Defining Exploratory Modeling and Analysis (EMA)

EMA is a systematic approach to perform sensitivity analysis using models when many of the model inputs cannot be asserted with confidence, so that a wide range of different input assumptions can be tested simultaneously, looking for patterns in the results to guide **robust decision-making** (RDM)

What is typically allowed to vary in long-term travel demand forecasts?

Yes	No
Spatial allocation of households and employment	Total regional population, employment, demographics
Transportation infrastructure, services, and pricing	Basic types of modes available (especially for auto)
Travel demand management	Model relationships and parameters

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Sometimes socio-demographic growth scenarios allow these to vary, but….

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… to model AV/CV and "sharing economy" scenarios, these have to be varied >>> Many uncertain assumptions

Approaches that Allow for Uncertainty

- Scenario-based planning
- Quantitative risk analysis
- Exploratory modeling and analysis / Robust decision-making

Exploratory Modeling & Analysis / Robust Decision-Making

Lempert, R.J., S.W. Popper and S.C. Bankes (2003). "Shaping the Next One Hundred Years: New Methods for Quantitative, Long-Term Policy Analysis". RAND Corporation

- Define the scope of the system to be analyzed.
- Define the key system relationships and sources of uncertainty.
- Define a method for modeling the system (interactions and inputs).
- Define a method for simultaneously varying the input assumptions to cover a wide range of future scenarios along the defined dimensions of uncertainty.
- Define the method for investigating and communicating the results of applying the model(s) across the wide range of scenarios.

CV/AV Example
Define the scope of the system to be analyzed.

- The transportation supply and demand in an urban metropolitan region over a 25-30 year time horizon. (The same as for an MPO long-range plan.)

CV/AV Example: Key Variables & Assumptions

CV/AV Variables Network Side:

- Dedicated lanes for CV/AV
- Following distance / platooning
- Vehicle operating speeds
- Traffic control systems
- Parking supply and location
- Operating characteristics of paid ride-share/vehicle-share services
- Priority for empty vehicle-trips on the network.
- Frequency/severity of accidents

CV/AV Variables Demand Side:

- Private CV/AV ownership
- Use of paid ride-share/vehicle-share services
- Disutility of in-vehicle time
- Changes in parking behavior
- Changes in intra-household vehicle sharing and coordination
- Generation of empty vehicle-trips
- Latent demand for car travel in currently congested areas
- Supply and service levels for transit
- Location/density of housing and employment

CV/AV Example: Define a Method for Modeling the System

- Adapted existing models for the Jacksonville, Florida region:
  - *DaySim* activity-based travel demand simulation
  - *TransModeler* dynamic traffic simulation
  - Feedback between the simulation models
- **Assumptions**
  - Detailed simulation models will facilitate a realistic representation of new aspects of AV/CV demand and supply for exploratory analysis
  - Relevant findings from these detailed models can be adapted for use with simpler (trip-based and static) models.

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CV/AV Example: method for varying the input assumptions

Experimental design for 16 scenario runs

Scenario	Private AV Adoption	Shared AV Adoption	Reserved AV Capacity	Automation Level
BB–N0	None	None	None	None
MM–L3	Medium	Medium	Interstate left lanes	Level 3
MM–AC	Medium	Medium	None	Level 3 + ACC
MM–LC	Medium	Medium	Interstate left lanes	Level 3 + ACC
MM–IC	Medium	Medium	Interstate all lanes (only inside the I 295 ring road)	Level 3 + ACC
LH–L3	Low	High	Interstate left lanes	Level 3
LH–AC	Low	High	None	Level 3 + ACC
LH–LC	Low	High	Interstate left lanes	Level 3 + ACC
LH–IC	Low	High	Interstate all lanes (only inside the I 295 ring road)	Level 3 + ACC
HL–L3	High	Low	Interstate left lanes	Level 3
HL–AC	High	Low	None	Level 3 + ACC
HL–LC	High	Low	Interstate left lanes	Level 3 + ACC
HL–IC	High	Low	Interstate all lanes (only inside the I 295 ring road)	Level 3 + ACC
HH–L3	High	High	Interstate left lanes	Level 3
HH–AC	High	High	None	Level 3 + ACC
HH–LC	High	High	Interstate left lanes	Level 3 + ACC
HH–IC	High	High	Interstate all lanes (only inside the I 295 ring road)	Level 3 + ACC

CV/AV Example:

Define the method for investigating and communicating the results of applying the models across the wide range of scenarios.

