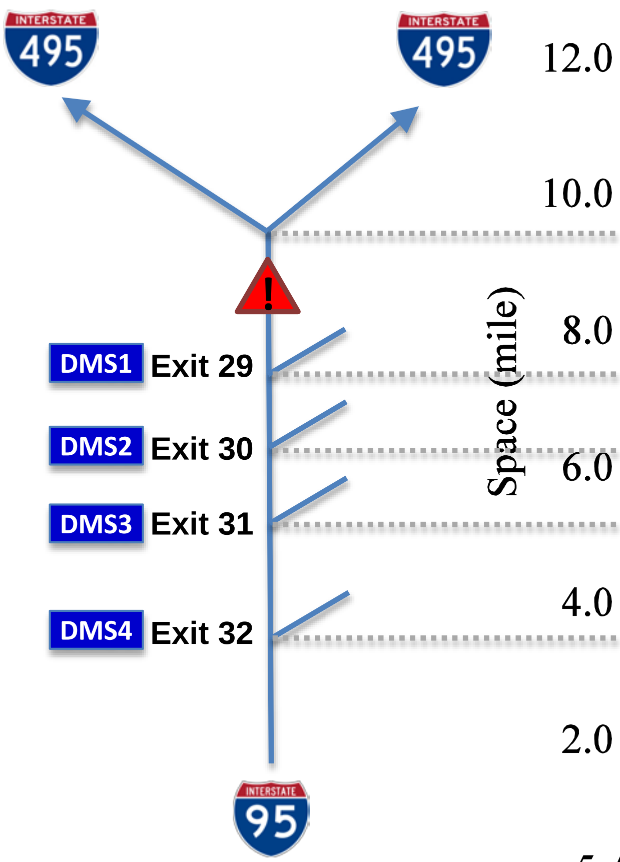
Congestion: Baseline Scenario

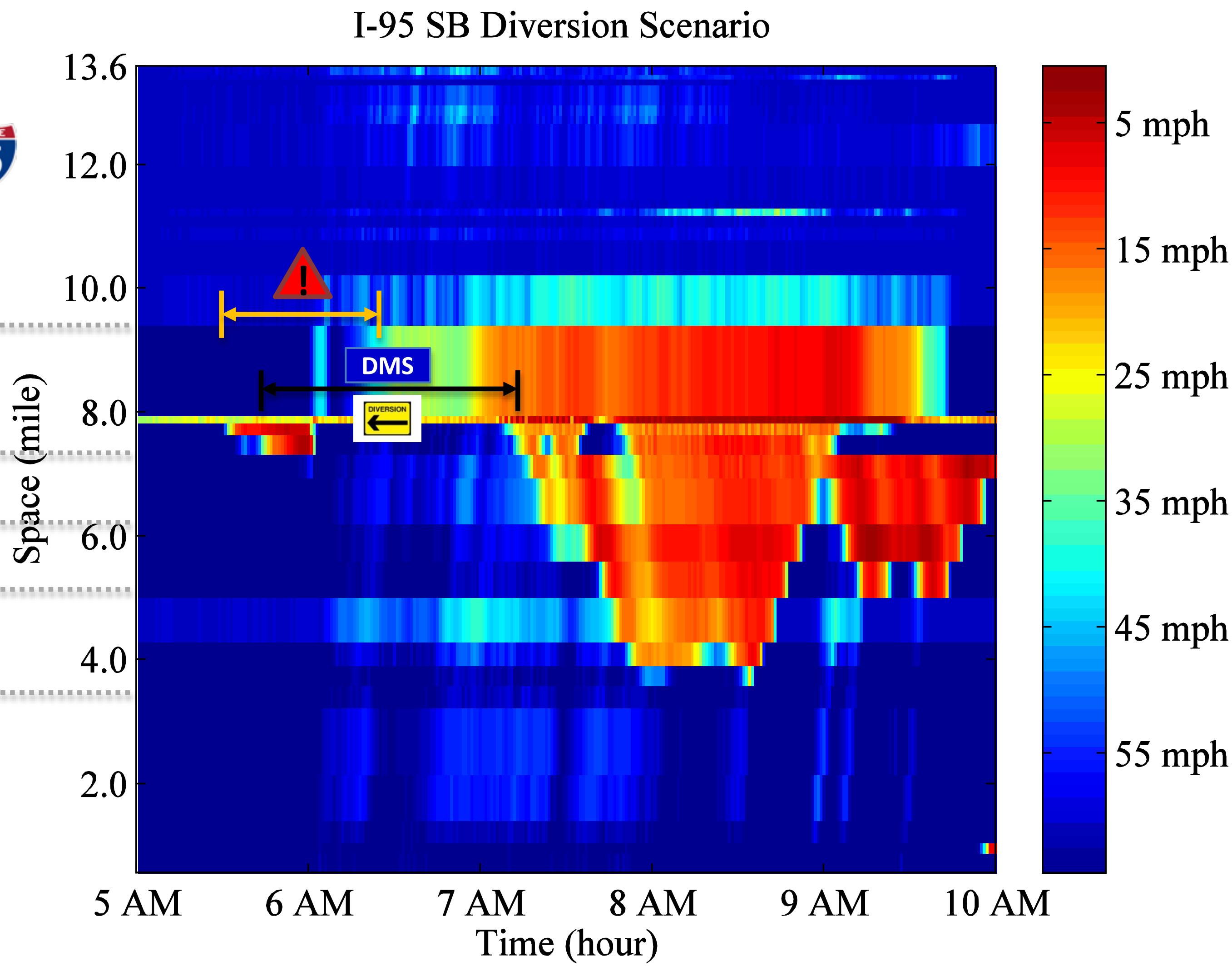


Accident without ATM

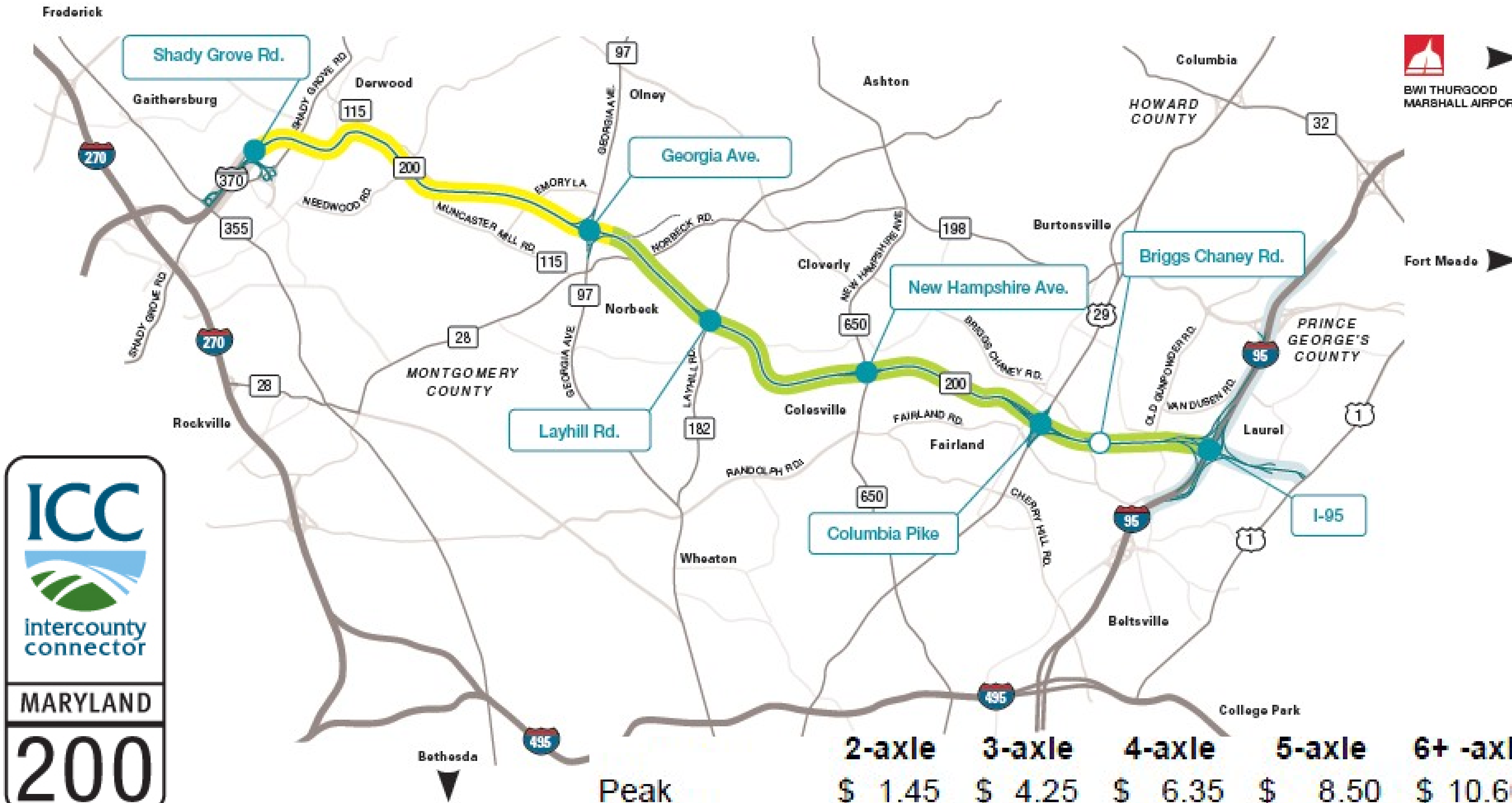


