Risk Analysis Workshop

Session 2: An Approach to Better Understanding Forecasting Risk – Exploratory Modeling and Analysis

Moderator: Brian Gardner

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Outline

- Overview of Travel Model Improvement Program (TMIP) Exploratory Modeling and Simulation projects – **Sarah Sun**
- Phase 1 and 2: Adapting existing models to evaluate disruptive technologies – **Ben Stabler**
- Phase 3: Developing a tool (TMIP-EMAT) to support exploratory modeling and analysis – **Marty Milkovits**
  - Example case study
  - Work flow review with breakout and group discussions
- Discussion facilitators: **Tom Rossi, Rachel Copperman, Jason Lemp, Jeff Newman, Jay Evans, Mark Bradley**

TMIP Exploratory Modeling and Simulation Project Background

TRAVEL MODEL IMPROVEMENT PROGRAM (TMIP)

- TMIP Vision - The TMIP provides technical support and promotes knowledge and information exchange in the transportation planning and modeling community.
- TMIP Mission - The TMIP helps transportation planners and analysts provide better information through effective use of quantitative methods and tools.
- TMIP Goals
  - Outreach: Get transportation planning research into practice and promote good practices in travel data analyses and quantitative methods application.
  - Agency Support: Build transportation planning agencies institutional capacity to effectively apply analytical tools in the transportation planning decision-making process.
  - Tool Enhancement: Develop a dynamic desk reference for applying travel analysis tools to support data-driven, performance-based transportation planning incorporating principles of risk management.

MOTIVATION FOR EXPLORATORY MODELING AND SIMULATION STUDY

"The committee finds that there is no single approach to travel forecasting or set of procedures that is "correct" for all applications or all MPOs. Travel forecasting tools developed and used by an MPO should be appropriate for the nature of the questions being posed by its constituent jurisdictions and the types of analysis being conducted."

-- TRB Special Report 288 METROPOLITAN TRAVEL FORECASTING Current Practice and Future Direction, Page 3

THE GOAL OF TMIP EXPLORATORY MODELING AND SIMULATION PROJECT

- Provide an additional tool for planning agencies to manage the uncertainties in transportation planning
- Encourage agencies to continuously improve their current travel modeling methods and practices

BACKGROUND OF TMIP EXPLORATORY MODELING AND SIMULATION PROJECT

The project is inspired by and modeled after RAND'S EMA and Robust Decision Making (RDM) work.

- 2016 – 2017 (Phases 1 & 2): Using Exploratory Modeling and Analysis (EMA) framework to Evaluate Impacts of Disruptive Technology on Regional Surface Transportation System
- 2017 – 2020 (Phase 3): Conducting full Exploratory Modeling and Simulation Study

EXPLORATORY MODELING AND SIMULATION STUDY (PHASE 3) OBJECTIVES

- Focus on exploring (rather than predicting) future transportation system impact (due to technological revolutions);
- Develop a tool that helps agencies to manage uncertainties by creating an EMA tool with a comprehensive framework that will
  - illuminate interactions between transportation supply and demand on urban surface transportation system (especially at the corridor level) through exploratory modeling and simulation;
  - provide insights of potential, possible, plausible, probable or preferred futures;
  - support robust regional transportation planning decision-making incorporating principles of risk management.

FOUR TASKS IN EXPLORATORY MODELING AND SIMULATION STUDY

- Creating a TMIP Exploratory Modeling and Analysis Tool (TMIP EMAT) with a Comprehensive Framework
  - Develop detailed implementation plan for the project
  - Conduct proof of concept of the proposed Exploratory Modeling and Analysis (EMA) tool and its framework
- Building upon previous task
  - Make further improvement to the tool, focusing on theoretical soundness
  - Investigate uncertainties associated with origin and destination flows
- Assessing previous two tasks and complete the tool development
  - Continue to focus on theoretical soundness
  - Improve further on the tool with an emphasis on regional corridor level flows
- Developing a Robust Decision Making Framework (RDMF)
  - Demonstrate how the TMIP EMAT can be used in long range regional transportation planning

Phase 1 and 2 of Project

Phase 1 and 2 Objectives

Use **Exploratory Modeling and Analysis (EMA)**

with detailed simulation models (ABM + DTA) *to help* transportation planning agencies *understand* the impacts of CAV and ride-hailing (TNC) technologies

EMA Definition

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).

EMA Definition

- 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 futures 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.

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

Example Exercise

Define a Method for Modeling the System

- Adapted existing models for the Jacksonville, Florida area:
  - 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 CAV demand and supply for EMA
  - Relevant findings from these detailed models can be adapted for use with simpler (trip-based and static) models

Key Sources of Uncertainty Investigated

Travel Demand

- Market penetration and use of AVs
- Disutility of in-vehicle time in AVs
- Level of use of carsharing and ride-hailing as a substitute for private vehicle use

Network Supply

- Different vehicle headway and speed characteristics for CAVs
- Provision of CAV-only lanes
- Paid ride-hailing (TNC) operator characteristics* (partially explored)

Experimental Design for the 16 Scenarios Run

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

ABM + DTA Interface

ABM to DTA

- The ABM outputs a list of trips (over 6 million daily trips), parcel-to-parcel, minute-to-minute.
- The DTA model aggregates the parcel-level trips to traffic analysis zones (TAZs) and then builds several zone connectors to simulate the diversity of real-world loading points.
- The non-ABM demand for freight, externals, etc. are passed to the DTA as aggregate trip matrices. These trips are processed into individual trip lists with more detailed simulated times and locations.

ABM + DTA Interface

DTA to ABM

- The DTA outputs dynamic TAZ-to-TAZ travel time skims, in 30-minute periods, by user class (e.g., conventional vehicles and AVs).
- The dynamic travel time skims are created by first running the simulation and then calculating a shortest-path travel time for each origin, destination, and departure time period. The skimmed paths include average simulated turn movement delay.
- The nonauto network LOS skims (e.g., walk-to-transit) remained fixed from the existing model.

ABM + DTA Interface

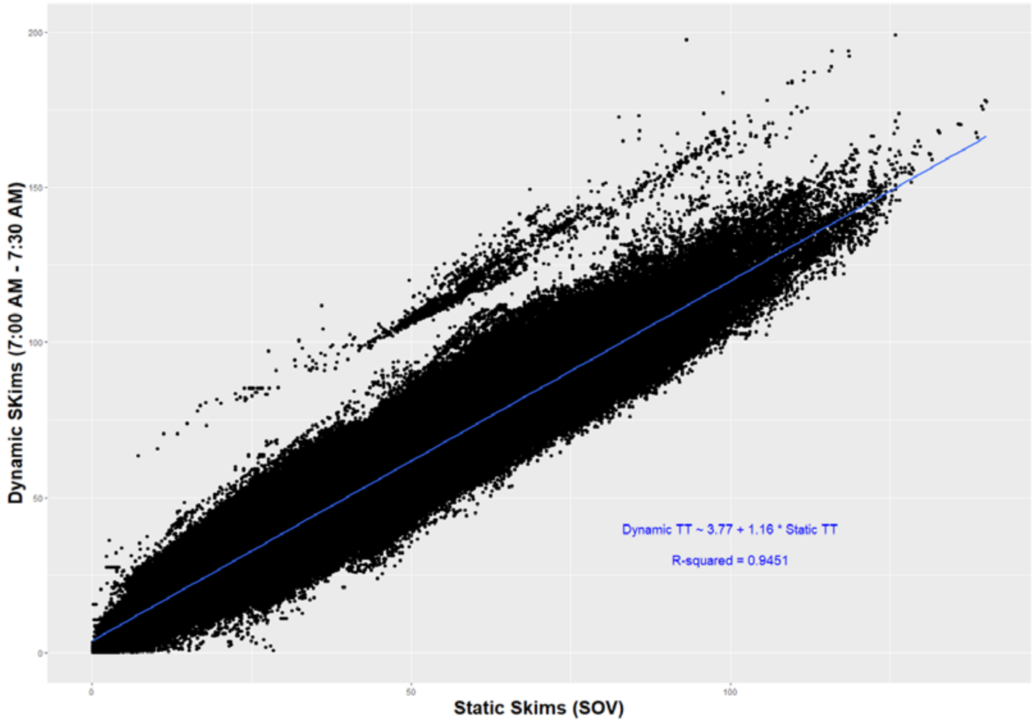
- Windows machine with 12 cores
  - TransModeler DTA – AM period, 25 iterations → 24 hours
  - DaySim ABM → 1hr
  - DaySim using AM dynamic skims + transpose for PM and static assignment for other time periods
  - Ran 3 to 5 feedback loops
  - Transit skims held constant
- As expected, runtimes limited the scoped of the EMA

Verification of Dynamic Skims

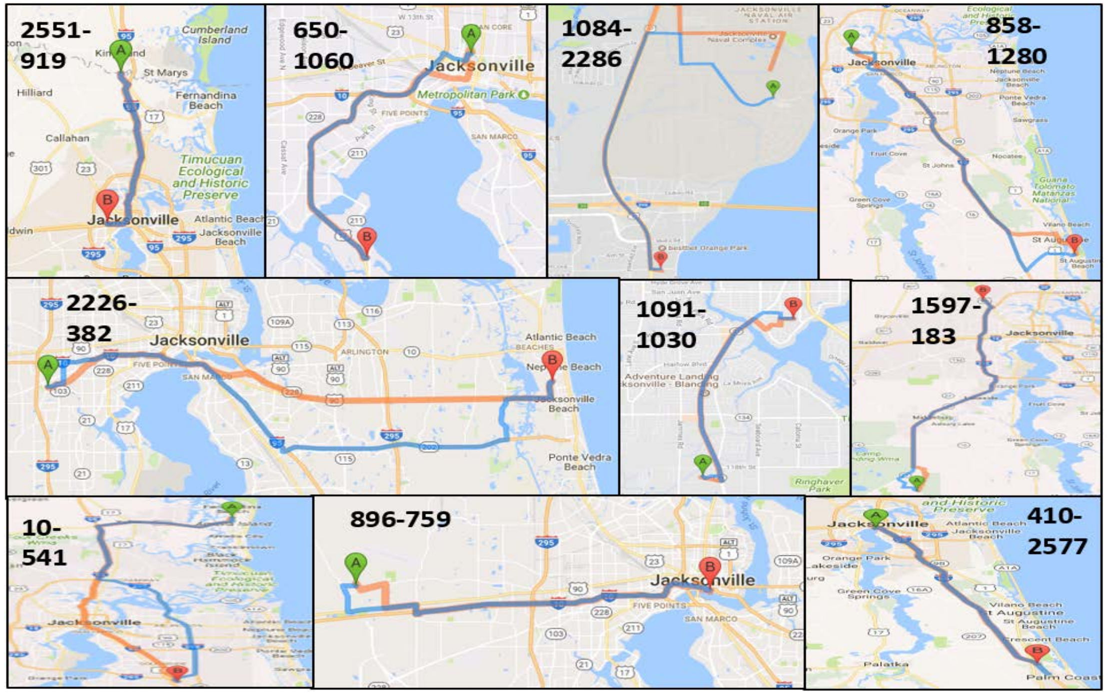
OD Pair		Static			Dynamic (AM)							Google Maps (AM) (Monday April 2, 2018)						
Origin	**Destination**	**SOV**	**HOV2**	**HOV3**	**5:30–6:00**	**6:00–6:30**	**6:30–7:00**	**7:00–7:30**	**7:30–8:00**	**8:00–8:30**	**8:30–9:00**	**5:30–6:00**	**6:00–6:30**	**6:30–7:00**	**7:00–7:30**	**7:30–8:00**	**8:00–8:30**	**8:30–9:00**
10	**541**	50	50	50	54	55	59	60	59	55	55	50–70	50–75	55–90	55–85	55–80	55–75	55–75
410	**2577**	53	53	53	52	52	52	52	53	52	52	50–65	50–65	50–65	50–65	50–70	50–70	50–65
650	**1060**	9	9	9	12	13	13	14	15	15	14	12–16	12–18	12–18	12–20	12–20	12–22	12–22
858	**1280**	49	49	49	54	55	55	56	56	55	55	55–70	55–75	55–75	55–85	55–85	55–80	55–80
896	**759**	18	18	18	22	24	25	25	25	24	24	22–28	24–35	26–45	28–50	28–45	26–40	24–35
1084	**2286**	5	5	5	6	7	7	7	7	7	7	5–7	5–8	5–9	5–9	5–9	5–9	5–9
1091	**1030**	5	5	5	7	7	7	8	8	8	7	9–14	9–14	10–14	10–16	10–14	10–14	10–16
1597	**183**	49	49	49	53	57	62	62	61	60	59	60–80	60–80	60–80	60–80	60–80	60–80	60–80
2226	**382**	28	28	28	32	34	35	37	36	35	34	35–45	35–55	35–60	40–70	40–65	40–60	35–55
2551	**919**	33	33	33	34	34	37	37	38	35	34	30–40	30–40	30–40	30–45	30–40	30–40	30–40

