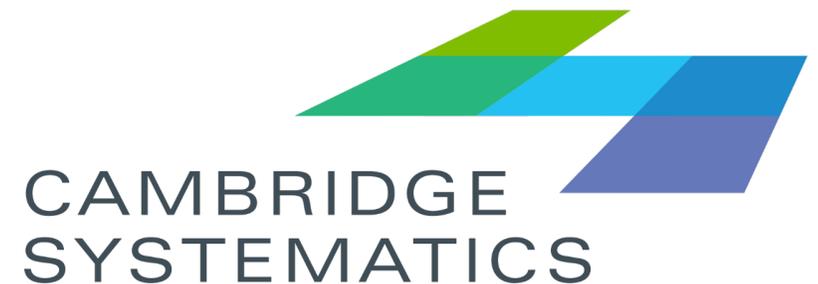


Southeast Florida FSUTMS Users Group  
Travel Demand Forecasting and Model Application  
Friday, September 17, 2021

# Is a Hot Dog a Sandwich?

Presented by Jeff Newman



Think  Forward

Southeast Florida FSUTMS Users Group  
Travel Demand Forecasting and Model Application  
Friday, September 17, 2021

# Exploratory Modeling and Analysis Tools and Travel Demand Models

— *or* —

## Is EMAT a sandwich?

Presented by Jeff Newman



Think  Forward

# Today's Agenda

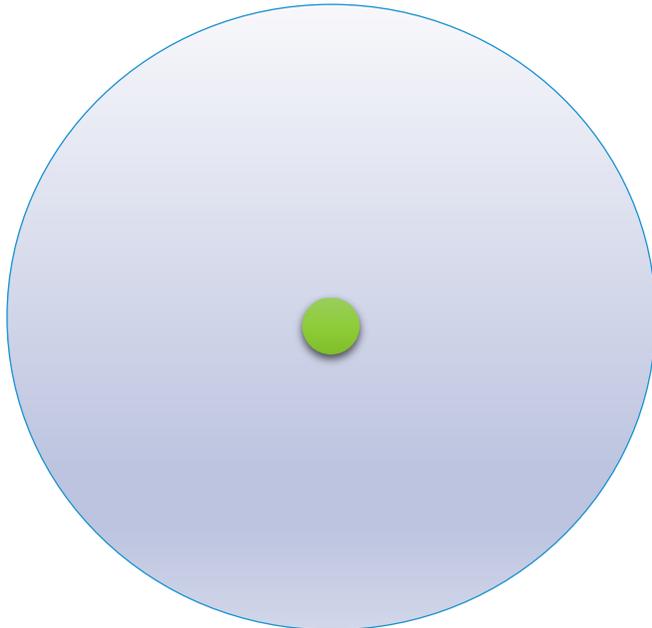
---

- What do we mean by Exploratory Analysis?
- What is EMAT and how is it helpful?
- What do we need to do to connect EMAT and a travel demand model?
- Once we've built that connection, what can we do with it?
  - We will focus today on methodology and functionality, not particular results

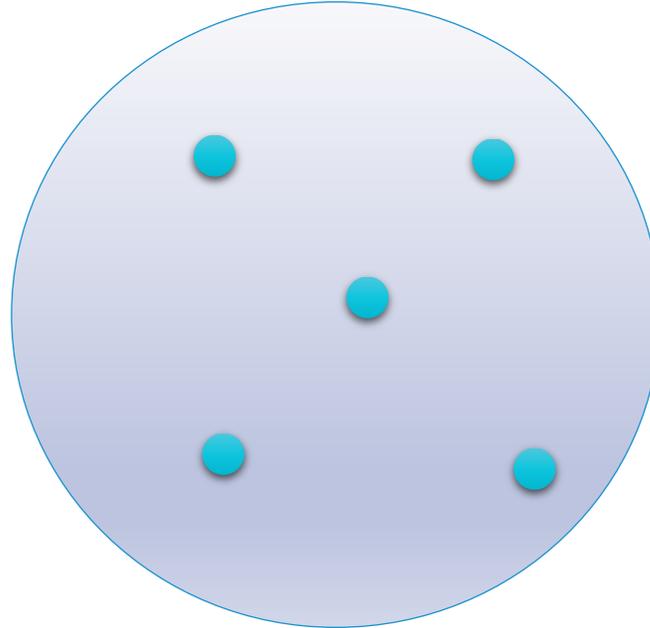
# The Evolution of Decision Making

POINT PREDICTION	SCENARIO PLANNING	EXPLORATORY MODELING
One Best Guess	Several Best Guesses	Lots of Guesses