Accident with ATM





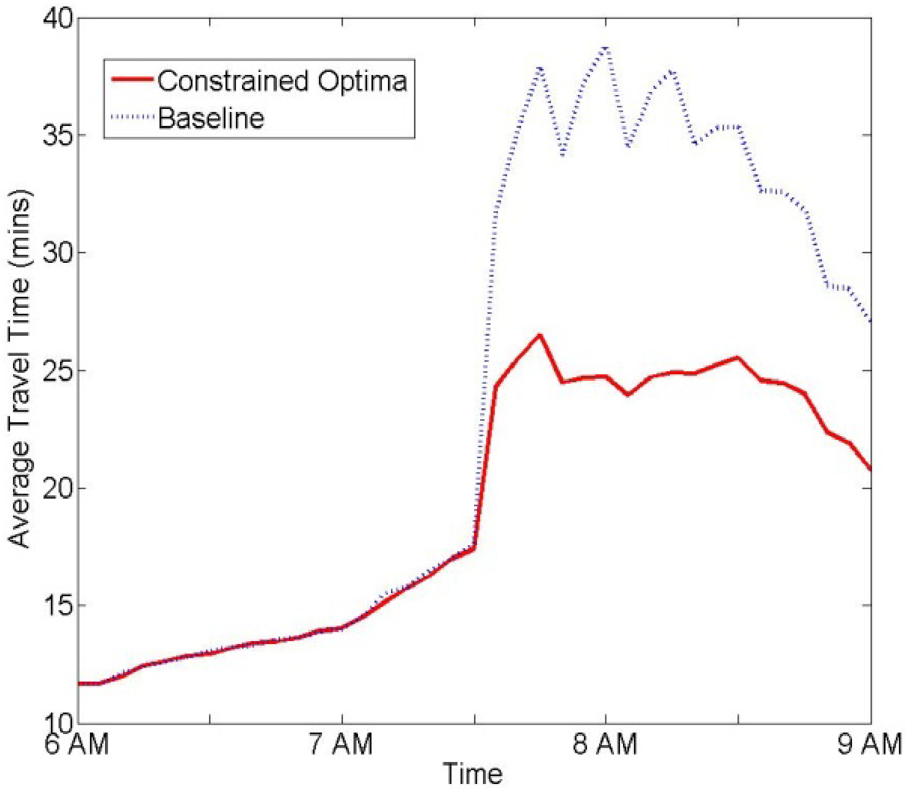
Dynamic Pricing Optimization



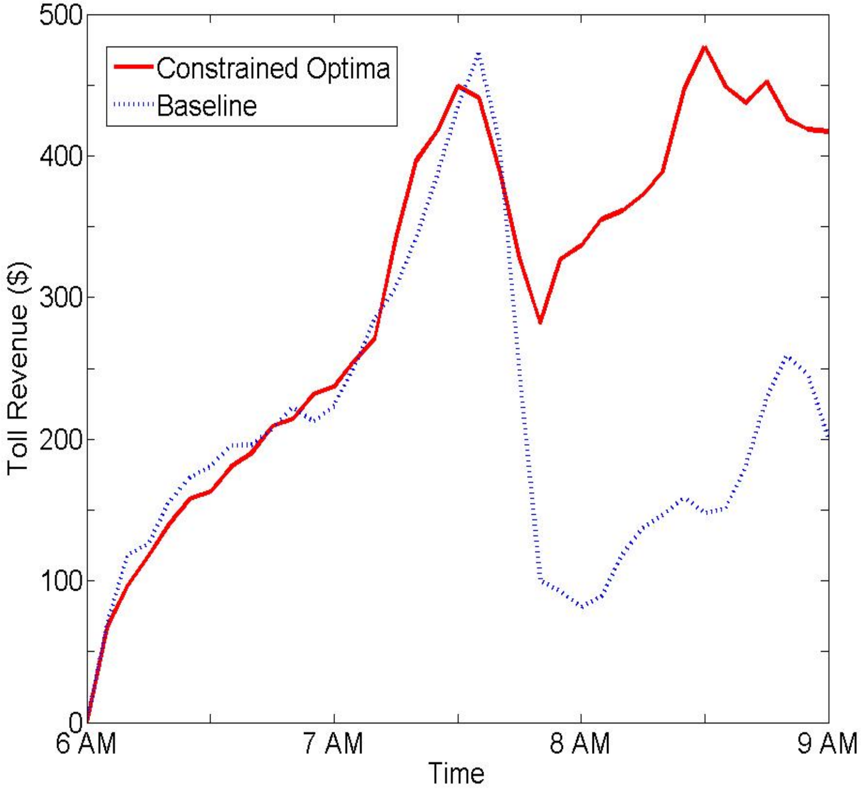
	2-axle	3-axle	4-axle	5-axle	6+ -axle
Peak	$ 1.45	$ 4.25	$ 6.35	$ 8.50	$ 10.60
Off-Peak	$ 1.15	$ 3.40	$ 5.10	$ 6.80	$ 8.50
Overnight	$ 0.60	$ 1.70	$ 2.55	$ 3.40	$ 4.25