Verification of Dynamic Skims

Dynamic vs. Static



Outlier Review



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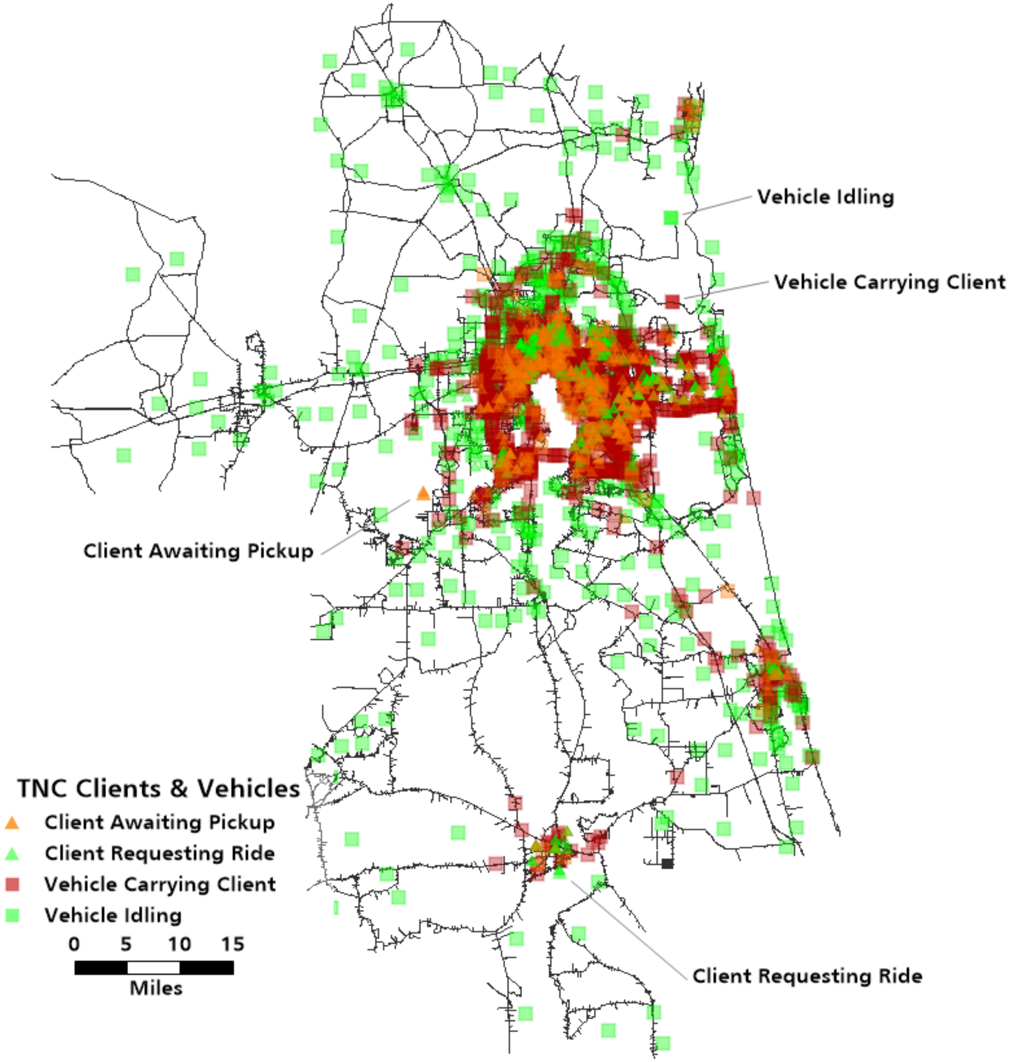
DTA TNC Fleet and Client Status at 8:00 am



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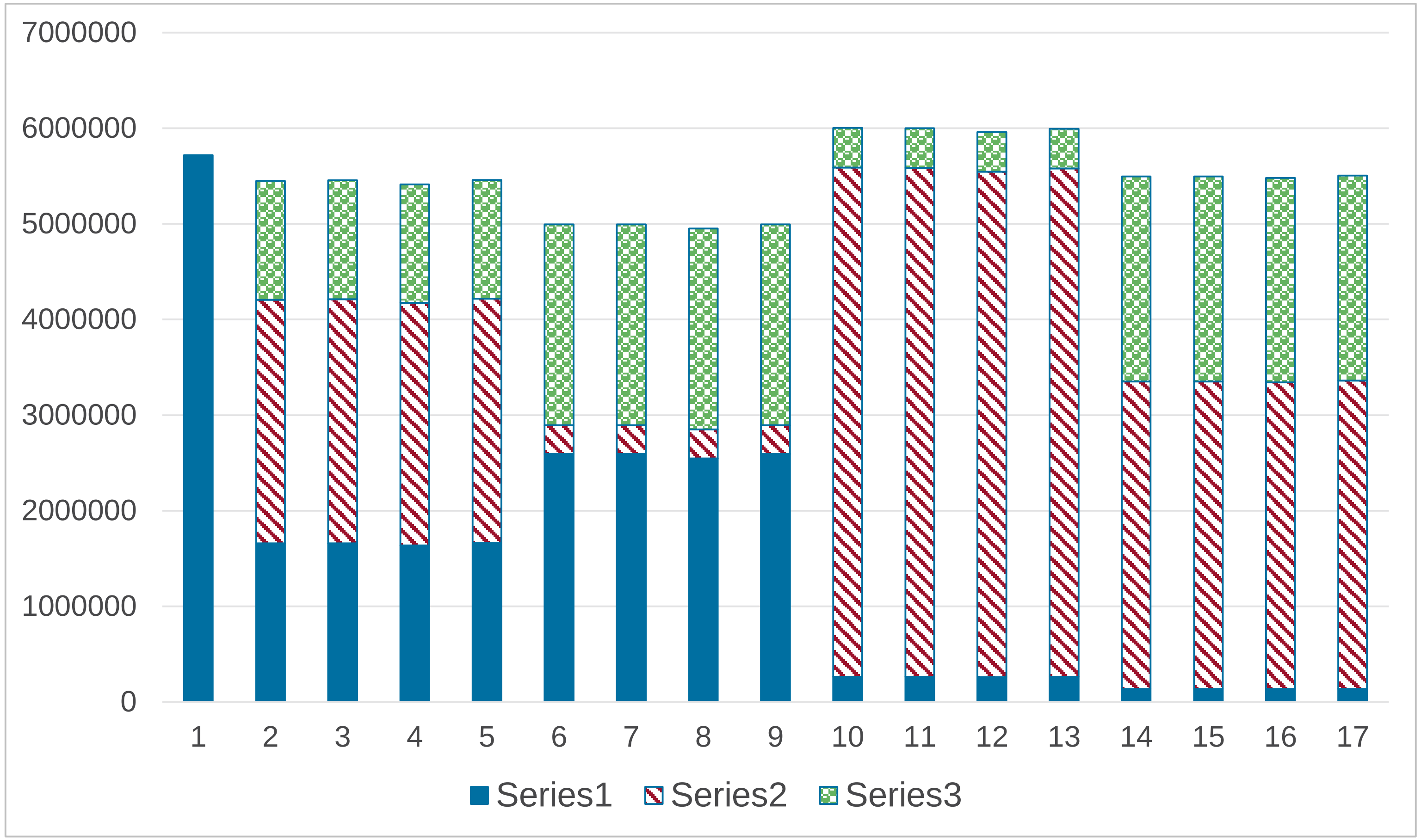
ABM + DTA Integration Issues and Resolutions

- DTA runtimes → *simulate just AM period*
- Zone resolution and loading → *use more precise MAZ zone system and smarter connector choice methods*
- Quality dynamic skims → *use DTA for loading network and then use shortest paths skims for every OD pair*
- DTA TNC fleet characteristics (size, initial location, matching with requests, repositioning, etc.) → *still investigating*

AM VMT by Vehicle Type and EMA Scenario

- VMT goes up with more private AVs due to trip length increases
- VMT goes down with more shared AV (TNC) usage because the costs are higher



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Regression Model of VMT based 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

Some Conclusions and Key Findings

- The introduction of new types of network users like CAVs only becomes significant once they reach high market penetration.
- The relative use of private and shared CAVs and their occupancy levels greatly influence the scenario results (VMT, delays, etc.).
- A comprehensive and realistic investigation of the impacts of CAVs and TNCs requires an ABM+DTA model even though they require significant resources and runtime.

  These disaggregate models are better able to model the complex relationships between individual persons (including drivers and passengers), individual vehicles (CAV or not), and network vehicle communication (V2V, V2I, V2X).

What Else Did We Learn?

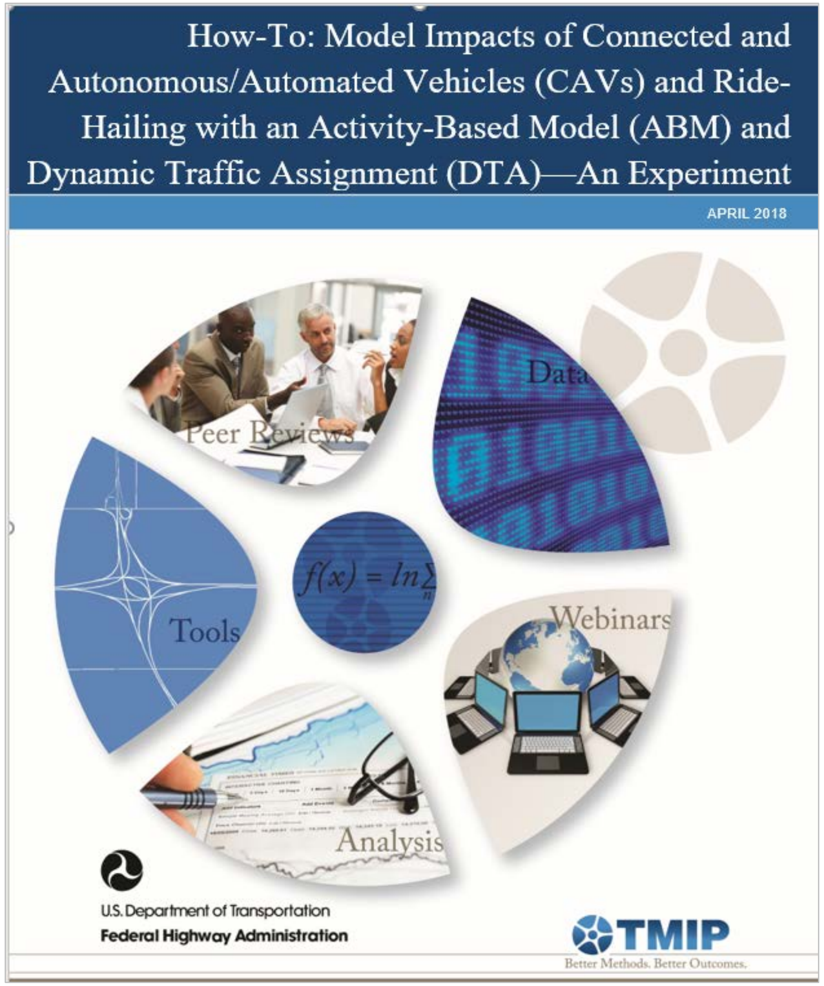
- This project was an experiment in making assumptions (which applies to all modeling, but here it is more explicit).
- Our industry's most advanced tools can only tell us a limited amount about a future with CAVs and TNCs because:
  - We have to make so many significant assumptions.
  - We have to design and estimate a detailed set of interactions (i.e., models) between components that are not yet well understood.
  - We have to develop and test complex software simulating all of this.
  - We have to do this within a reasonable time to be relevant.
- Yet, we cannot investigate how to prepare for an uncertain future if we do not even try to, and complex models can address more questions than simpler models.

Assumptions

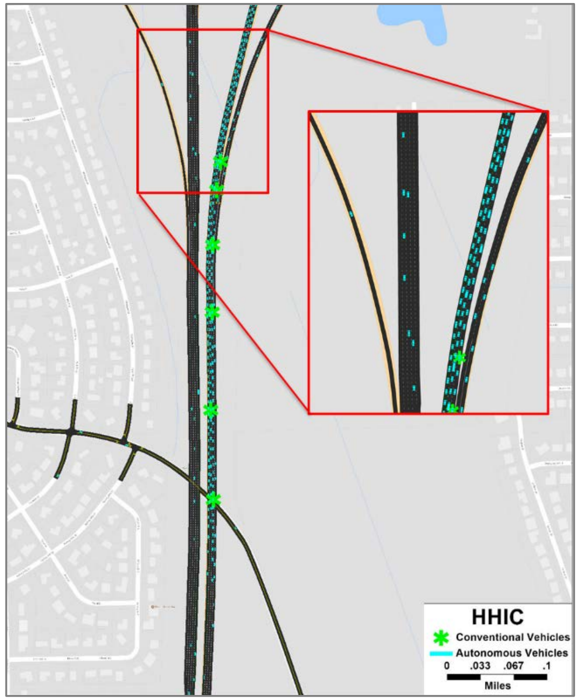
- land use
- need and supply for parking
- level of vehicle automation
- in-vehicle experience
- stability of daily travel patterns
- TNC fleet operations
- future transit network structure
- policy futures
- etc.