Network Side:

- **Speeds, delays and effective capacities for CV/AV by class:**
  - **Conventional vehicles**
  - **Occupied CV / AV**
  - **Empty CV / AV**

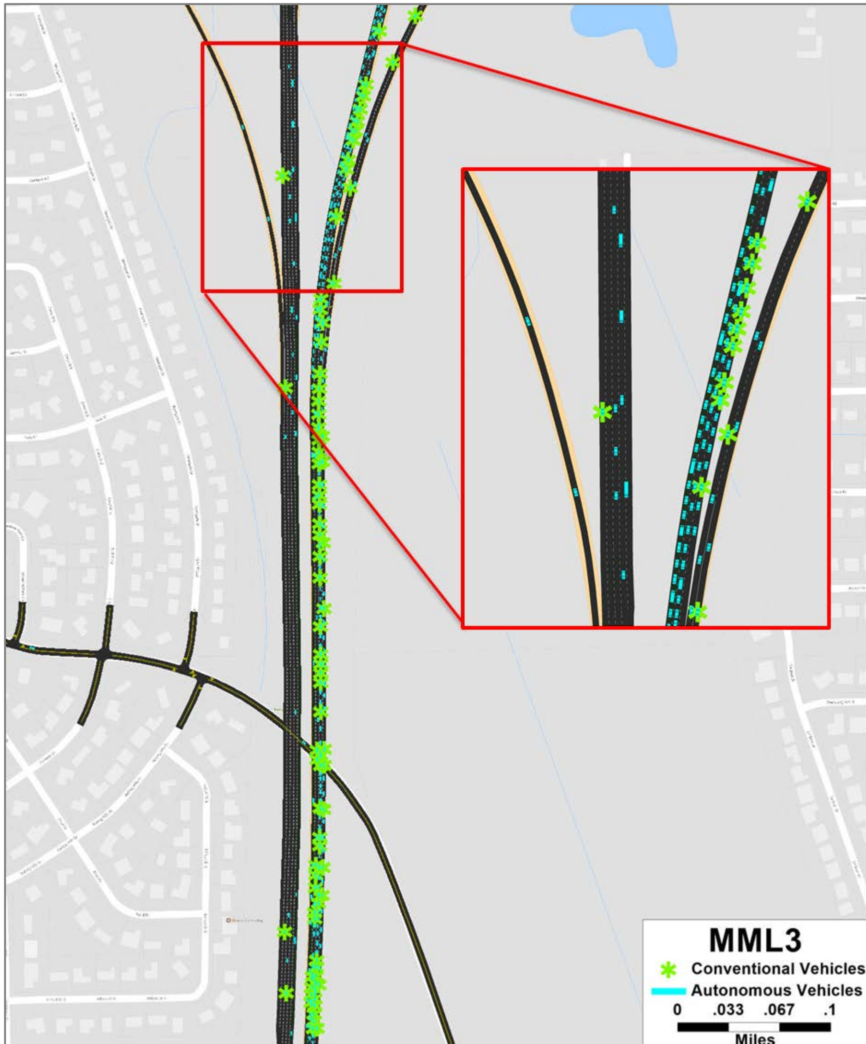
- *Network maps and/or animations, by time of day*
- *Comparative graphics for key links under different types of scenarios*

Demand Side:

- **Vehicle ownership levels, trip-level mode shares, average trip distances, VMT and PMT for:**
  - **Conventional vehicles**
  - **Private CV / AV**
  - **Shared CV / AV**

- *Comparative graphics for different market segments under different types of scenarios*
- *Regression of outputs on inputs*