Multi-Objective Optimization Results

Average Travel Time



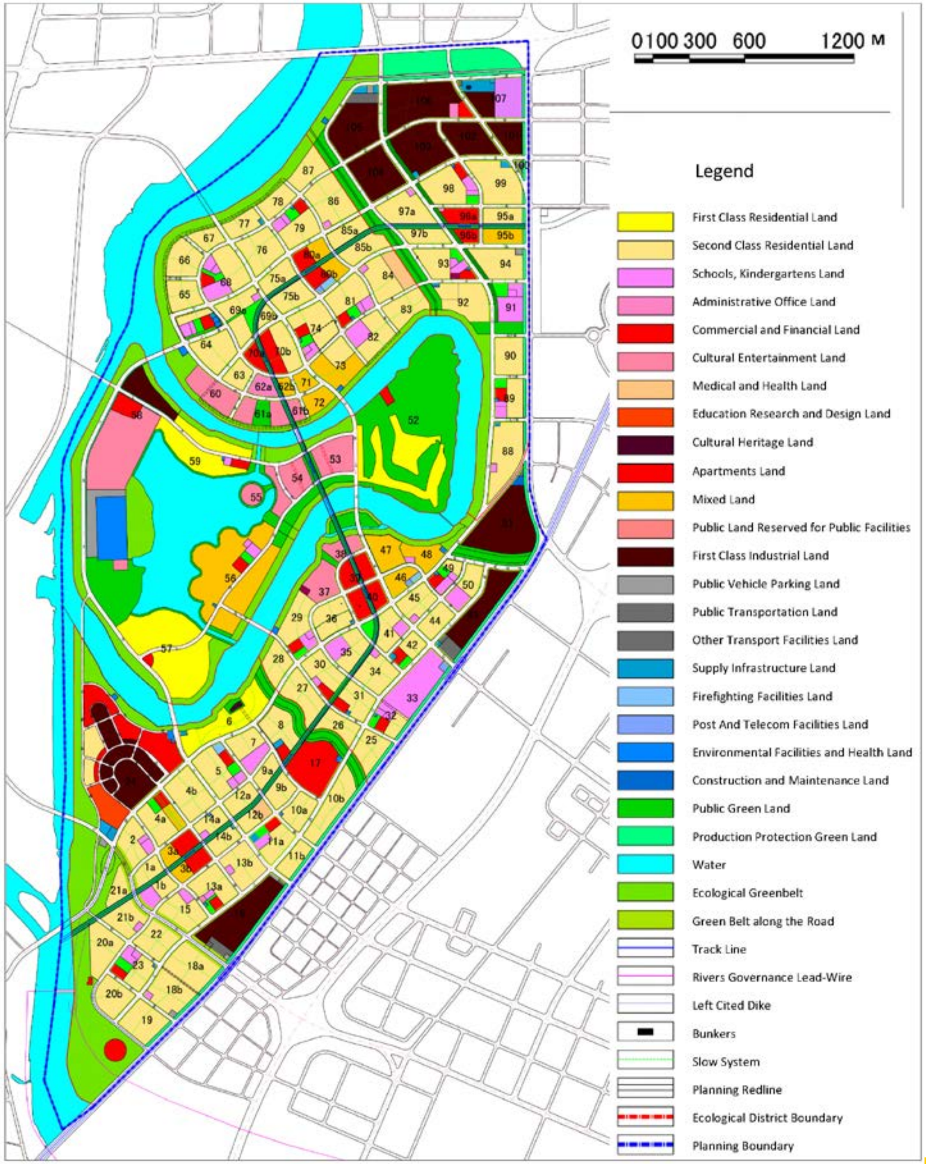
Total Toll Revenue



China-Singapore Eco-City in Tianjin

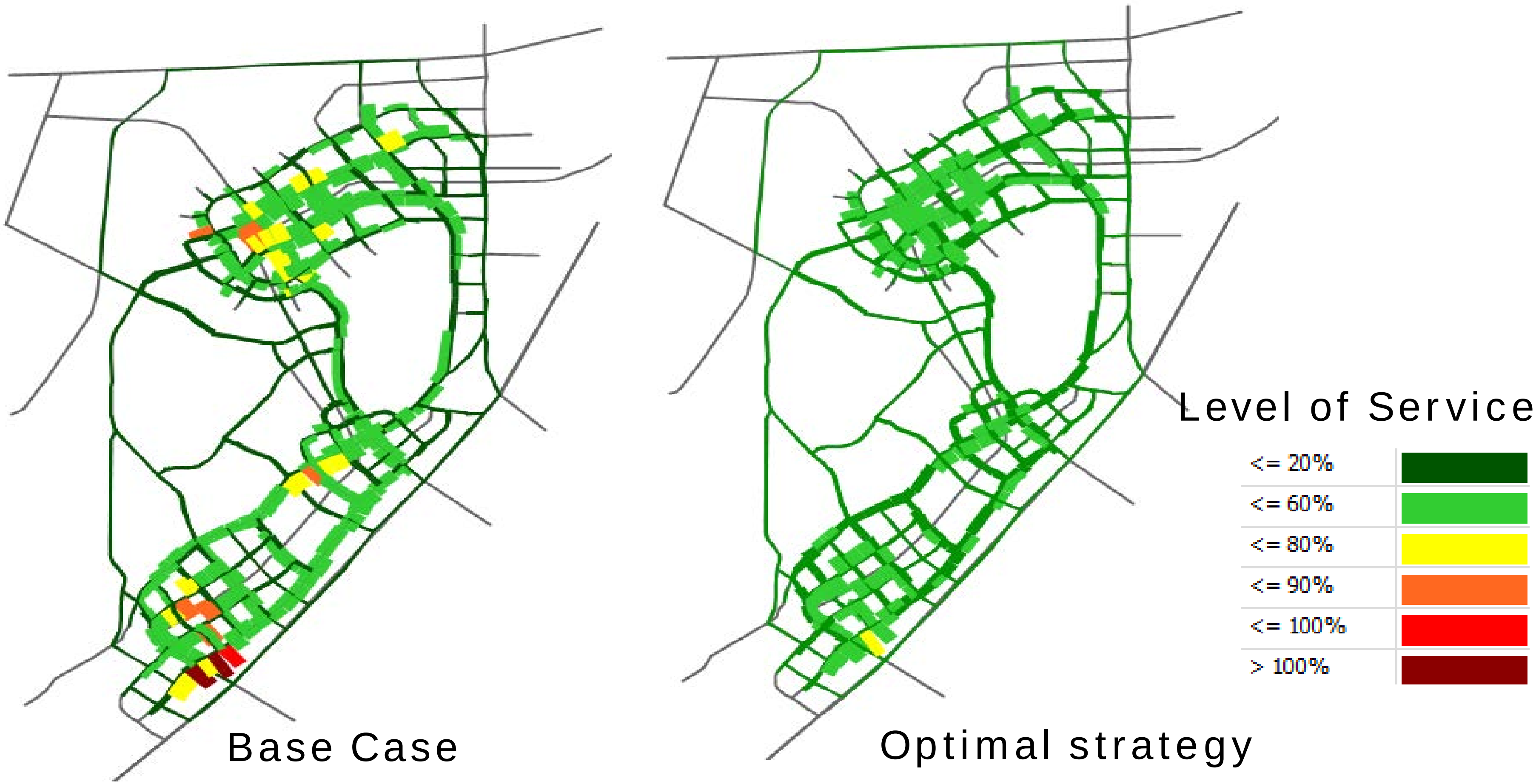
Multimodal Transportation Planning and Optimization

- Target year 2020, area 30 km^2
- Projected 350,000 residents
- Green transportation planning
- 145 TAZs, 556 nodes, 1,770 links
- 9 bus lines and 3 LRT lines
- 7 population groups, 7 activity pairs and 5 travel modes (Bus, rail, car, bike, walk)
- Transportation Planning goal: Public transportation and non-motorized modes > 90% mode share by 2020