For More Information

How-To Guide

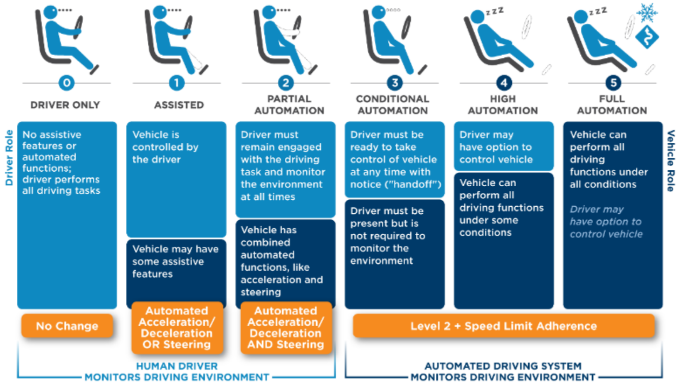


which includes lots of additional info



simulation results

SAE automation levels



Potential superstacked parking locations

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Phase 3 Workshop: Introduction to TMIP-EMAT

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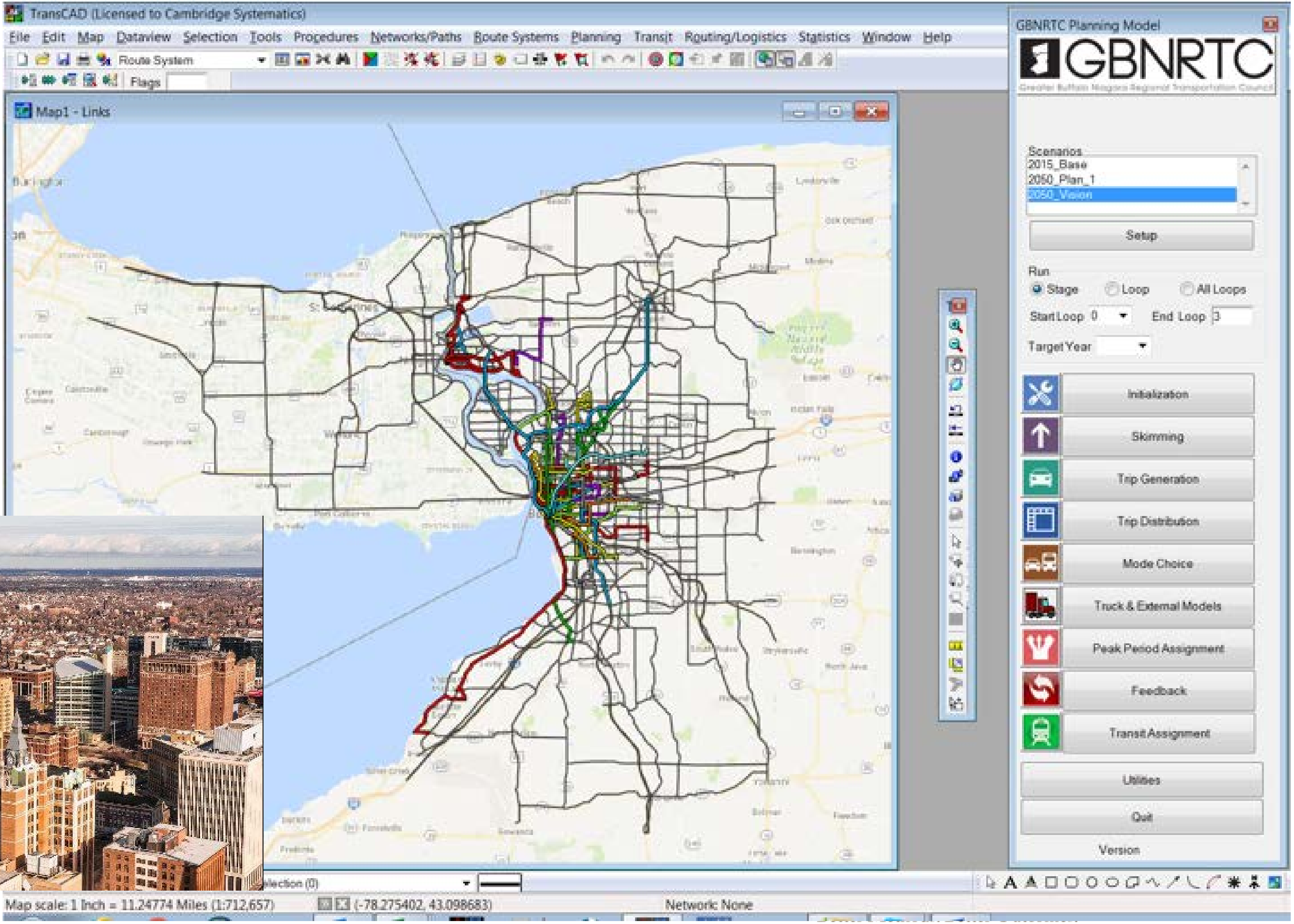
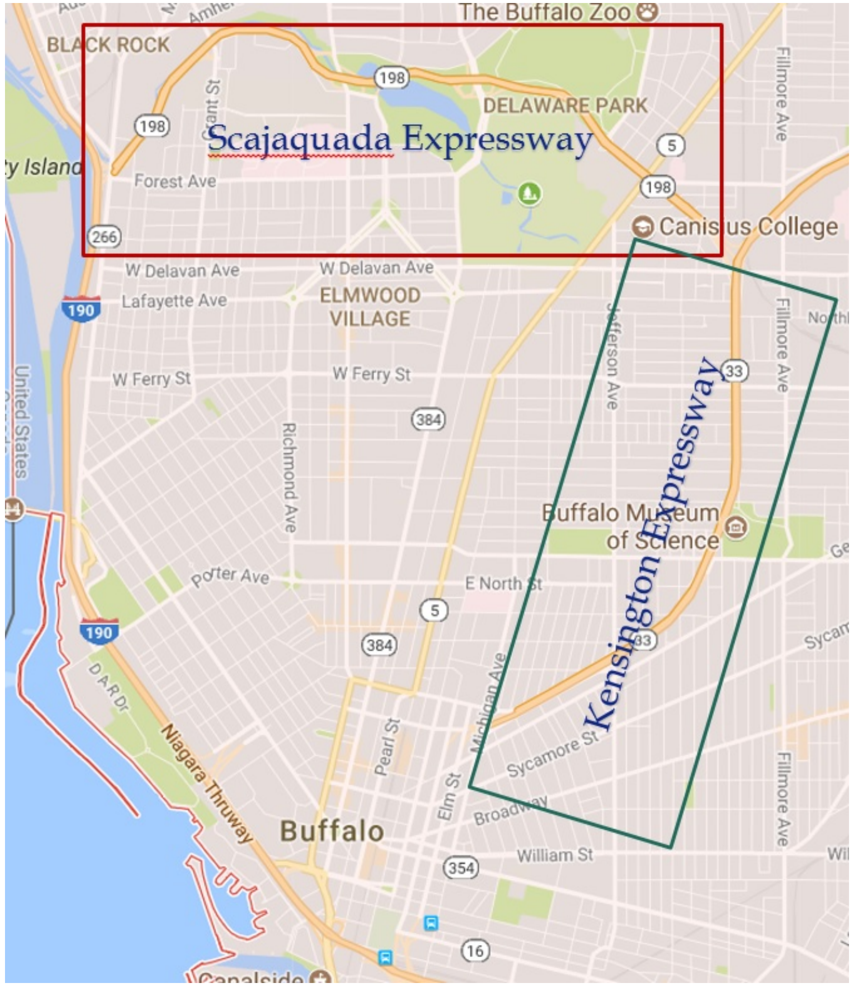
Workshop outline

- Case Study Materials
  - Core Model
  - Strategies
  - Performance measures
  - Uncertainties
- Introduction to TMIP-EMAT
  - User work flow
  - Scoping
  - Experiment design
  - Meta-models
  - Analysis


TransCAD (Licensed to Cambridge Systematics)
File Edit Map Dataview Selection Tools Procedures Networks/Paths Route Systems Planning Transit Routing/Logistics Statistics Window Help
Route System
Flags
Map1 - Links
GBNRTC Planning Model
GBNRTC
Scenarios
2015_Base
2050_Plan_1
2050_Vision
Setup
Run
Stage
Loop
All Loops
Start Loop 0
End Loop 3
Target Year
Initialization
Skimming
Trip Generation
Trip Distribution
Mode Choice
Truck & External Models
Peak Period Assignment
Feedback
Transit Assignment
Utilities
Quit
Version
Map scale: 1 Inch = 11.24774 Miles (1:712,657)
(-78.275402, 43.098683)
Network: None

Strategy 1: Decommissioning Kensington Expressway



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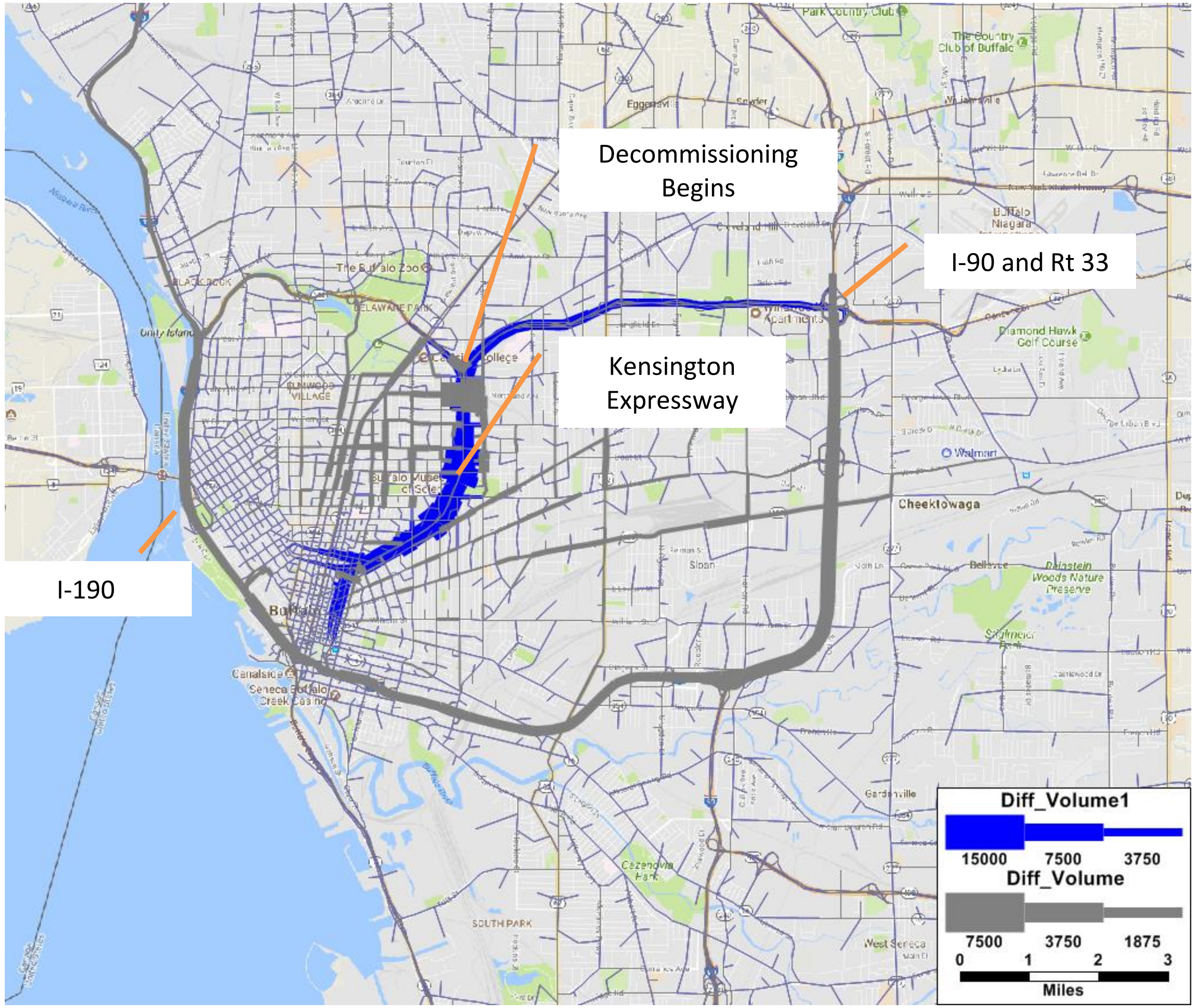
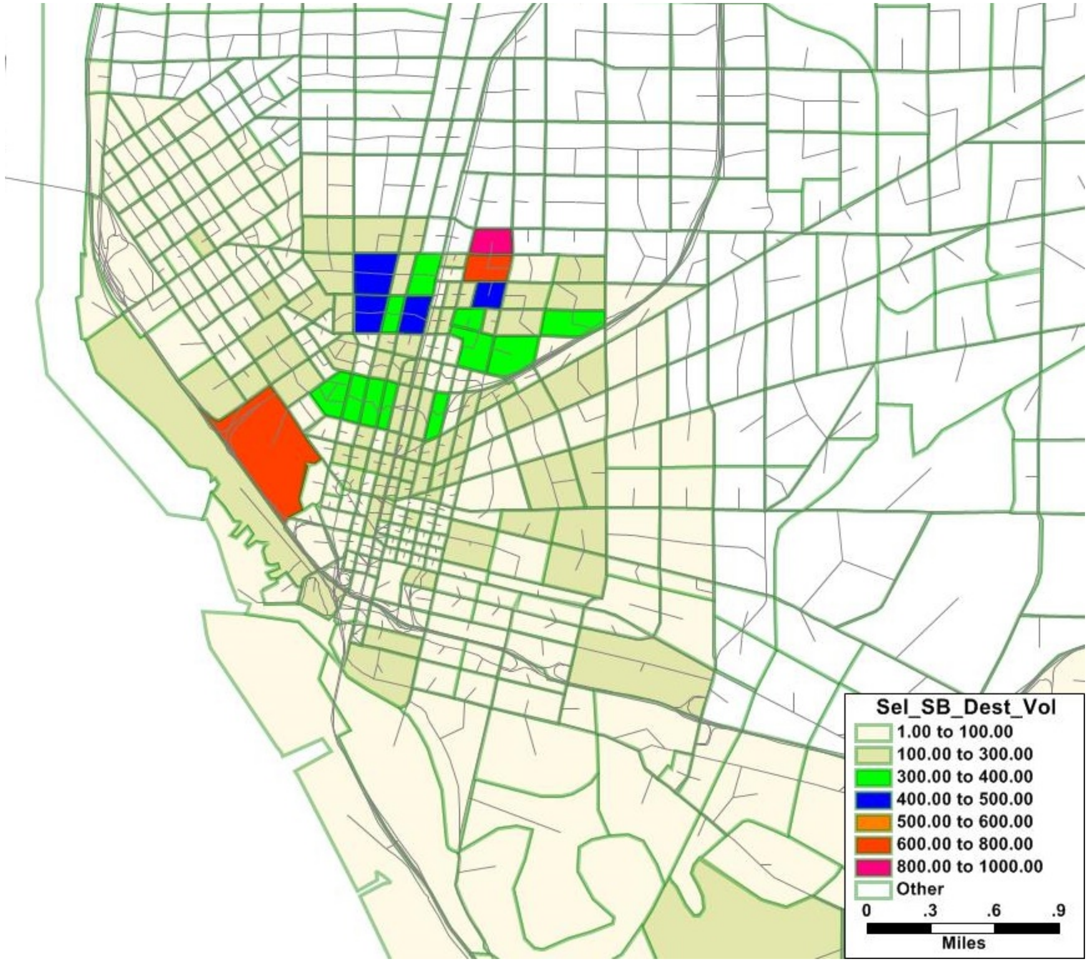
Initial Consideration of Kensington Decommissioning Conditions