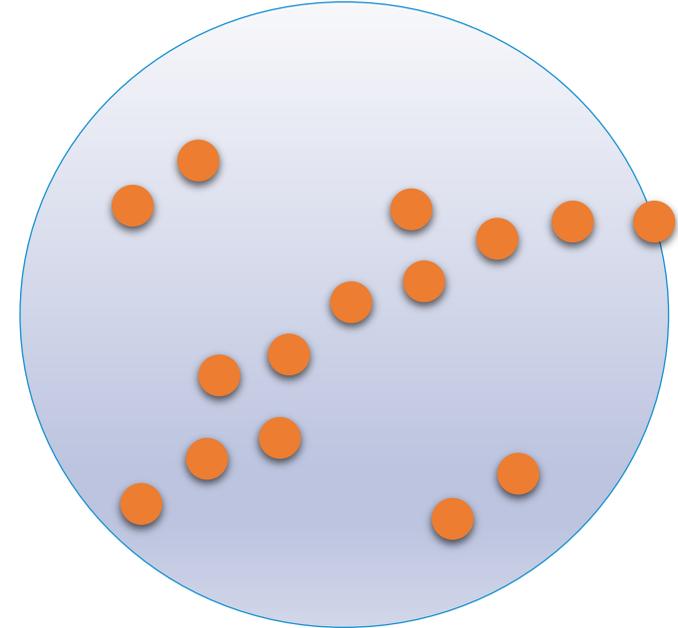
UNCERTAINTY SPACE



UNCERTAINTY SPACE



UNCERTAINTY SPACE



# The XLRM Conceptual Framework for Exploratory Analysis

---

## **X: Exogenous Uncertainties**

Aspects of the future that are variable and outside of our control

## **R: Relationships**

The connections between inputs and outputs, i.e. a transportation model

## **L: Policy Levers**

Aspects of the future that are changeable and at least conceptually under our control

## **M: Performance Measures**

Outcomes of interest that can be used to evaluate the performance of the system

The  
Exp

# EMAT

X: Exogenous Uncertainties

L: Policy Levers

Aspects of the future that are variable and outside of our control

Aspects of the future that are changeable and at least conceptually under our control

## INPUTS

Can have lots of different values

R: Relationships

The connections between inputs and outputs, i.e. a transportation model

## MODEL

Gets run a bunch of times

M: Performance Measures

Outcomes of interest that can be used to evaluate the performance of the system

## OUTPUTS

Not just a point estimate

# What is EMAT? *Is it some kind of sandwich?*

---

EMAT is a collection of exploratory modeling and analysis tools designed to work with travel demand models

- A structure to define an **exploratory scope**, to translate the abstract XLRM framework into a concrete, application-specific form,
- A process to create a systematic **design of experiments** to explore,
- A **database** to organize and store results from experiments,
- A facility to automatically create a **metamodel** from experimental results, and
- A suite of **analytical and visualization tools** to explore the relationships between modeled inputs and outputs

# What is in an Exploratory Scope?

---

- What are the policy levers and exogenous uncertainties?
- How are these input factors expressed in our travel demand model?
- How can we vary these factors systematically?
- What are the performance measures of interest?
- How are these output measures expressed by our travel demand model?
- What constitutes an “improvement” in a measure?

# A Scope YAML File

- For EMAT we define the exploratory scope in a YAML file.
- Here we define the data types and range and distribution of the inputs that will be explored
- We also define what the performance measure outputs will be

```
scope:
  name: Demo
  desc: Demonstration of Exploratory Analysis
inputs:
  cav_rate:
    shortname: CAV Penetration
    ptype: uncertainty
    desc: Percentage of households owning CAVs
    dtype: int
    default: 0
    min: 0
    max: 70
    dist: uniform
  tnc_rate:
    shortname: Rideshare Cap
    ptype: lever
    desc: >-
      Maximum number of rideshare vehicles operating
      simultaneously within city limits
    dtype: int
    default: 9
    min: 5
    max: 90
    dist: uniform
  tnc_los:
    shortname: Rideshare Taxes
    ptype: lever
    desc: Level of rideshare taxes
    dtype: real
    default: 1
```