Multimodal System Optimization

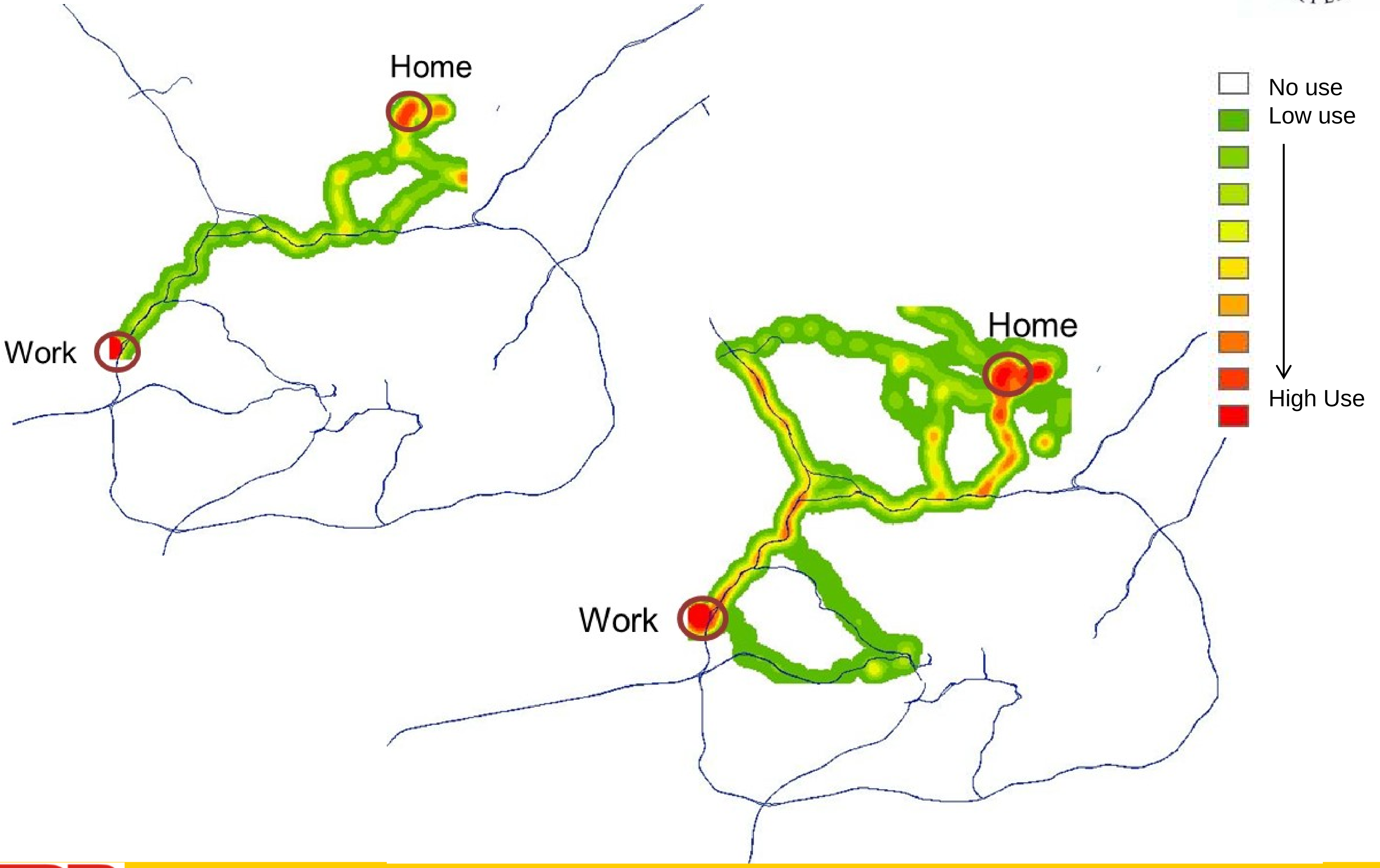
Optimal [Parking restriction + Car sharing incentive + + Transit fare] for maximum user benefits