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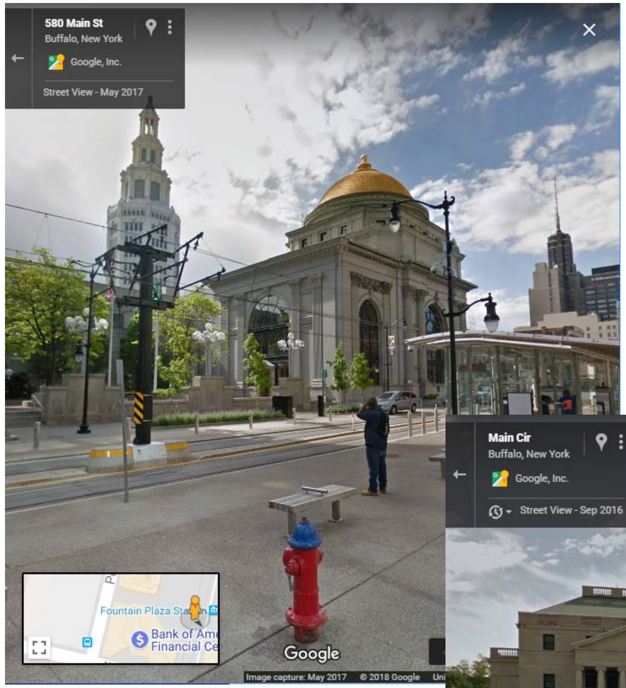
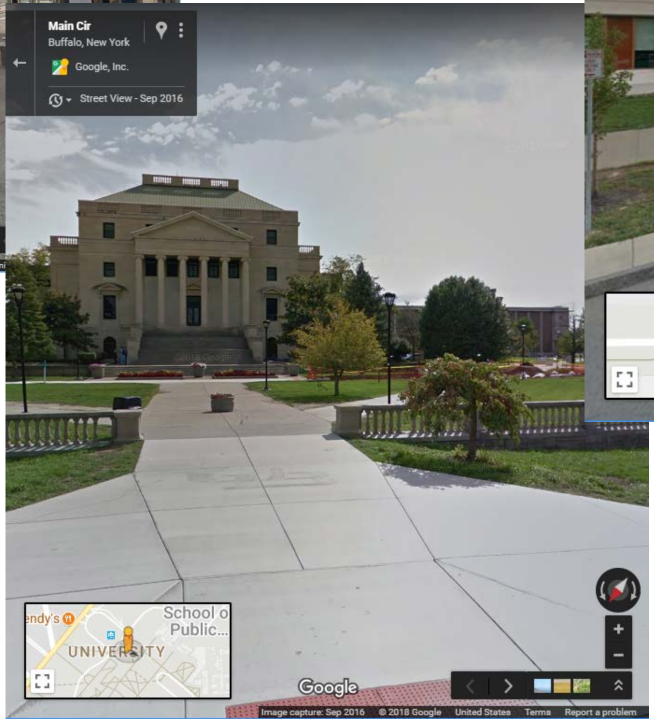
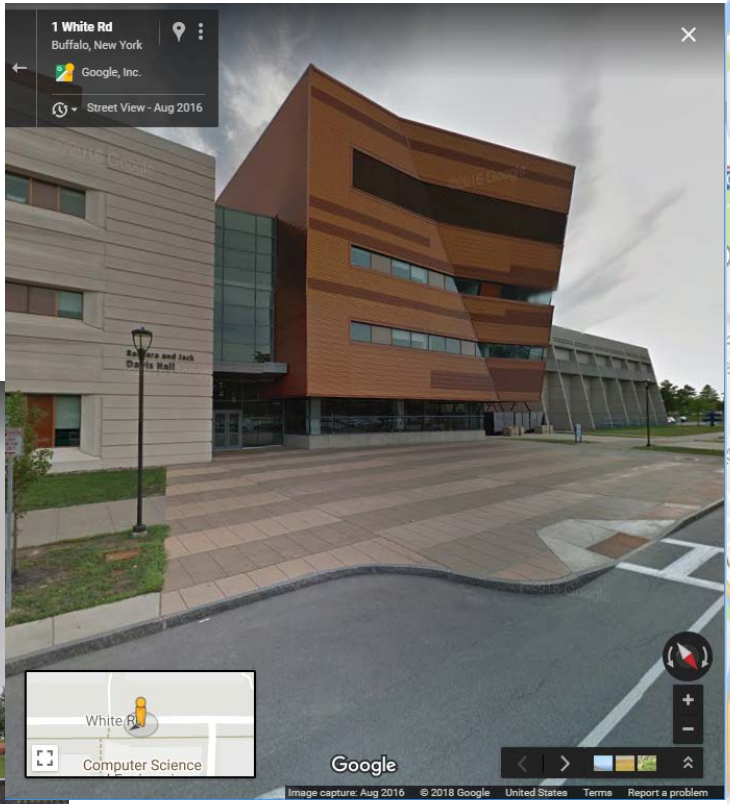
Performance Measures for Kensington Decommissioning

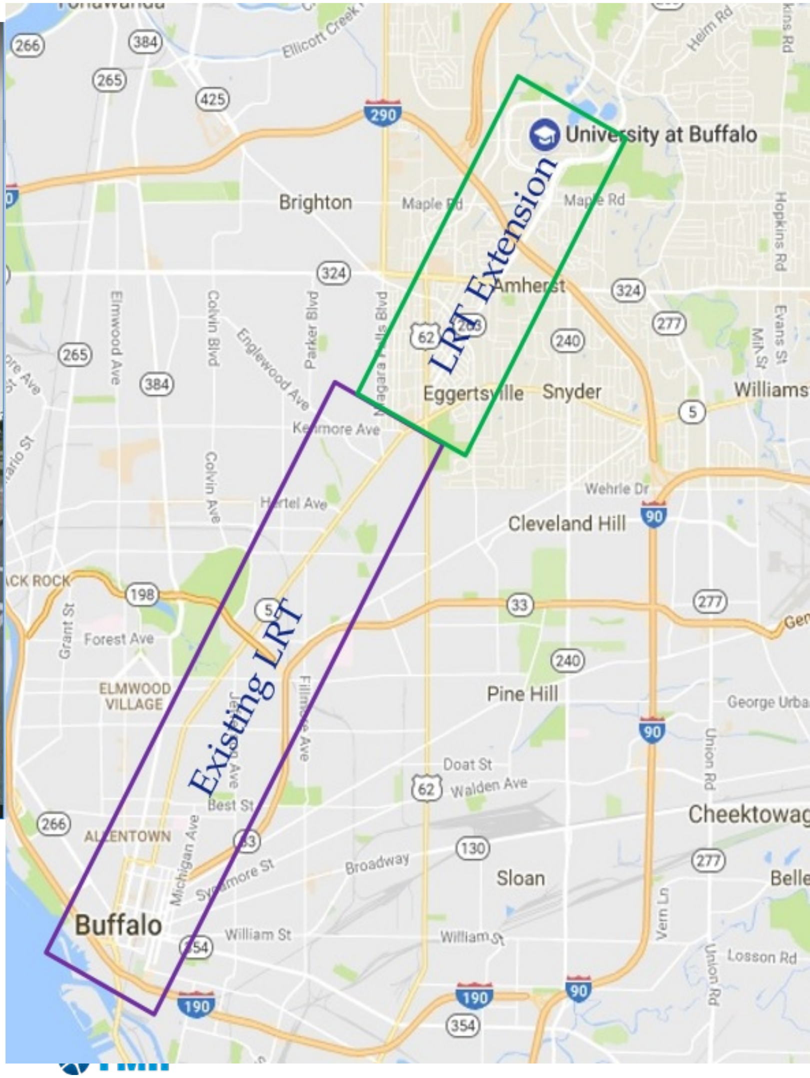
- **VMT and Trip Length**
  - Region-wide VMT
  - VMT by facility
  - Congested VMT by facility type in peak periods
  - Regional average trip length (miles)
- **Accessibility**
  - Households within 30 minutes of CBD
- **Corridor Level**
  - Kensington Expressway VMT / VHT
  - Travel time from downtown to airport
  - Targeted segment volumes
  - Change in Trips to/from Downtown

Strategy 2: Extending Amherst LRT









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Performance Measures for Amherst LRT

- **VMT and Trip Length**
  - Region-wide VMT
- **Mode Share**
  - Share of transit
  - Share of non-motorized travel
- **Corridor Level**
  - Change in Trips to/from Downtown
- **Accessibility**
  - Number of HBW trips with <=45 minute transit travel time
- **Transit related**
  - Total Boardings (LRT + Bus)
  - LRT-only Boardings

Uncertainties (Risk Factors)

- **Economy**
  - Land use development patterns
  - Impact of a new large employer coming/going
  - Growth/decline within or outside the region
- **Auto Environment**
  - AV/CV
  - Shared mobility
  - Energy mix
  - Fuel Cost
- **Highway network**
  - Tolls
  - Speed limits
  - Ramp metering
- **Transit network**
  - Fares
  - PnR location and availability
  - Frequency
- **Travel patterns**
  - Telecommuting/shopping
  - Flex time
- **Model parameters**
  - VOT
  - Rates
  - Capacities

Introduction to TMIP-EMAT

Travel Model Improvement Program – Exploratory Modeling and Analysis Tool

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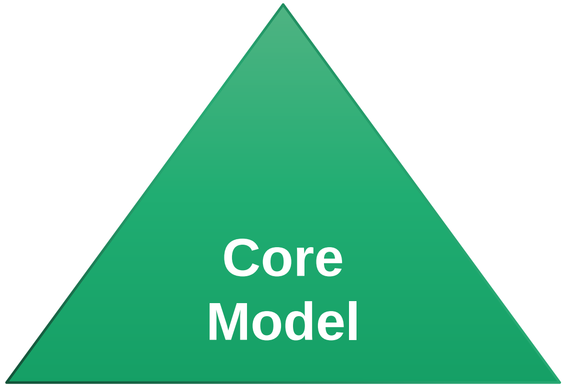
What is TMIP-EMAT?