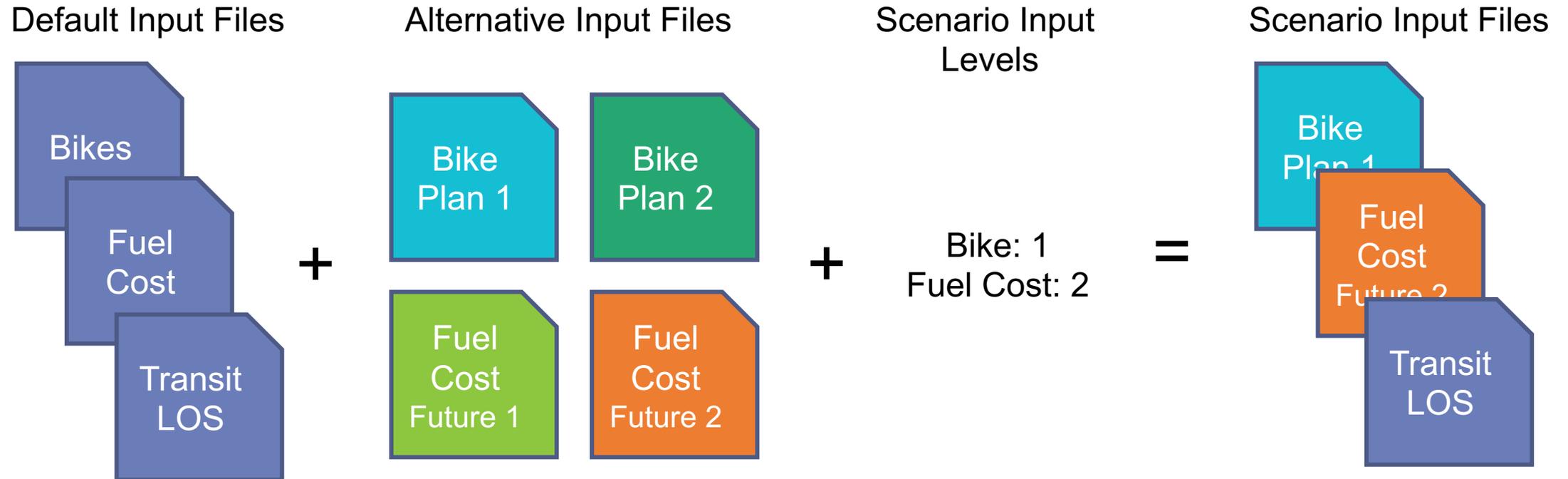
# A Python Interface

---

- Just four Python functions are required to connect your existing travel demand model to EMAT.
  - » `setup()`
  - » `run()`
  - » `load_measures()`
  - » `archive()`
- Other functions can be provided to unlock additional features.
- The core model need not be written in Python – any model that can be run from the command line can be connected to EMAT.

# Setting up Experiments

- One approach to preparing different experiments is to set levels for various inputs, and combine them to create scenarios



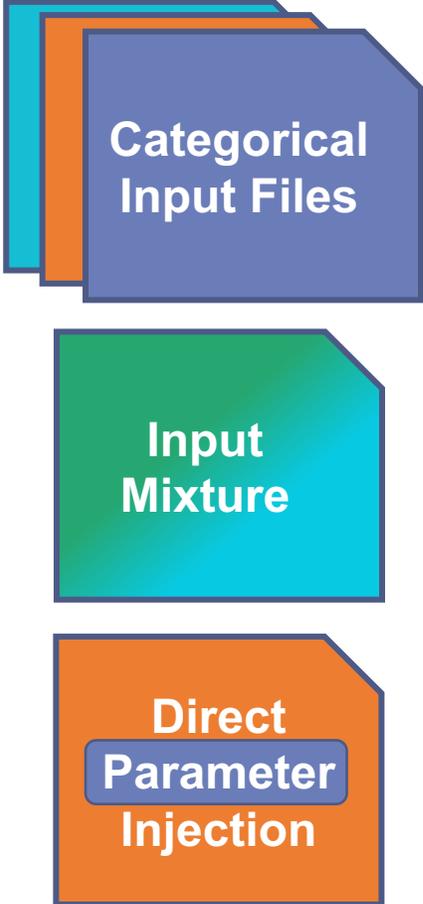
# Full Factorial Designs are Limiting and Expensive

Number of X & L	Number of Levels per X or L	Number of Full Factorial Experiments
6	3	729
9	2	512
9	3	19,683
12	3	

- Running every combination of input levels is a “full factorial” design
- It gives a lot of information but implies exponential growth in number of runs with added dimensions
- This limits the number of uncertainties and policy levers that can be considered

# Building Back Better Meta-Models

---



Categorical  
Input Files

Input  
Mixture

Direct  
Parameter  
Injection

- The categorical values don't work great for EMAT's meta-modeling tools, as fitting Gaussian process regression models is more stable with more variability in input levels
- We can use various approaches for setting input values, in addition to the categorical file swapping approach:  
**input mixtures** and  
**direct parameter injection**

# Input Mixtures

---

- Input mixtures create a new unique input file as a linear interpolation between two or more existing categorical input files. Every value appearing in each file is interpolated.
- A straight line uniform linear combination is the simplest process, but non-linear transformations of the mixture parameters, or a piecewise linear process with three or more defined files is possible.

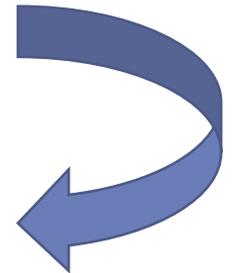


# Direct Parameter Injection

- Directly inject new parameter values into particular positions in one or more input files
- We start from a template file with unique tokens for each relevant value to make finding the right places simple

```
Geo,Year,FuelCost.2005,PowerCost.2005  
RVMPO,2010,2.43,0.08  
RVMPO,2038,__EMAT_PROVIDES_FuelCost__,__EMAT_PROVIDES_ElectricCost__
```