Base Case

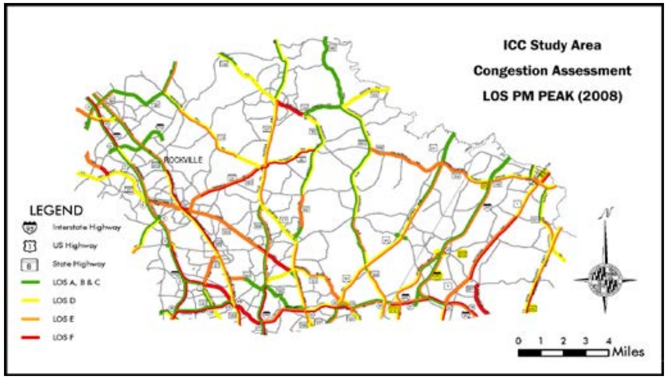
Optimal strategy

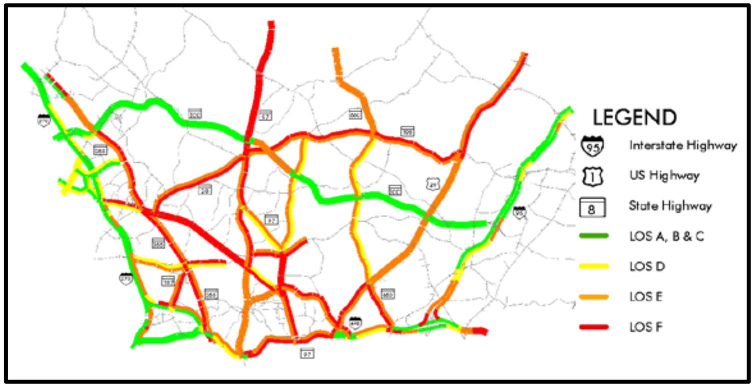
Key Challenges: Behavior Data



Model Calibration and Validation

Level-of-Service Comparison





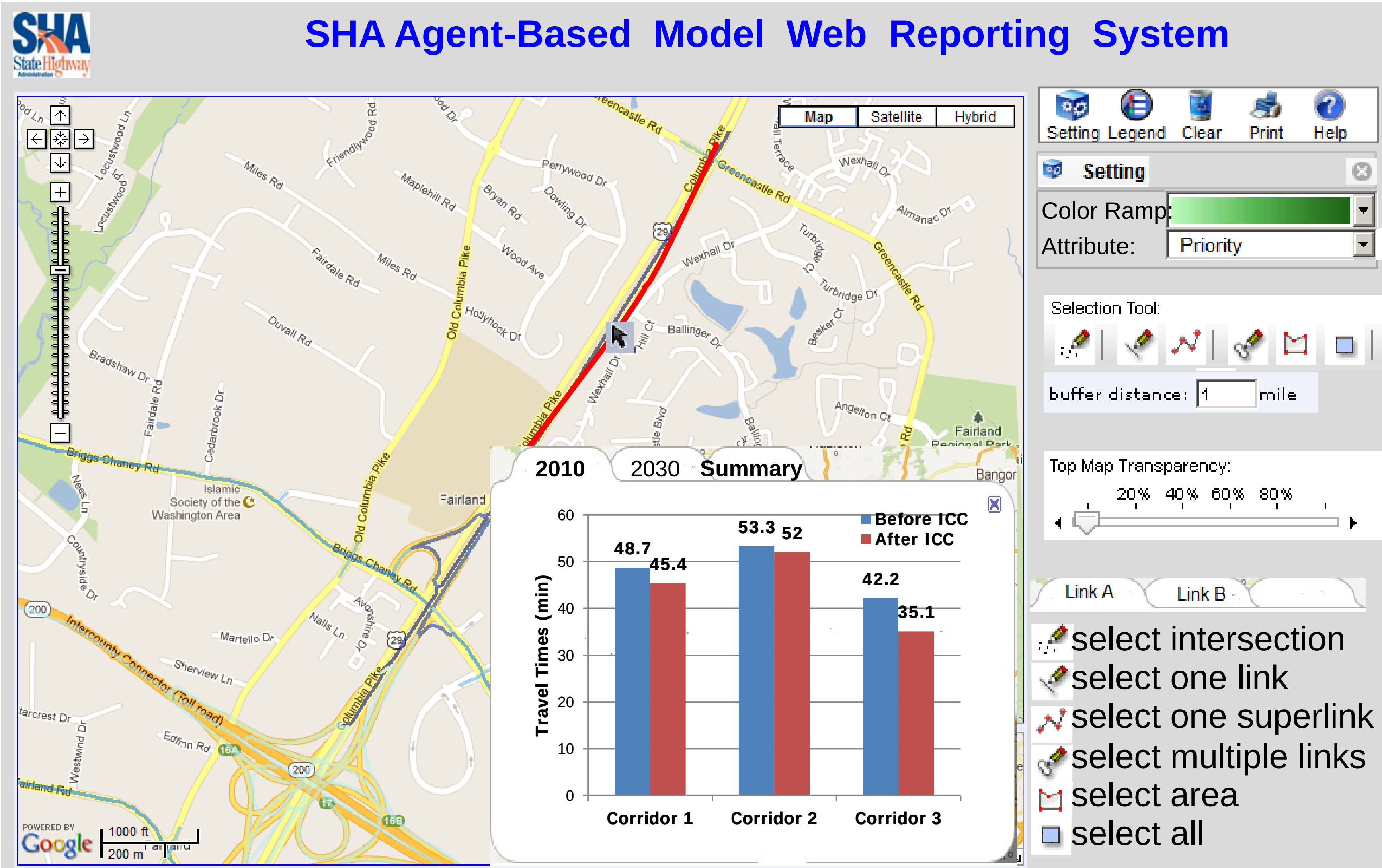
Traffic Count Comparison

	Freeways	Freeways + Arterials
Average Difference	11% (24 stations)	15% (62 stations)

Travel Time Comparison

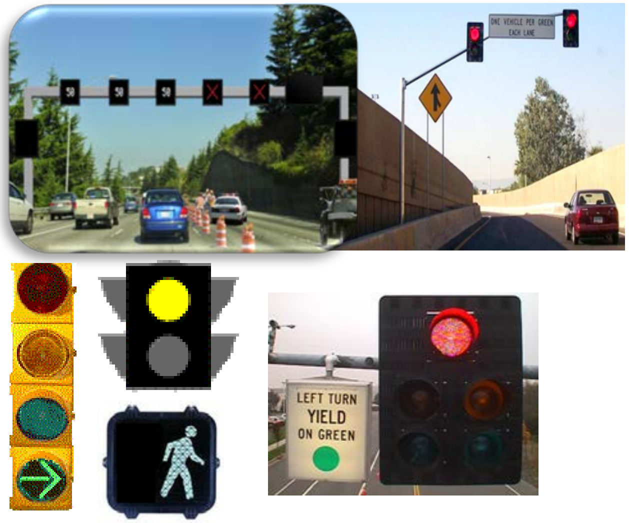
	AM Peak	PM Peak
Travel Time Difference $\|\Delta\|$	14% (9 corridors)	12 % (9 corridors)