- Travel Model Improvement Program – Exploratory Modeling and Analysis Tool
- Tool to support a quantitative Robust Decision Making approach to transportation planning with deep uncertainty
- Complements and enhances (does not replace) existing models, visualizations, or planning tools

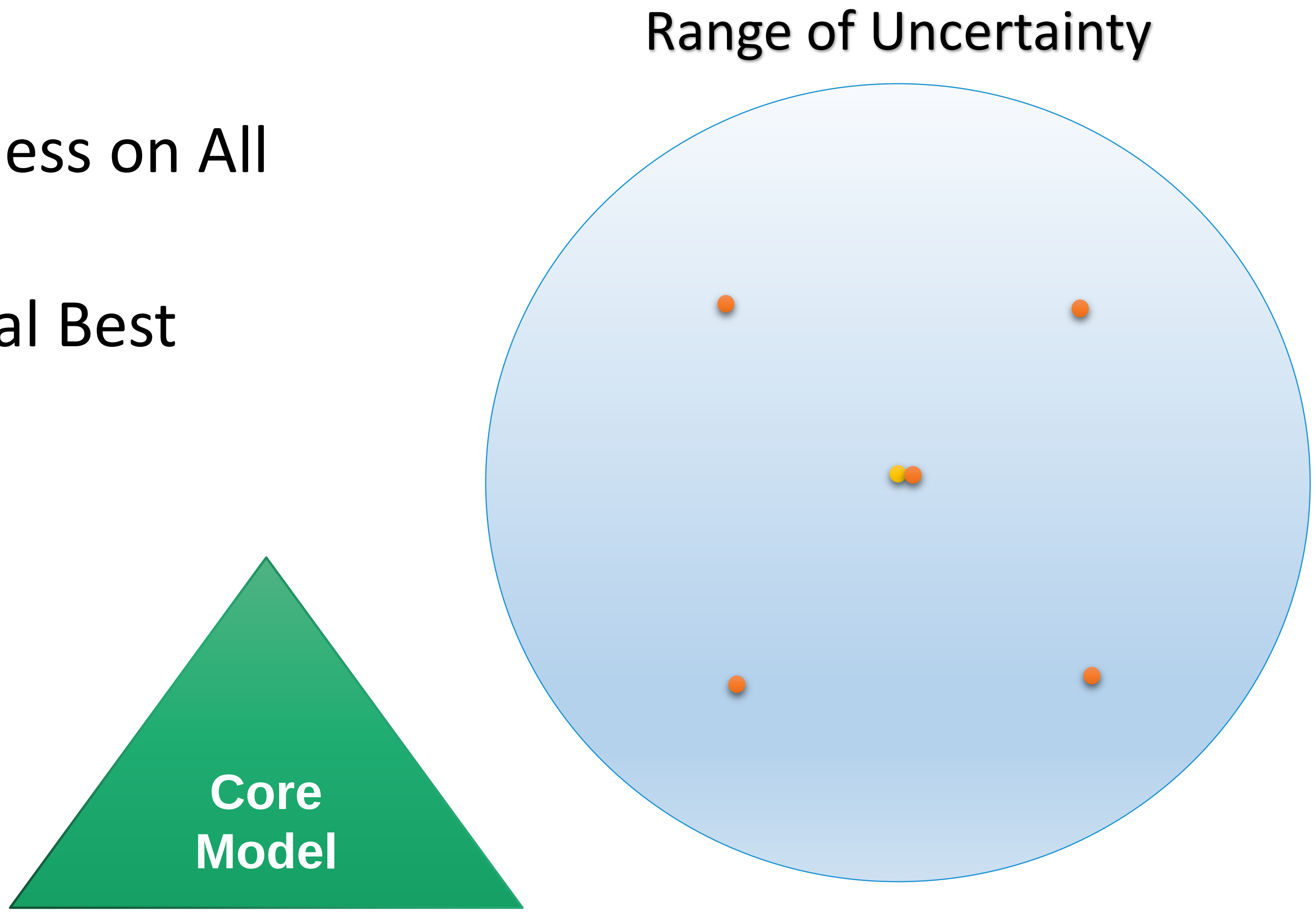
Available Tools

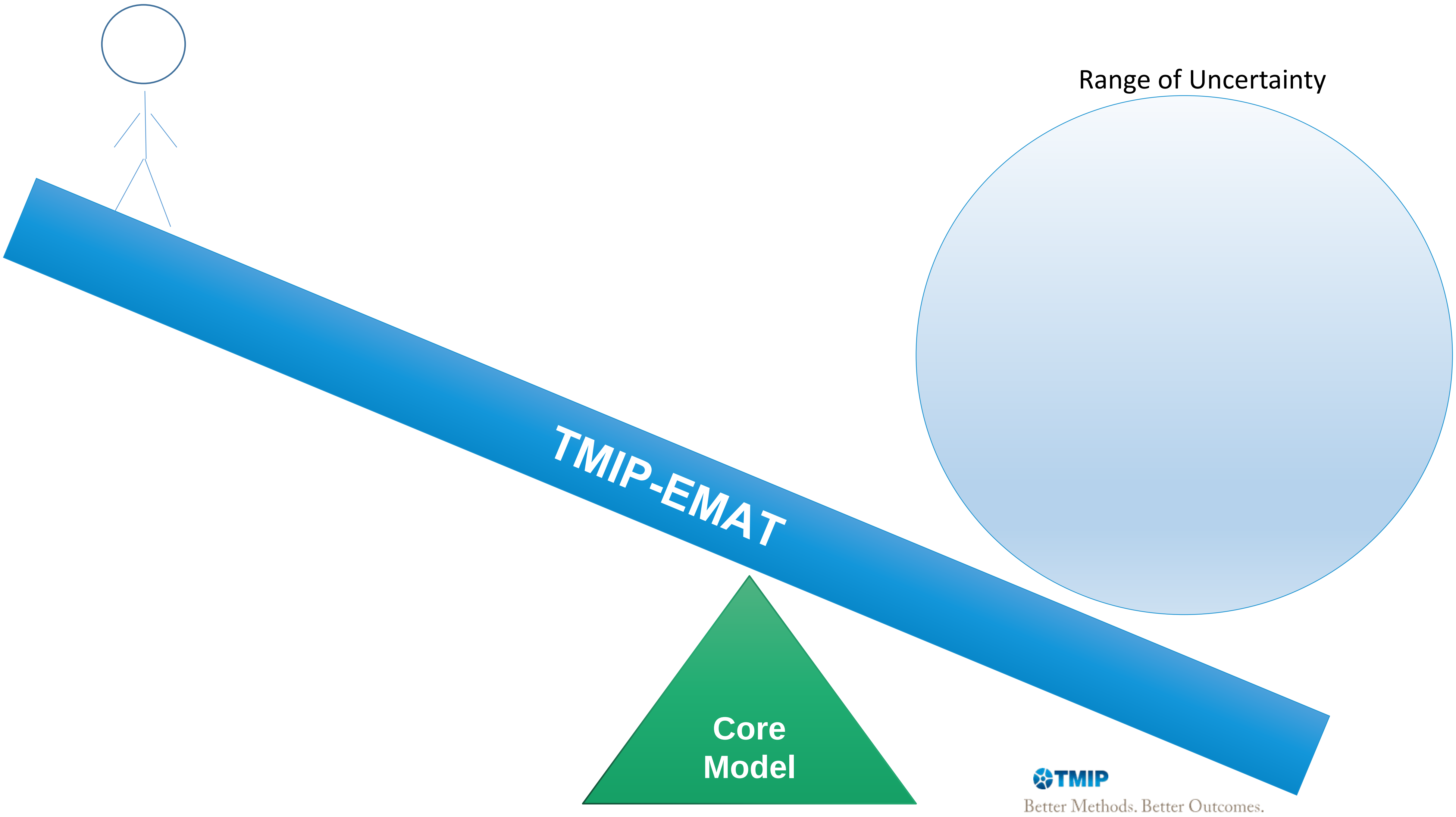
- Regional travel demand model
  - Trip-based
  - Activity-based
- Microsimulation
  - Corridor-level
  - Dynamic Traffic Assignment
- Hybrid
- Data driven
- Sketch (strategic)



What do we do?

- Point prediction – Best Guess on All Concerns
- Scenario planning – Several Best Guesses
- Why can’t we do it all?




Range of Uncertainty
TMIP-EMAT
Core
Model
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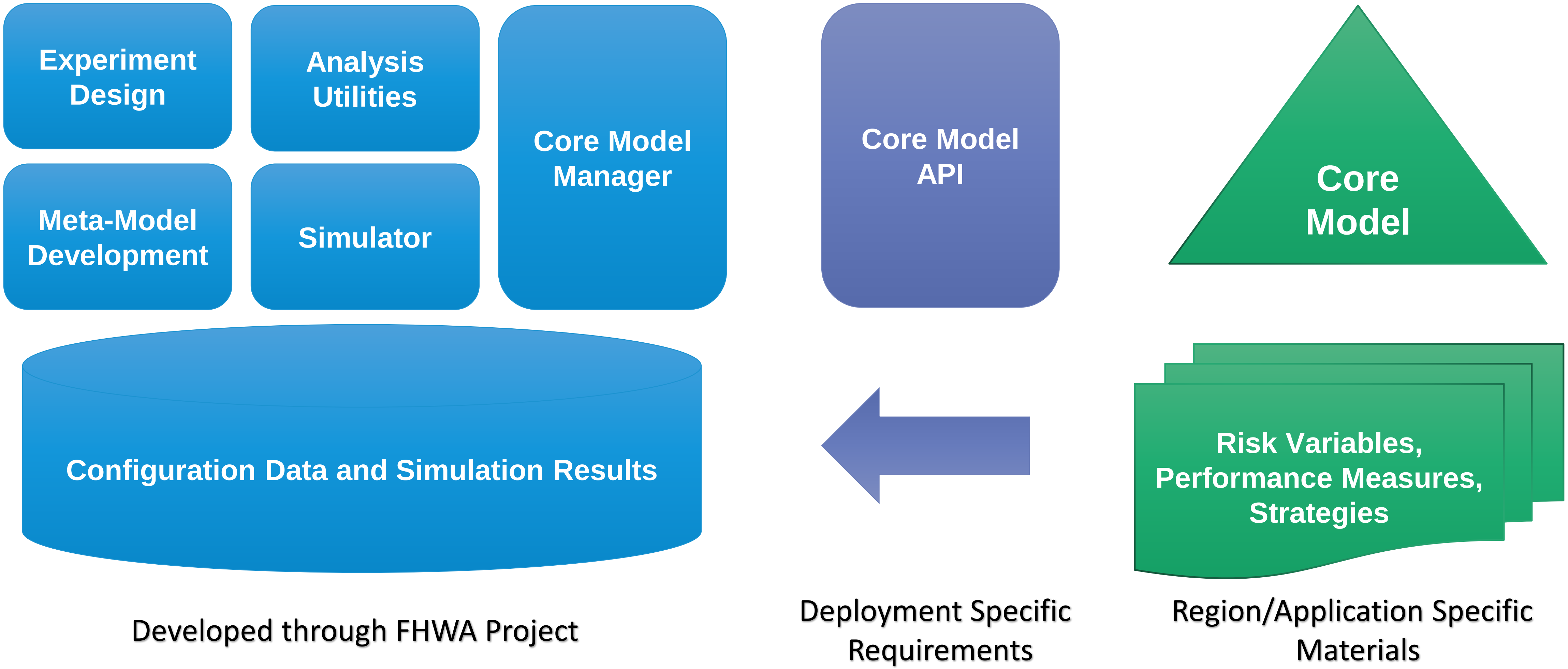
How does TMIP-EMAT work?

- Where necessary, leverages Core Model outputs to produce Meta-Models that can quickly explore the range of uncertainty
- Key Steps
  - Scoping (define uncertainty space)
  - Develop meta-models
    - Design experiments
    - Run core model
    - Estimate meta-models
  - Analysis
    - Simulate across range of uncertainty
    - Risk or exploratory