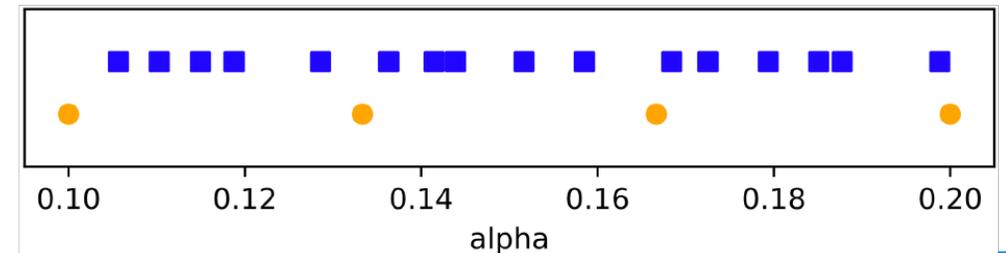
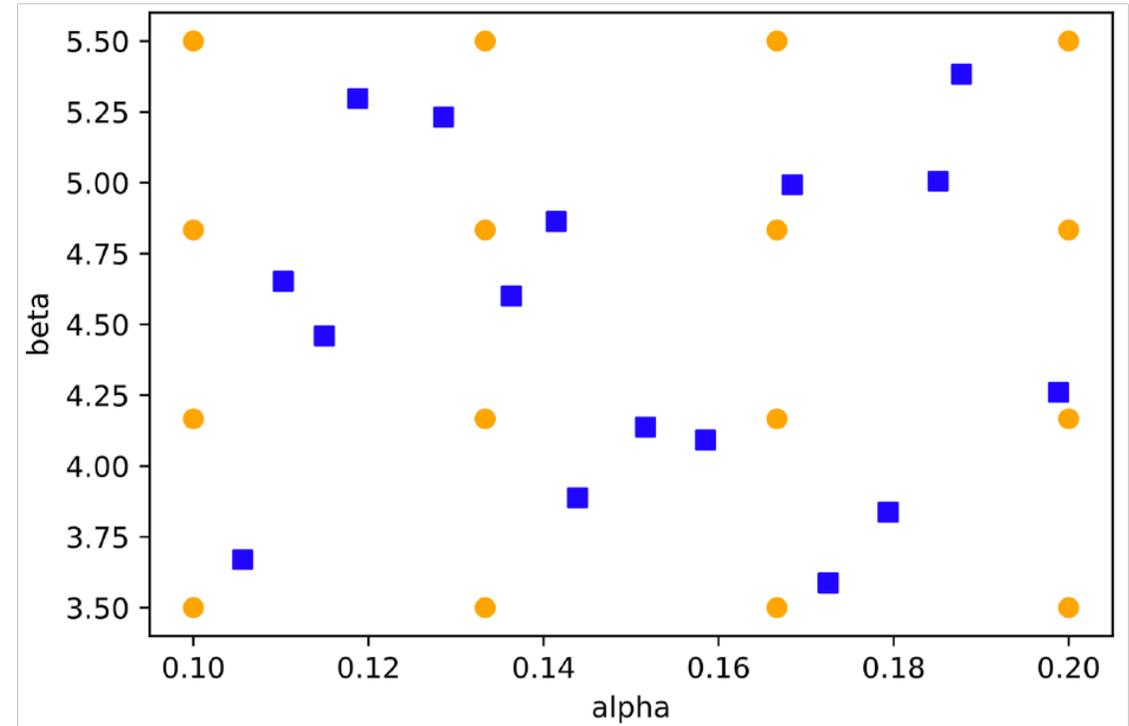
```
Geo,Year,FuelCost.2005,PowerCost.2005  
RVMPO,2010,2.43,0.08  
RVMPO,2038,5.42,0.11
```



- This also allows us to define multiple different and independent uncertainties in the same input file.

# Latin Hypercube, Maximum Information

- A Latin Hypercube design evenly slices each input dimension, draws one value in each slice, then randomly reorders the points across dimensions.
- All experiments can provide useful information, even if one dimension is unimportant
- Works great for continuous dimensions, also works for categorical dimensions too