Agency and User Support



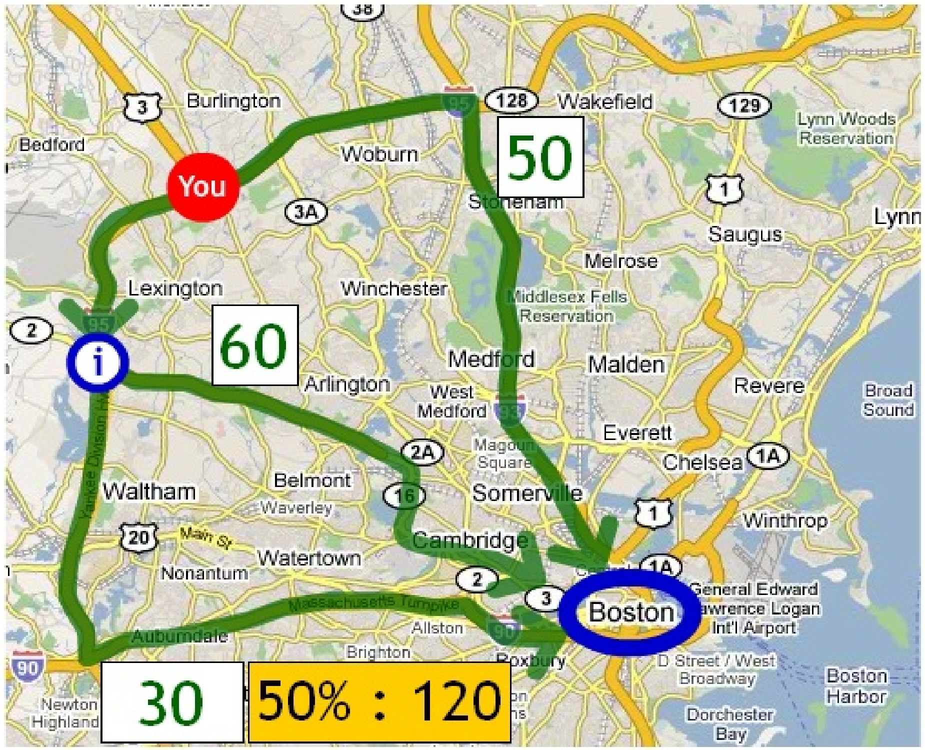
Real-Time Decision Support

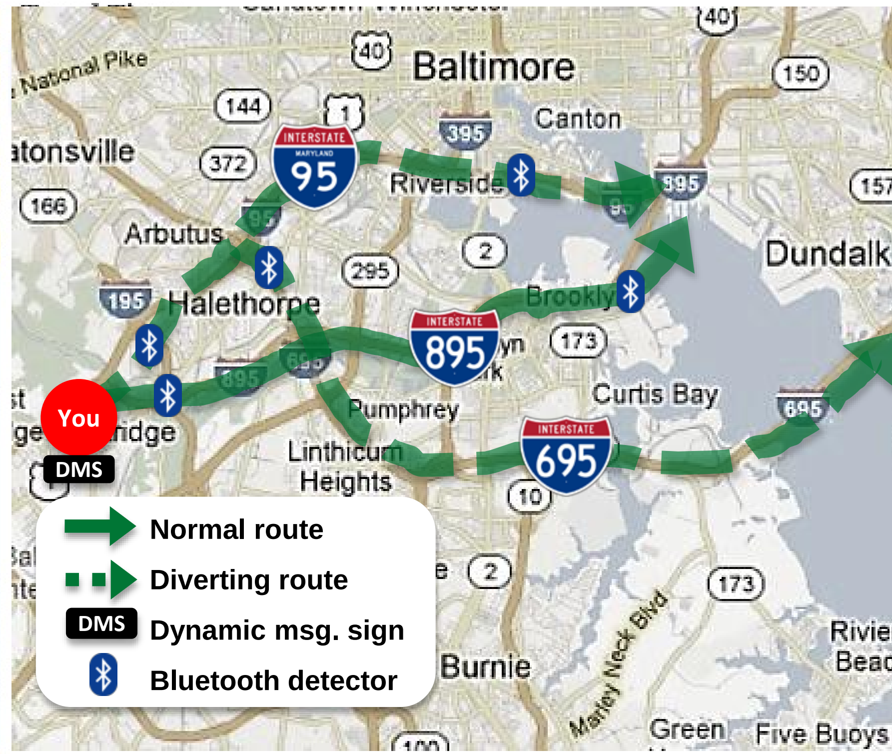
Decision-Maker



Model Transferability

Example: En-Route Diversion Model Transfer





Development Site
Boston

Application Site
Baltimore

Closing Remarks

- Similarity between Energy and Transportation Grids:
  Agents, Networks, Critical Infrastructure, …
- Opportunity: Nonlinear and complex relationships between agent behavior and system performance
- Systematic identification of feasible behavior shifts that can produce significant system benefits
- Model development should be driven by data availability and analysis needs
- Big, exciting, but still imperfect data
- Decision-makers want more information, better information, and they want it now, in real time

Thank You!

Questions, Comments, and Suggestions are Welcome. Please Contact:

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