Meta-models are regression models of the Core Model outputs that run very fast

TMIP-EMAT Components



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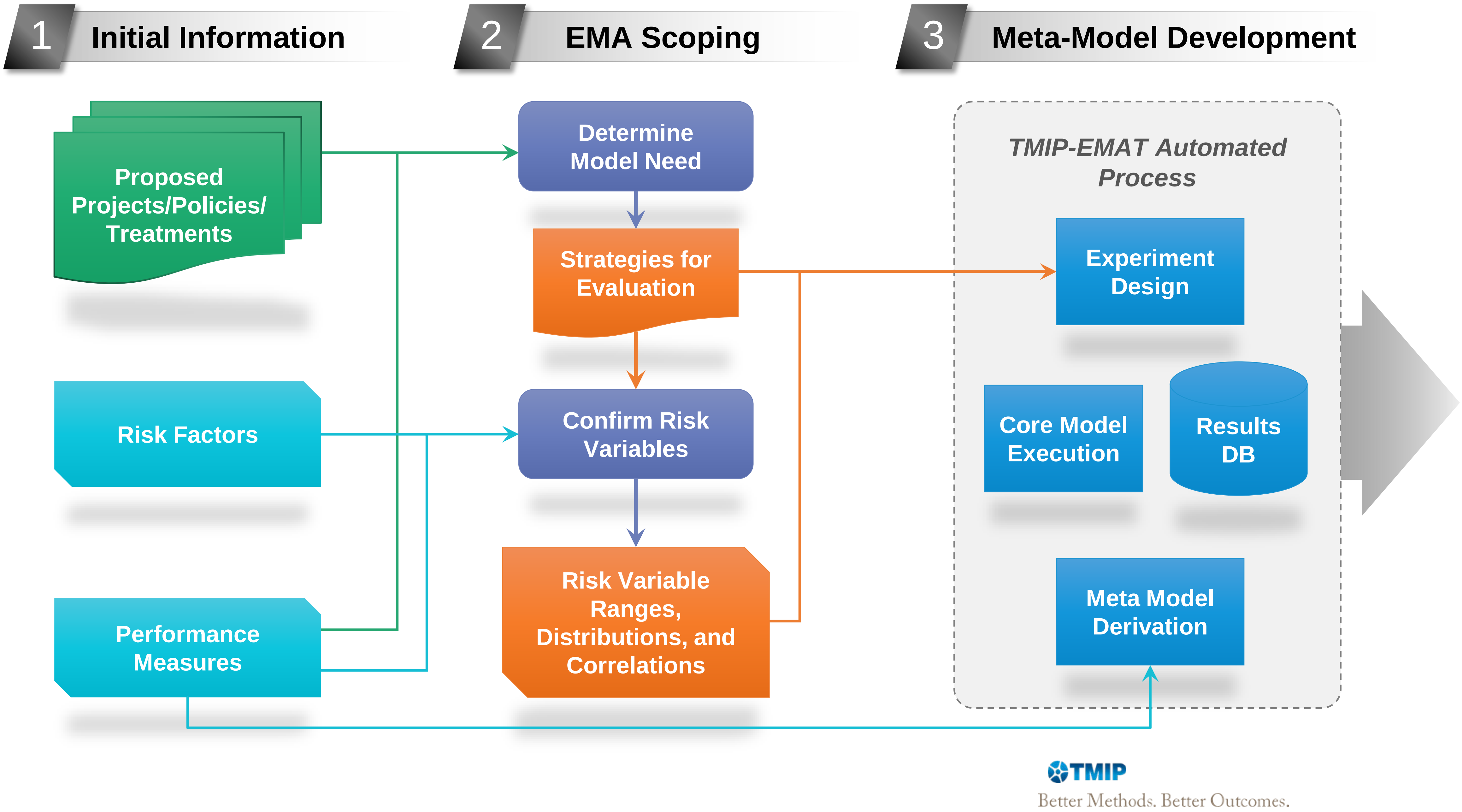
1 Initial Information
2 EMA Scoping
3 Meta-Model Development
Proposed Projects/Policies/ Treatments
Risk Factors
Performance Measures
Determine Model Need
Strategies for Evaluation
Confirm Risk Variables
Risk Variable Ranges, Distributions, and Correlations
TMIP-EMAT Automated Process
Experiment Design
Core Model Execution
Results DB
Meta Model Derivation
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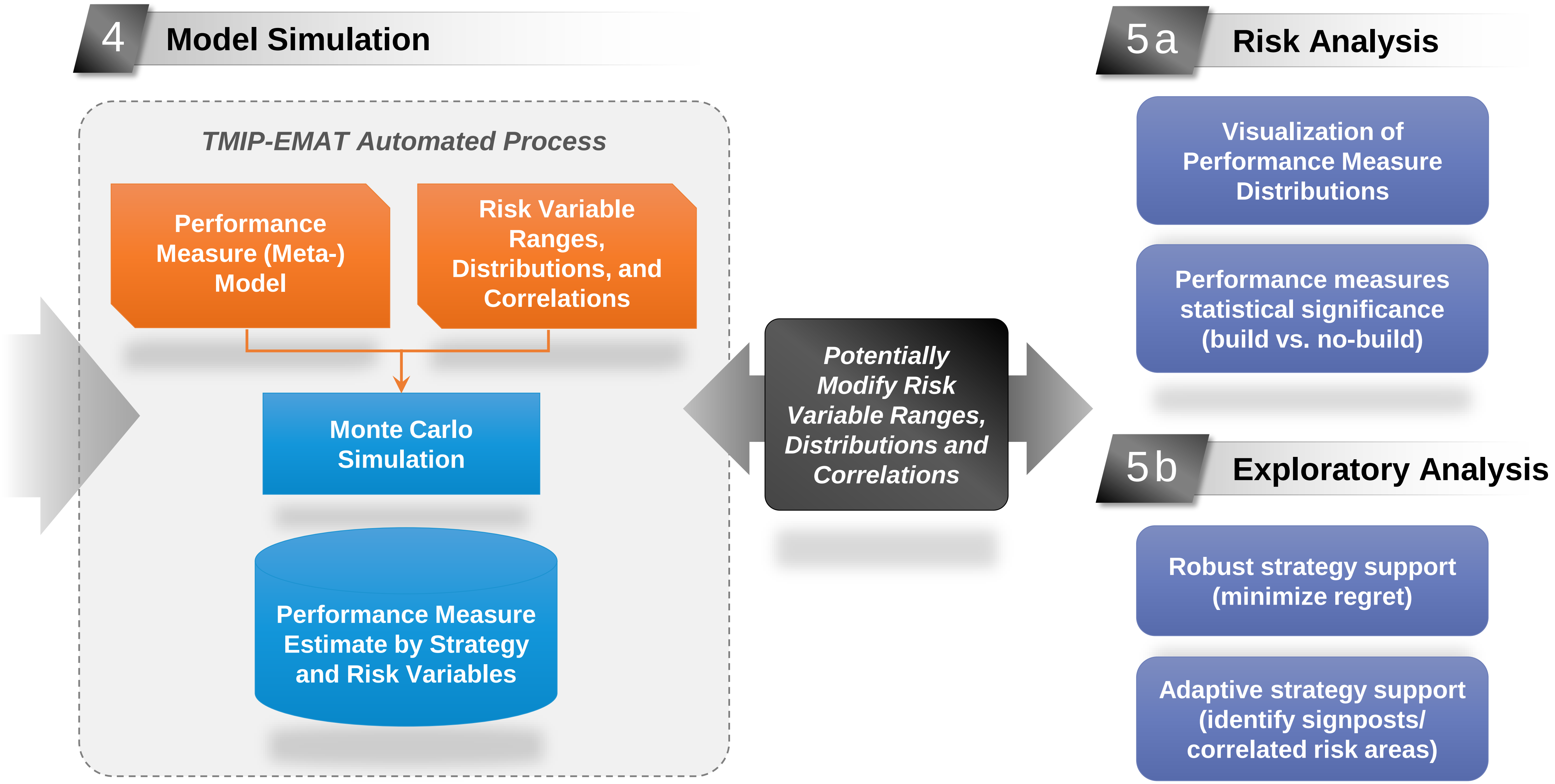

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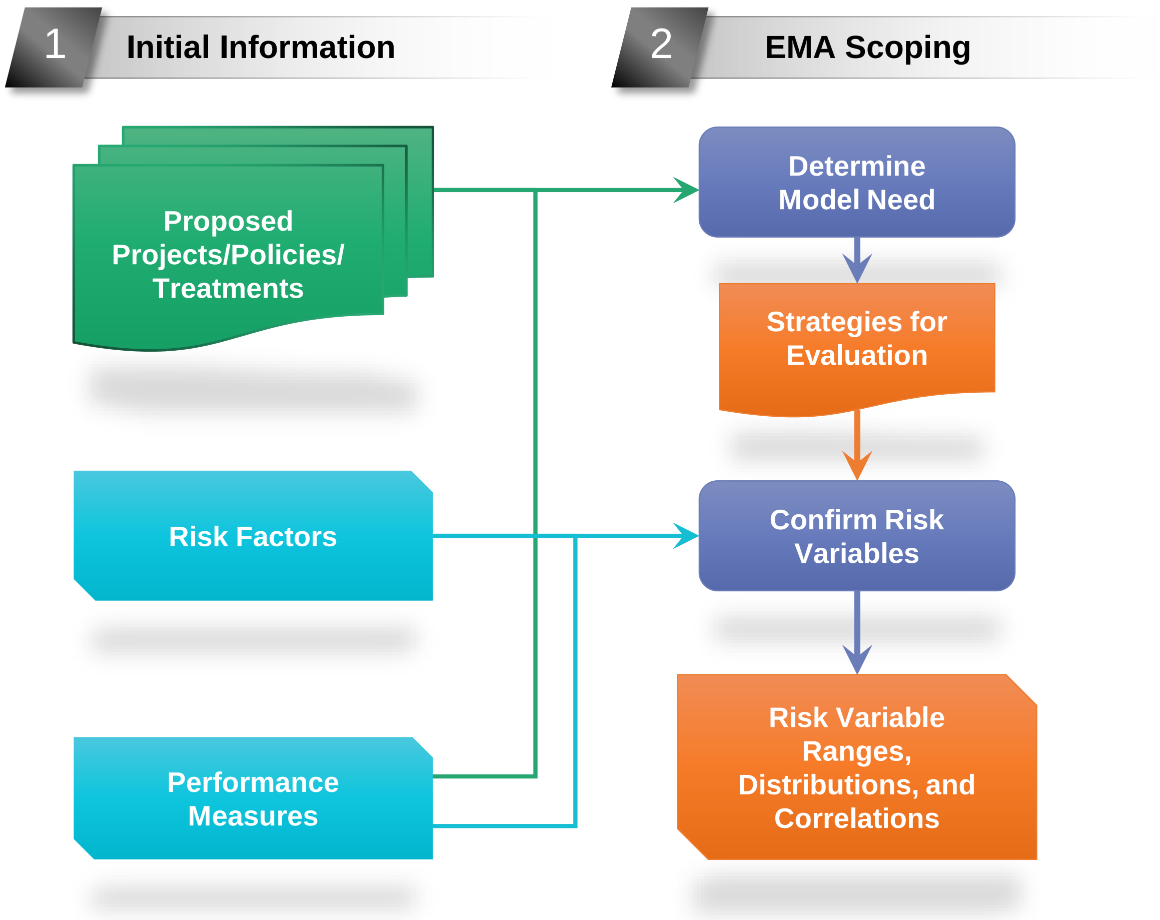
Step 1 and 2: Initial Information and Scoping

<u>Breakout Group Discussion</u>

- Choose a model (per group) to use as an example through the workshop
- What strategies would you test?
- Performance measures of interest
- Identify how risk factors could be represented in your model (a model)
  - What are the risk variables?
  - Ranges and distributions

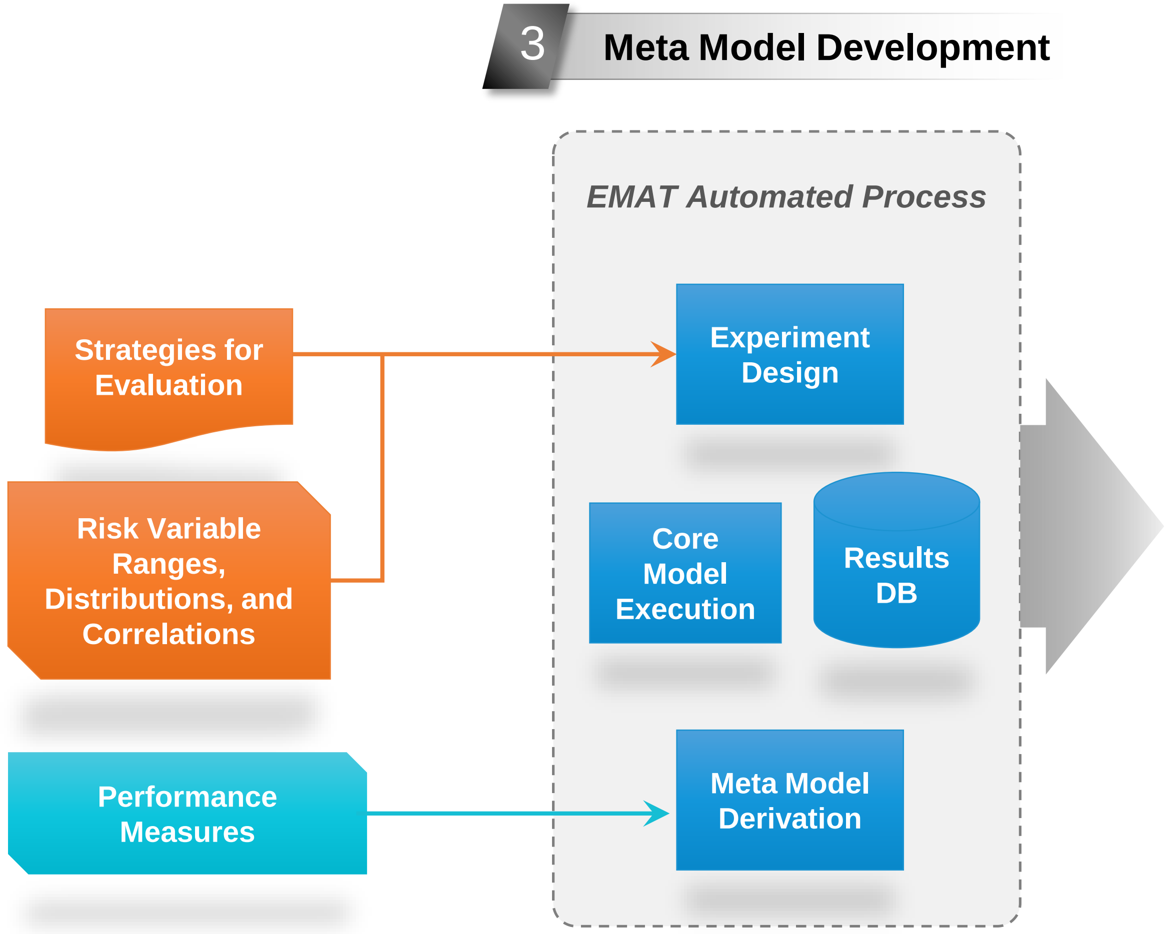


Risk Variable	Minimum	Most Likely	Maximum	Distribution	Unit
Households and Employment in downtown TAZs	-18%	0%	37%	PERT - Standard	Percent change from Base socio-economic dataset
Roadway Capacity	0%	50%	100%	Triangular	Percent increase in capacity on Interstates, Expressways, and on-ramps
Auto In-vehicle Time Coefficient	1- (0.25 / auto occupancy)	1- (0.15 / auto occupancy)	1.0	Triangular	Unit = Factor on coefficient
Vehicle Availability Alternative Specific Constants	0 Veh = 14.2% Veh < Workers = 7.1% Veh >= Workers = 78.7%	0 Veh = 7.1% Veh < Workers = 3.6% Veh >= Workers = 89.3%	0 Veh = 0% Veh < Workers = 0% Veh >= Workers = 100%	PERT - Standard	Unit = percentage of vehicle sufficiency categories resulting from vehicle. availability model

Step 3: Experiment Design and Meta Model

<u>Group Discussion</u>

- Is this step necessary for your model?
- Approaches to experiment design
- Factors to consider
- What makes a good meta model?