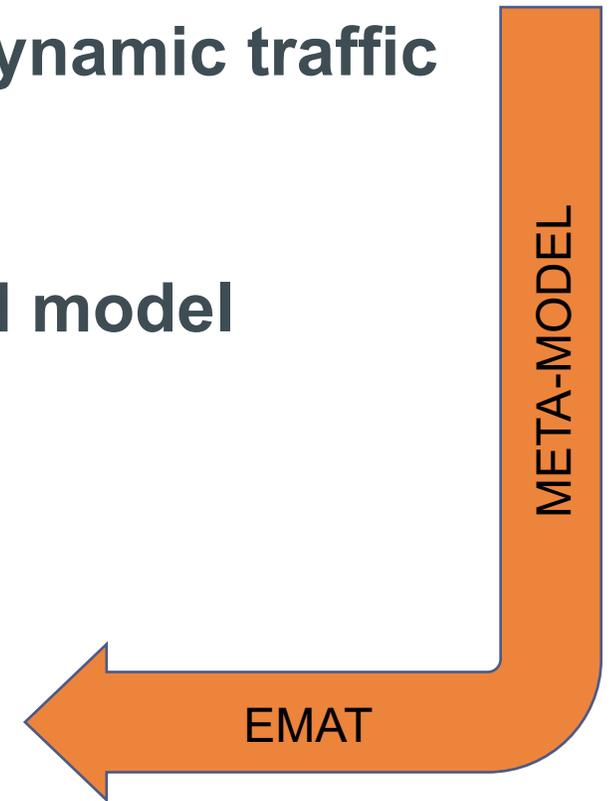


# Metamodels are So Meta

---

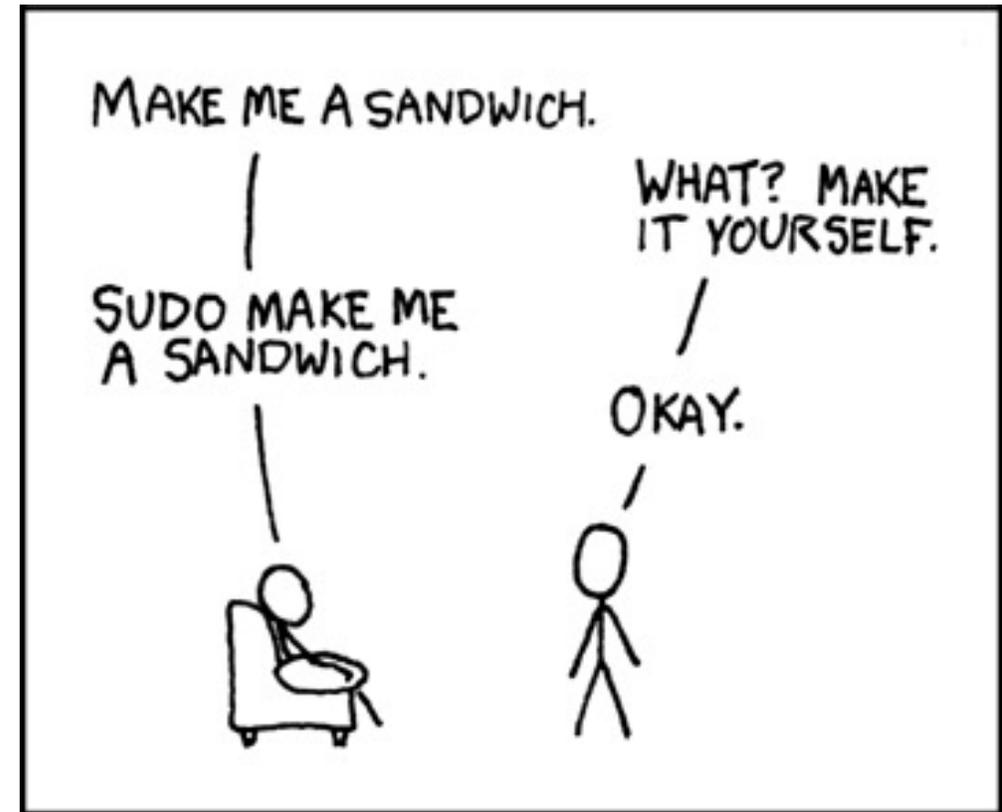
For “run the model a bunch of times”, we expect to be able to run...

- A **full-scale regional activity-based model with dynamic traffic assignment model**  
a few times
- A **traditional “trip-based” regional travel demand model**  
a few dozen times
- A **network-free strategic planning model**  
a few hundred times
- A **Gaussian process regression metamodel**  
a few hundred thousand times



# Running a Design of Experiments

- Once the model is properly configured according to the EMAT API, running a design of experiments is simply a matter of opening a Jupyter notebook and calling the `model.run_experiments` command.



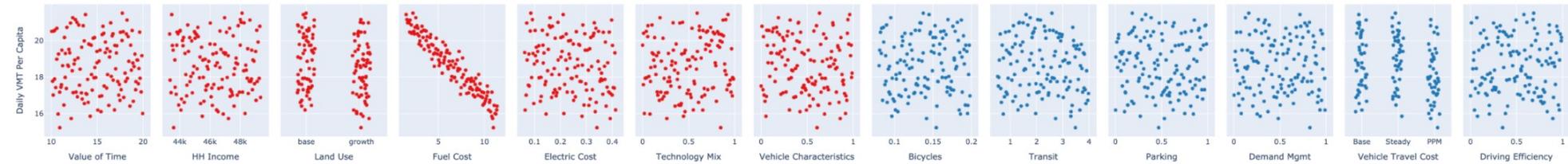
Comic Courtesy XKCD, <https://xkcd.com/149>

# Scatter Plot Matrix

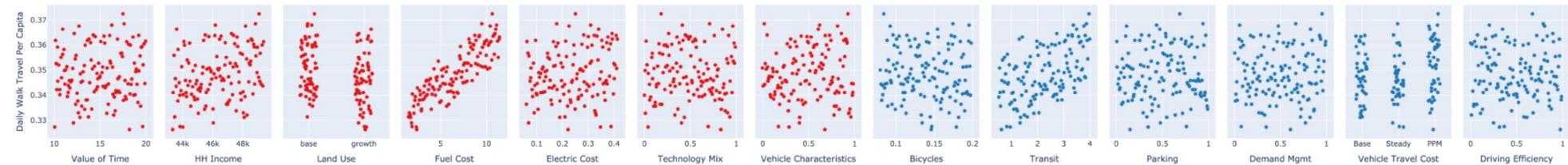
```
from emat.analysis import display_experiments
figs = display_experiments(scope, 'ulhs', db=db, rows=measures)
```