Visualizations of back of I-295 Northbound queue in



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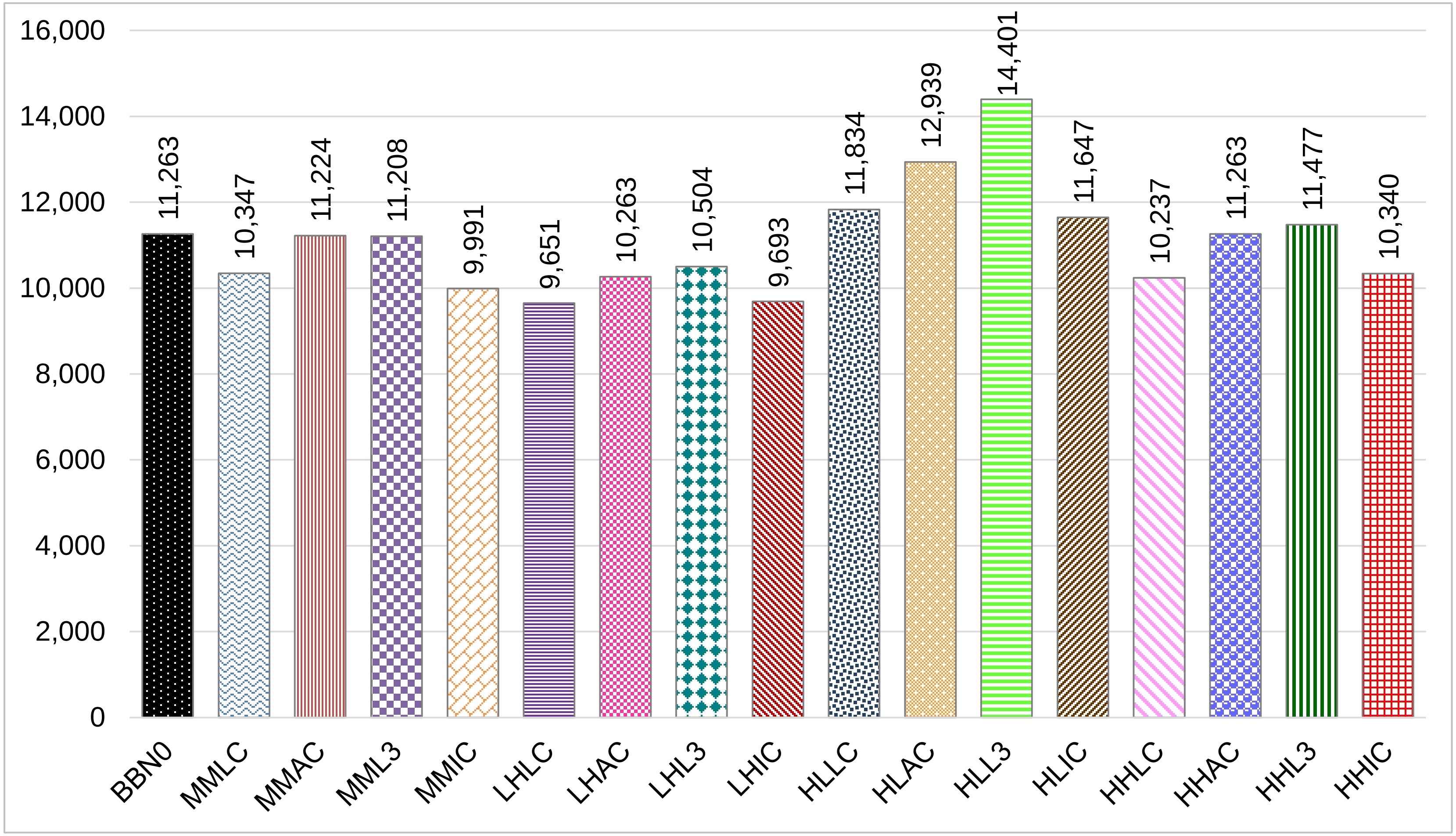
DTA Vehicle-Hours of Delay, by scenario