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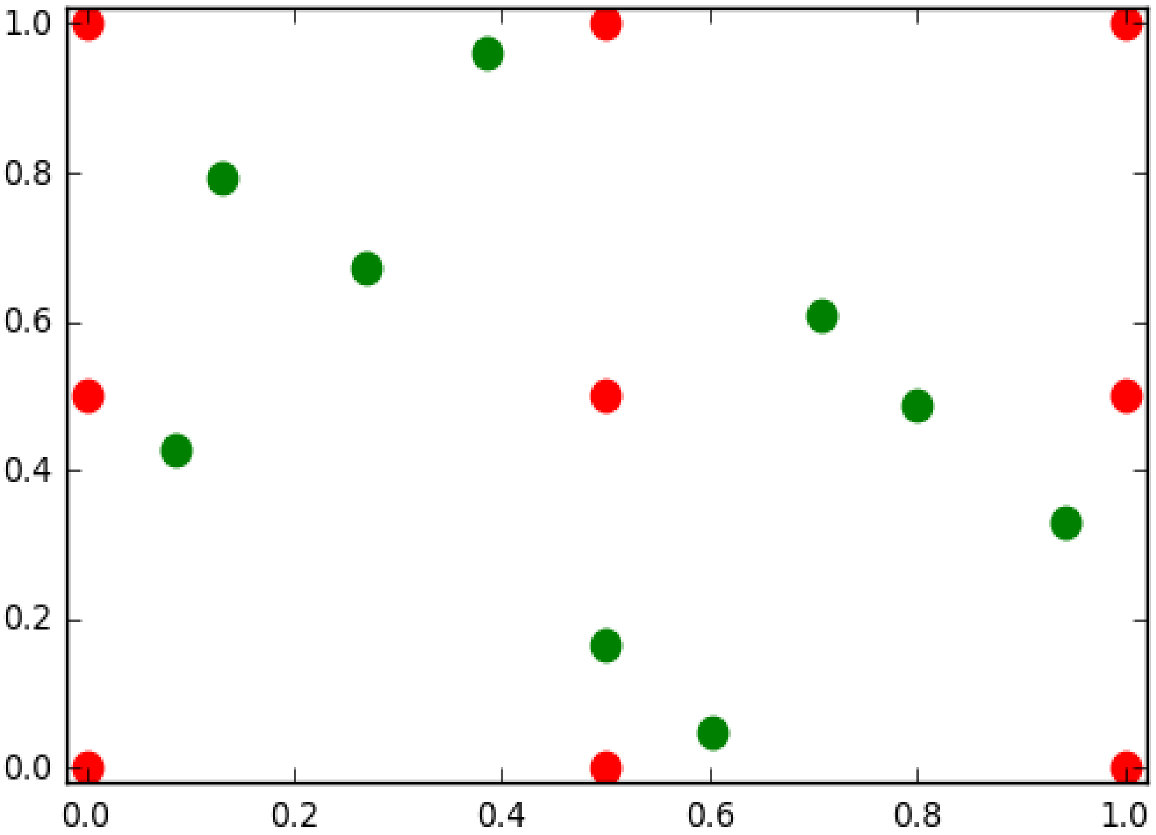
Latin Hypercube vs. Factorial Design

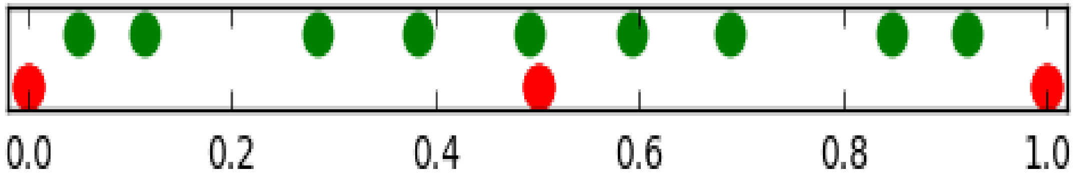
LHS vs. Factorial in 2 Dimensions

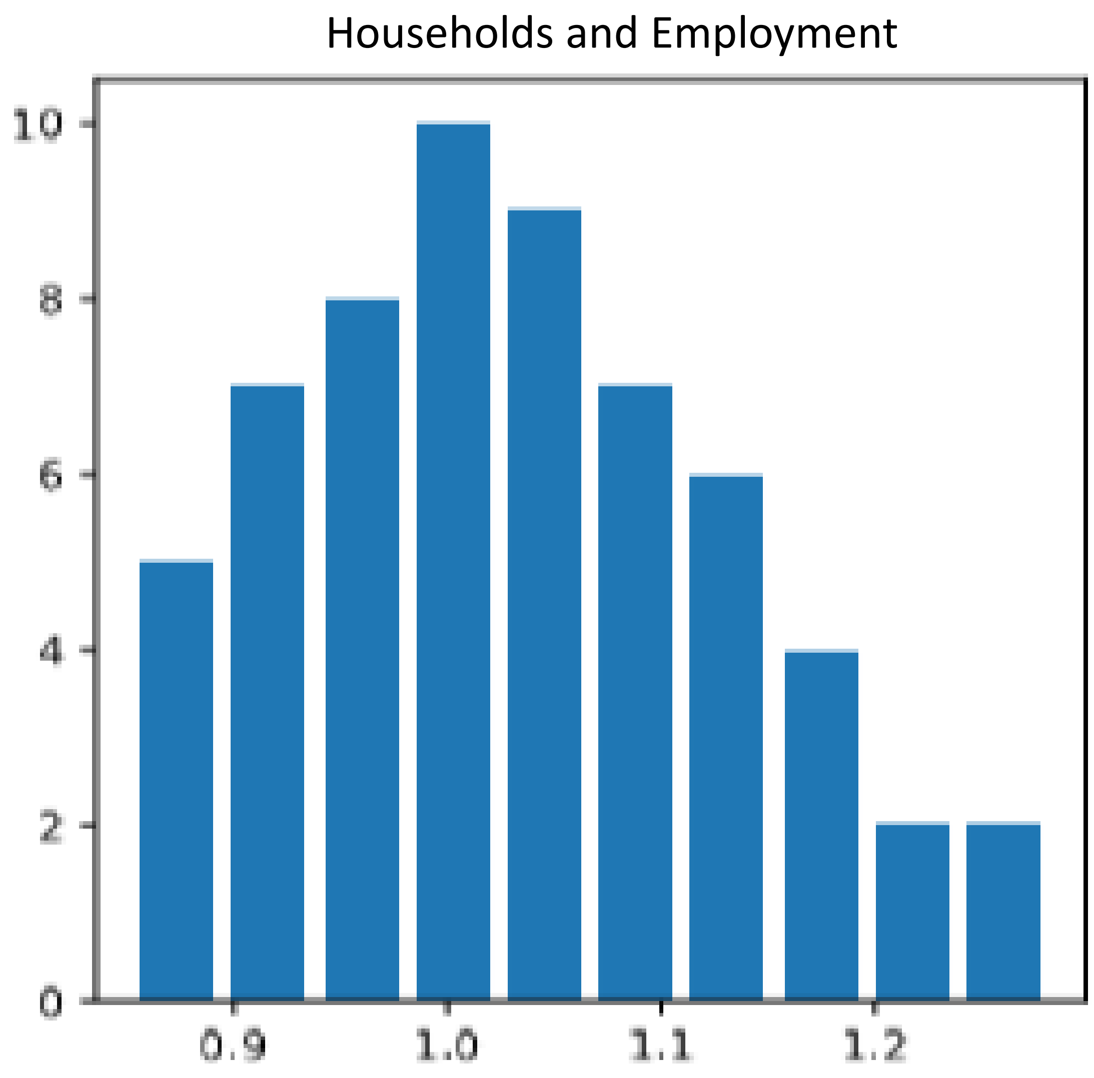


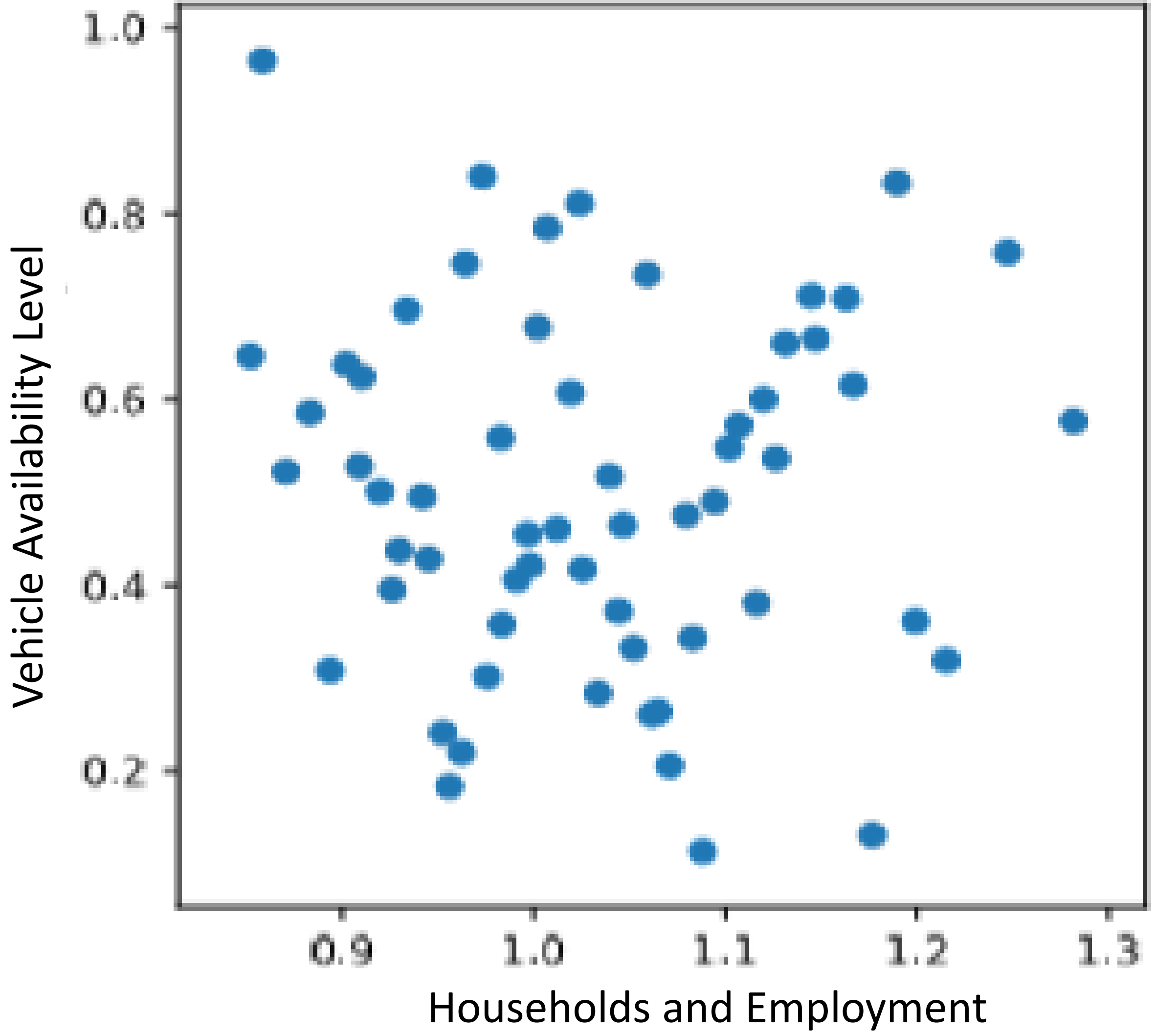
Full Factorial Experiment

Latin Hypercube Experiment

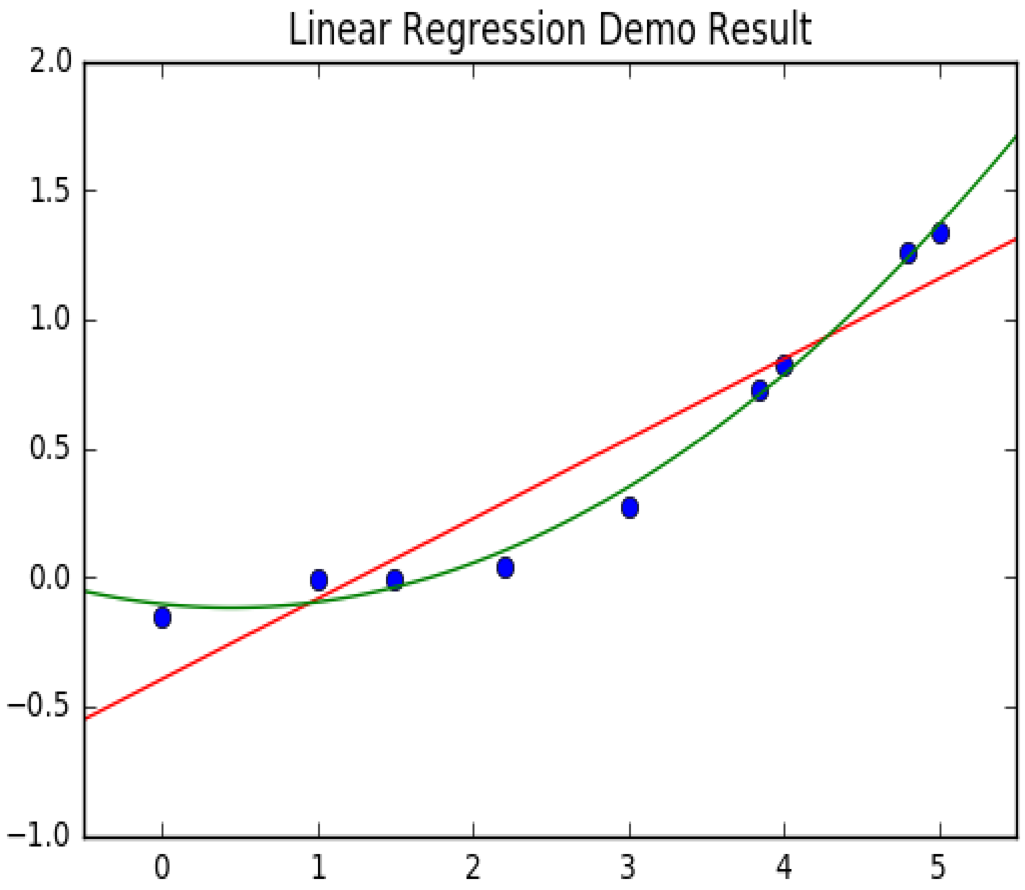
LHS vs. Factorial collapsed to 1 Dimension