executed in 5.74s, finished 18:45:07 2021-06-16

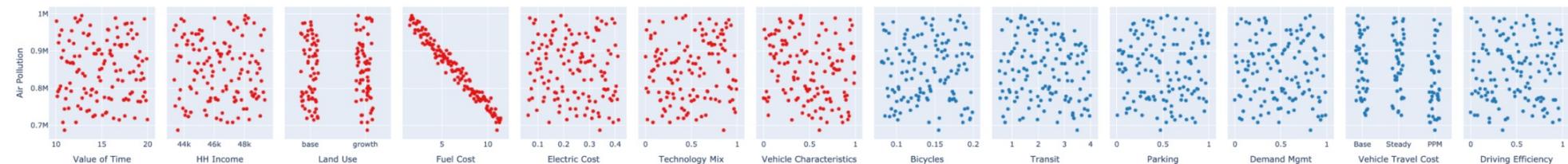
## Daily VMT Per Capita



## Daily Walk Travel Per Capita



## Air Pollution

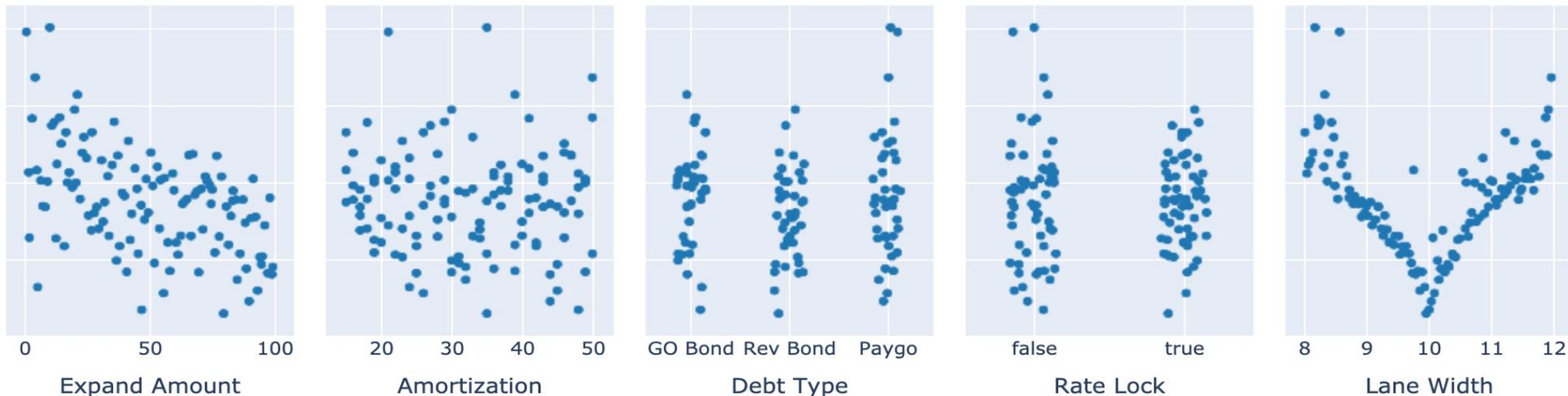


Fuel  
Cost

Transit

# Using Scatter Plots for Validation

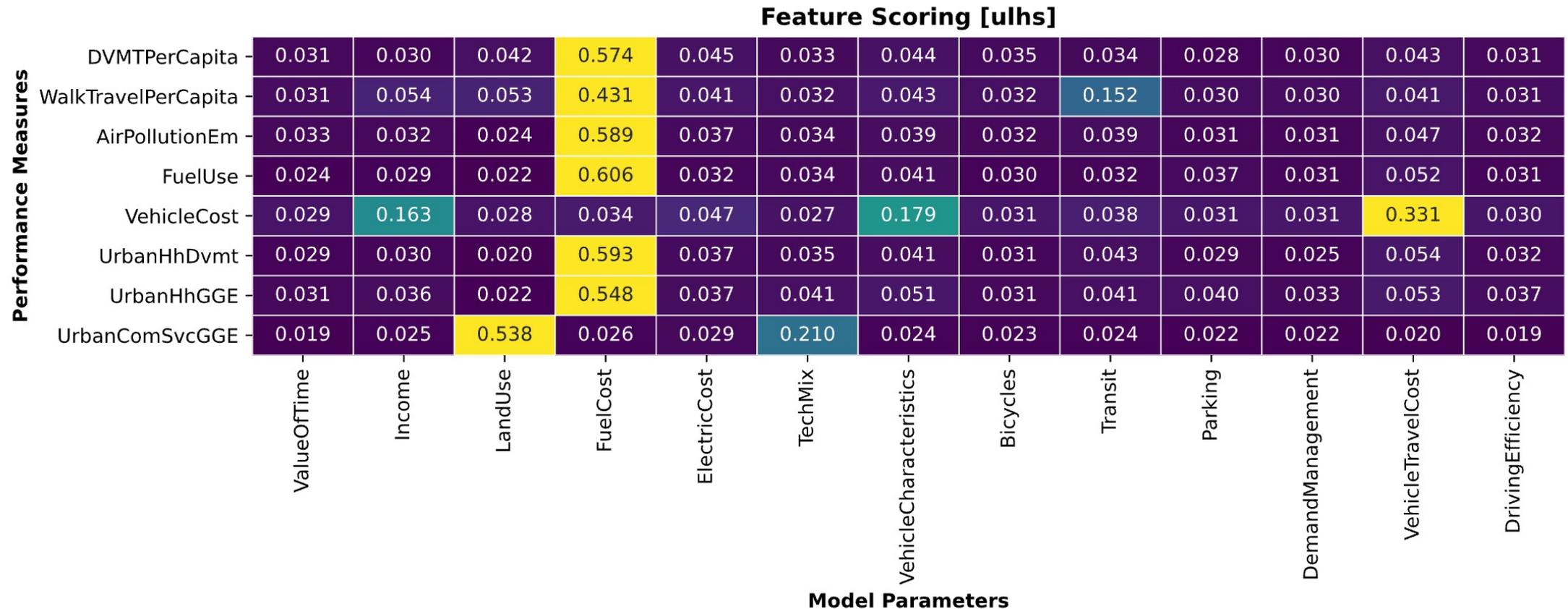
- During EMAT beta tests, we found that reviewing scatter plots offers a good way to validate that models are performing as expected.
- Don't wait until the experimental runs are complete to begin analyzing data