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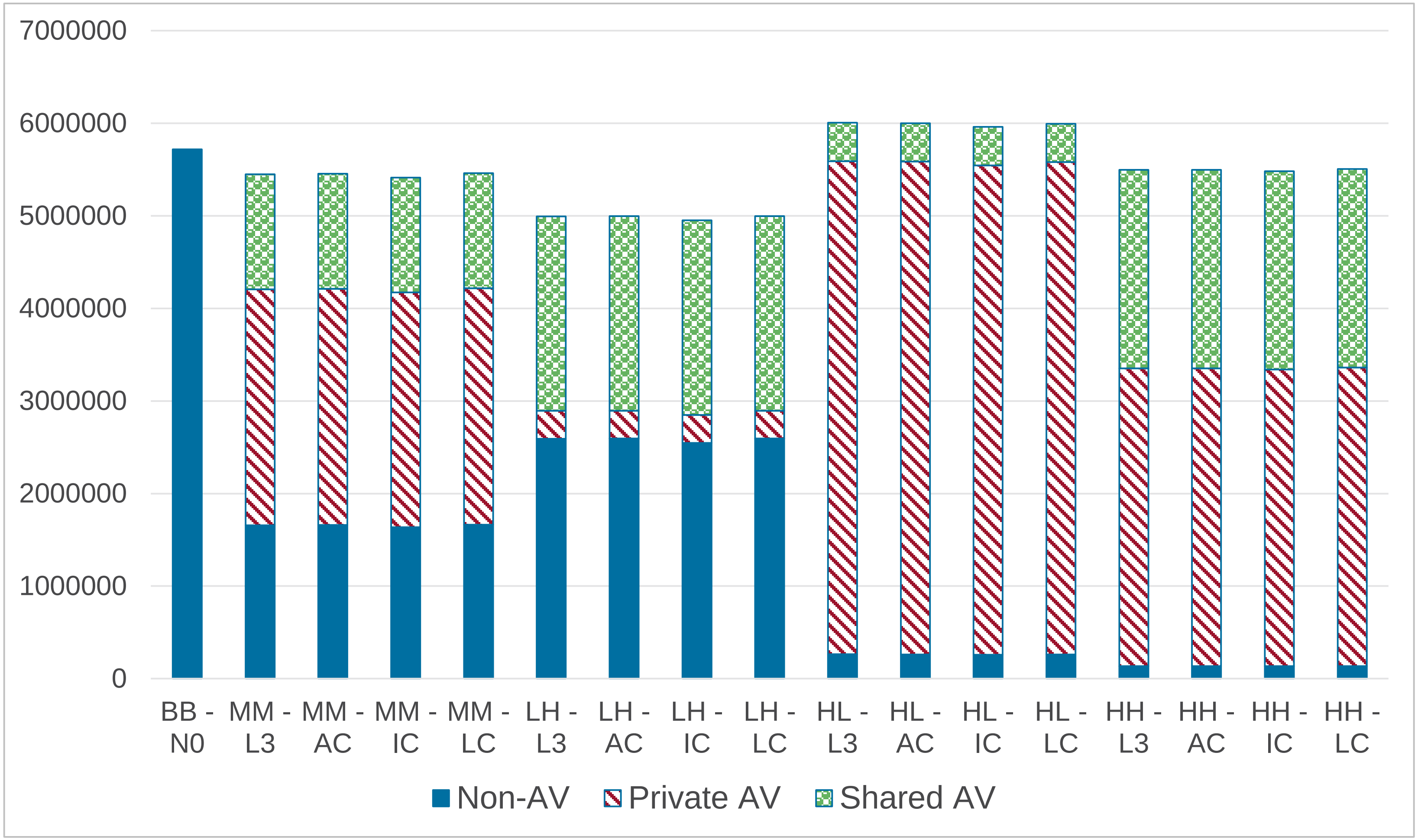
AM VMT, by vehicle type and scenario



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Regression model on ABM output: total VMT (millions), by scenario / time period / vehicle type

Vehicle Type	Non-AV	Non-AV	Private AV	Private AV	Shared AV	Shared AV	All types	All types
Variables	**Coeff.**	**T-stat**	**Coeff.**	**T-stat**	**Coeff.**	**T-stat**	**Coeff.**	**T-stat**
Constant	0.262	11.1	0.443	10.6	0.226	12.9	0.931	117.6
Demand - High Private, Low Shared	-0.174	-9.8	0.346	11.0	-0.103	-7.8	0.068	11.4
Demand - Low Private, High Shared	0.116	6.5	-0.281	-8.9	0.108	8.1	-0.057	-9.6
Demand - High Private, High Shared	-0.190	-10.6	0.083	2.6	0.113	8.5	0.006	1.1
Supply - Network scenario AC	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0
Supply - Network scenario IC	-0.002	-0.1	-0.002	-0.1	0.000	0.0	-0.004	-0.7
Supply - Network scenario LC	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.1
Arrive Period - 5:00 to 5:29	-0.182	-7.2	-0.434	-9.7	-0.237	-12.7	-0.853	-100.7
Arrive Period - 5:30 to 5:59	-0.177	-7.0	-0.422	-9.5	-0.231	-12.3	-0.830	-98.1
Arrive Period - 6:00 to 6:29	-0.051	-2.0	-0.109	-2.5	-0.075	-4.0	-0.235	-27.8
Arrive Period - 6:30 to 6:59	-0.057	-2.3	-0.125	-2.8	-0.081	-4.3	-0.263	-31.1
Arrive Period - 7:00 to 7:29	0.035	1.4	0.107	2.4	0.051	2.7	0.192	22.7
Arrive Period - 7:30 to 7:59	0.008	0.3	0.042	0.9	0.026	1.4	0.076	9.0
Arrive Period - 8:30 to 8:59	-0.017	-0.7	-0.048	-1.1	-0.018	-1.0	-0.083	-9.8

How-To: Model Impacts of Connected and Autonomous/Automated Vehicles (CAVs) and Ride-Hailing with an Activity-Based Model (ABM) and Dynamic Traffic Assignment (DTA)—An Experiment

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U.S. Department of Transportation
Federal Highway Administration

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