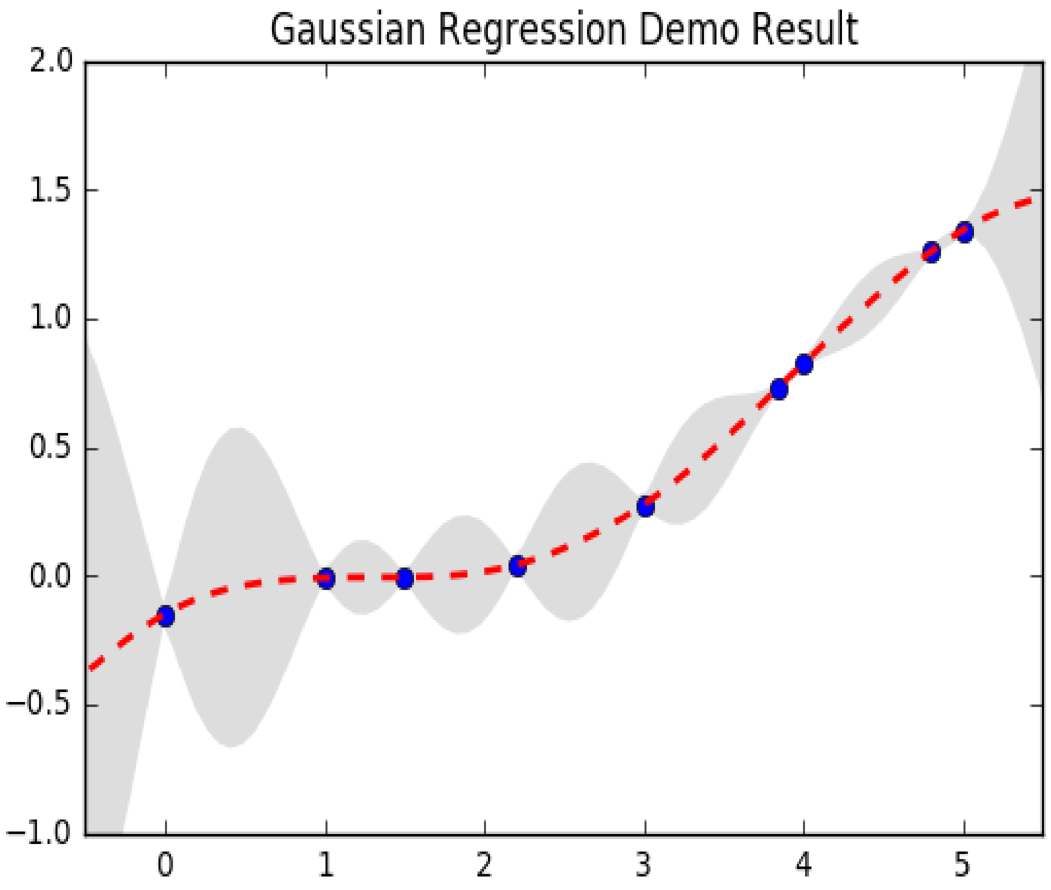



Households and Employment
0
2
4
6
8
10
0.9
1.0
1.1
1.2


Vehicle Availability Level
0.2
0.4
0.6
0.8
1.0
0.9
1.0
1.1
1.2
1.3
Households and Employment

Linear Regression and Gaussian Regression





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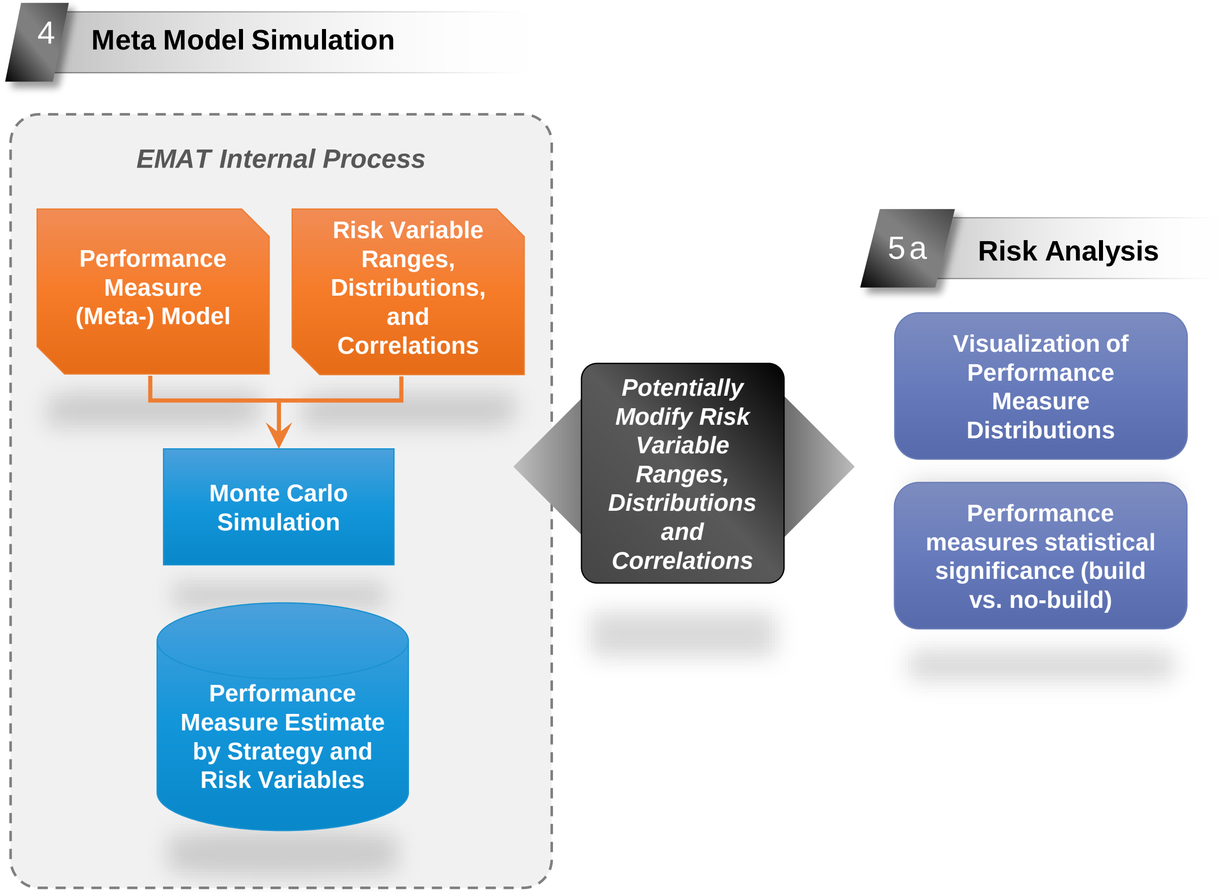
De-trending

- Deterministic model results will have a clear trend that can be largely explained with linear terms
- Meta Model Process
  - Estimate a simple linear regression model
  - Apply a Gaussian Process Regression to the linear model residuals
- Linear regression parameters useful in checking and analysis
- Gaussian regression used to represent more complex interactions

Performance Measures	Region-wide VMT	Total LRT Boardings	Downtown to Airport Travel Time
Constant	16.316 (1259.66)	8.038 (90.5)	2.615 (141.5)
Households and Employment in downtown	0.717 (122.3)	2.236 (55.66)	0.2 (23.96)
Roadway Capacity	0.016 (5.45)	-0.013 (-0.64)	-0.099 (-23.47)
Auto IVTT	-0.088 (-7.33)	-0.103 (-1.26)	-0.037 (-2.18)
Vehicle Availability	0.056 (17.94)	-0.456 (-21.2)	0.025 (5.49)
Kensington Decommissioning	-0.002 (-1.77)	-0.006 (-0.69)	0.009 (4.84)
LRT Extension	-0.004 (-3.06)	0.257 (30.84)	0.002 (0.93)
R-Square	0.997	0.989	0.959

Step 4 - 5a:Simulation for Risk Analysis

- Simulation: scoped and updated
- Types of measures



Risk analysis visualization utility

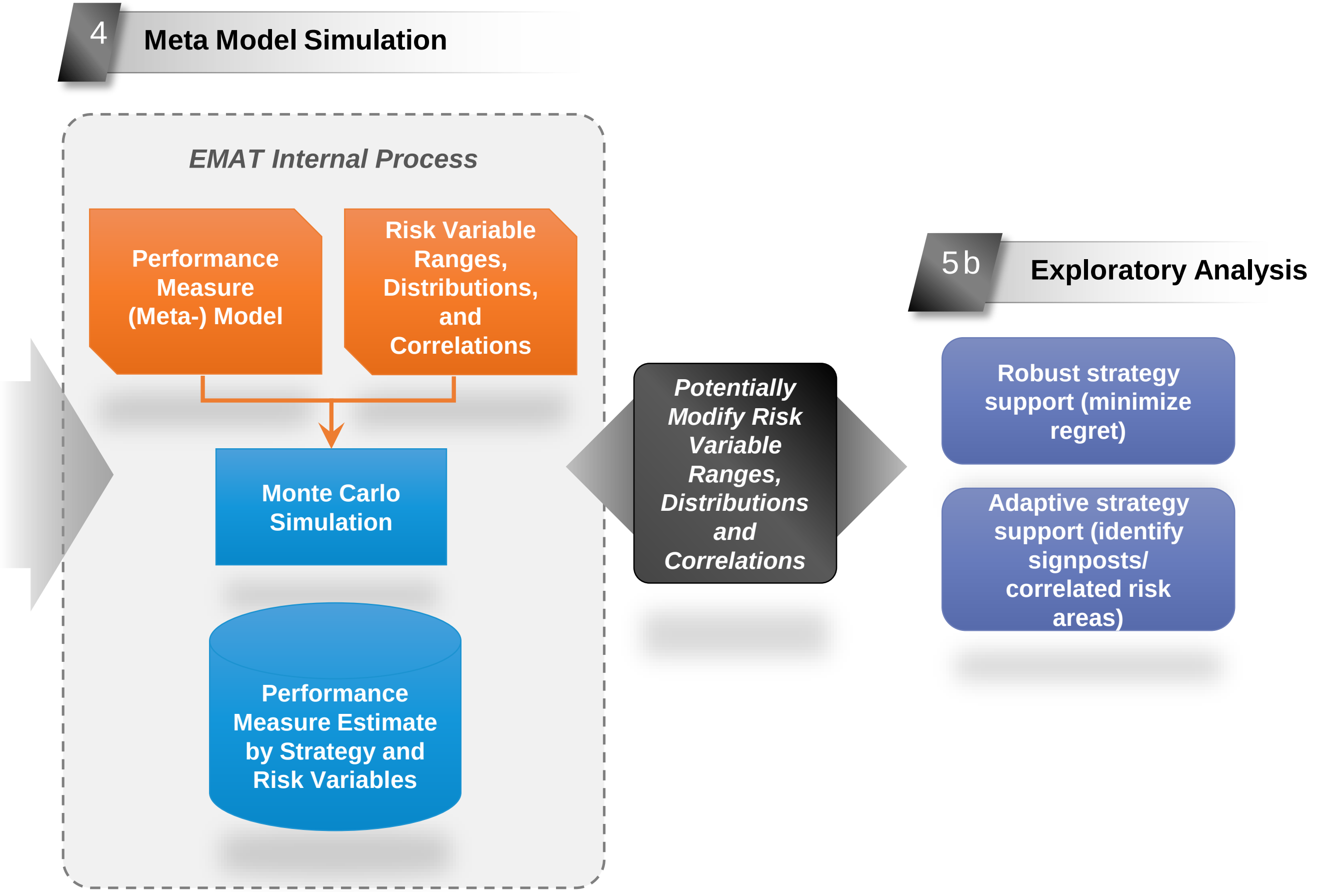
Group Discussion

- Range and probability of occurrence
- Cumulative distribution of performance measures
- Relative importance of risk

- Launch Risk Visualization Utility

Step 4 - 5b: Simulation for Exploratory Analysis

- Simulation: distributions to use?
- Exploratory process



Exploratory Analysis – Selection Sets

Group Discussion

- Understand strategy impacts given risk variable ranges
- Understand strategies for a given range of performance measures
- Understand risk variable significance given strategies

- Launch Exploratory Visualization Utility

How does TMIP-EMAT change the practice?

Benefits

- Produce performance measure estimates across range of uncertainty
- Leverage region/application specific tools

Costs

- Deployment
- Core model validation: response to range of inputs

TMIP-EMAT Next Steps

- Improve the usability
- Explore the value of the approach
- Improve meta-model formulation
- Collect feedback from potential users

Requested Feedback

- Key challenges to using TMIP-EMAT with your models and planning applications
- Complementary software
  - Models
  - Visualizers
- Other helpful tests / demonstrations / reports / visualizations

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