# Feature Scores

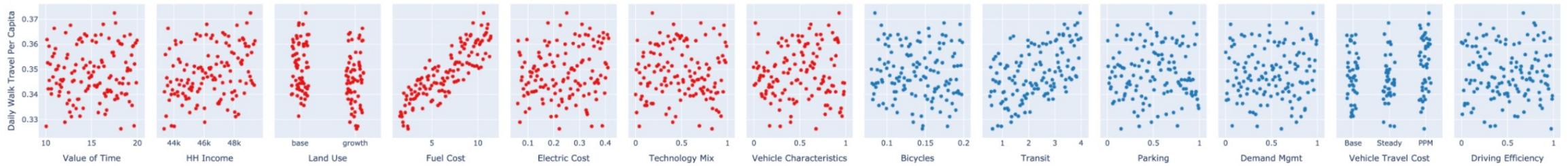
```
from emat.analysis import feature_scores
feature_scores(scope=scope, design='ulhs', db=db, measures=measures, return_type='figure')
```

executed in 1.46s, finished 18:43:19 2021-06-16



# Daily Walk Travel Per Capita

Daily Walk Travel Per Capita



0.031	0.054	0.053	0.431	0.041	0.032	0.043	0.032	0.152	0.030	0.030	0.041	0.031
ValueOfTime	Income	LandUse	FuelCost	ElectricCost	TechMix	VehicleCharacteristics	Bicycles	Transit	Parking	DemandManagement	VehicleTravelCost	DrivingEfficiency

# EMAT Interactive Explorer

Vehicle Travel Cost



any value

Fuel Cost



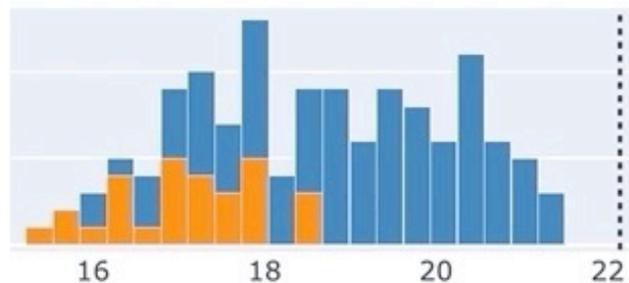
6.6 and up

Electric Cost



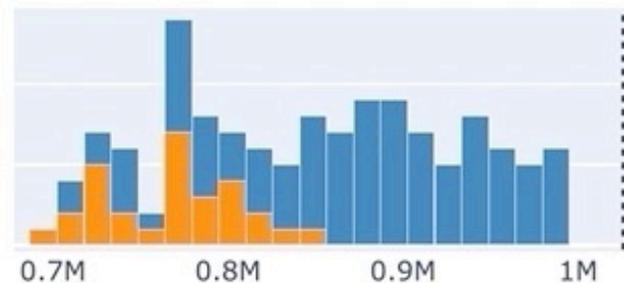
0.254 and up

Daily VMT Per Capita



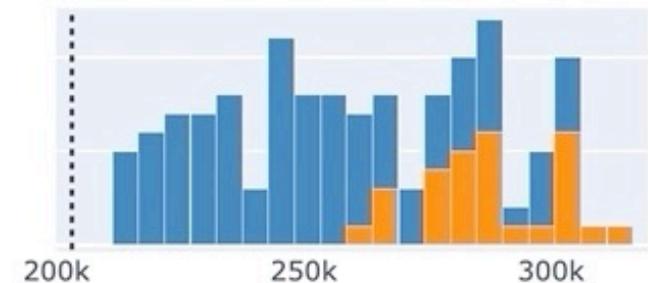
any value

Air Pollution



any value

Cars GHG Reduction



any value

# Meta-Model vs Core Model Results

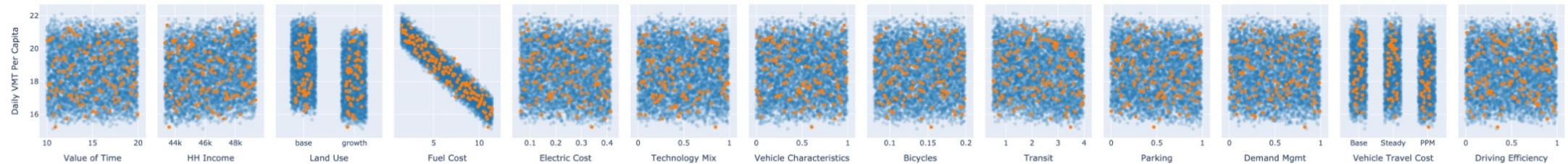
```
mm = emat.create_metamodel(scope, design_name='ulhs', db=db, include_measures=measures)
mm_design2 = mm.design_experiments(n_samples=5000, sampler='ulhs', jointly=True)
mm_results2 = mm.run_experiments(mm_design2, db=False)
```

executed in 11.5s, finished 19:53:06 2021-06-16

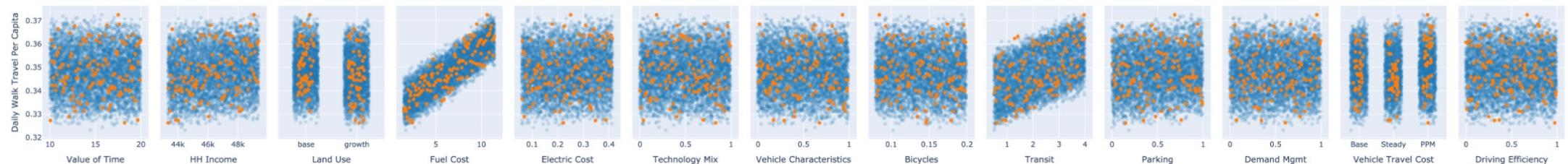
```
from emat.analysis import contrast_experiments
contrast_experiments(scope, mm_results2, 'ulhs', db=db, rows=measures)
```

executed in 9.43s, finished 21:35:36 2021-06-16

## Daily VMT Per Capita



## Daily Walk Travel Per Capita



# Cross Validation Scores

```
mm.cross_val_scores()
```

```
executed in 12.7s, finished 14:24:52 2021-06-17
```

	Cross Validation Score
<b>DVMTPerCapita</b>	0.9985
<b>WalkTravelPerCapita</b>	0.9982
<b>AirPollutionEm</b>	0.9984
<b>FuelUse</b>	0.9976
<b>VehicleCost</b>	0.9982
<b>UrbanHhDvmt</b>	0.9989
<b>UrbanHhGGE</b>	0.9982
<b>UrbanComSvcGGE</b>	0.9991

# Check Cross Validation Carefully!

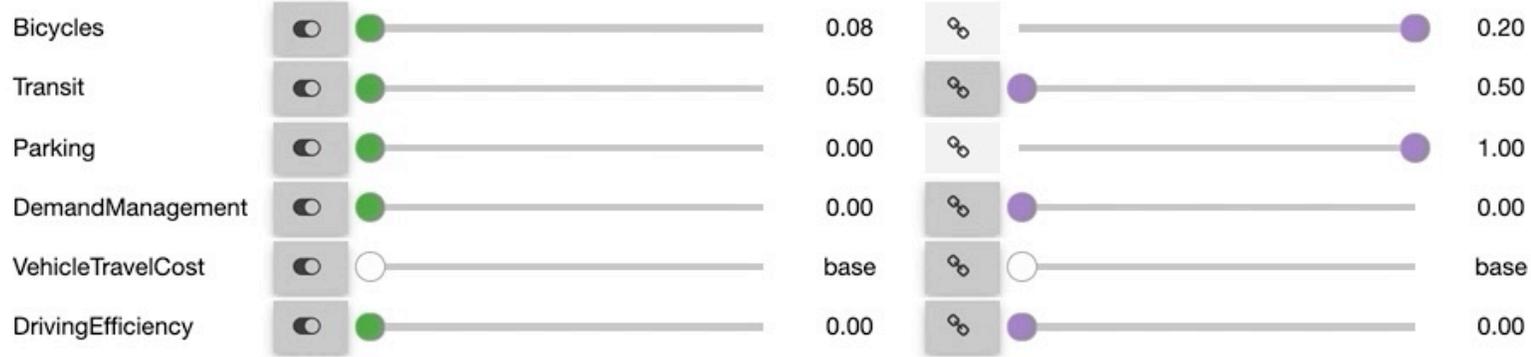
---

Some performance measures are difficult to metamodel:

- Measures that have excess variance (too much noise)
- Measures that are truncated or censored (too many values are identical)
- Measures with inconsistent or unexplainable outliers
- Measures that were calculated or stored incorrectly

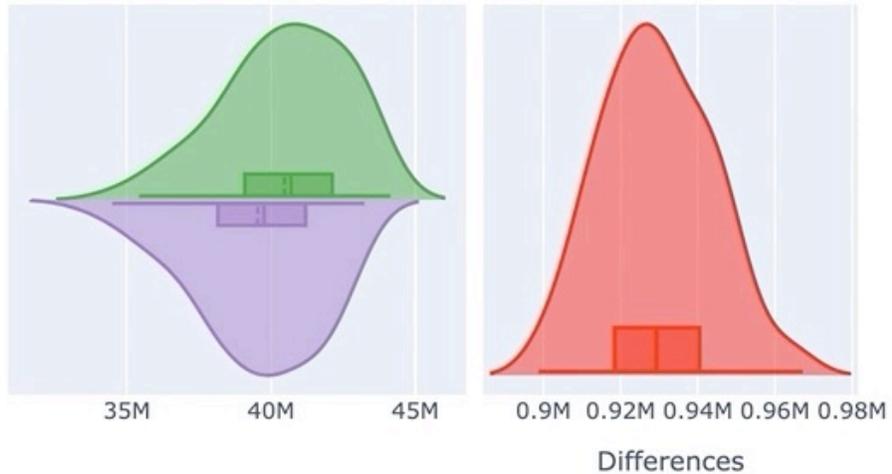
# EMAT Policy Contrast

## Policy Levers

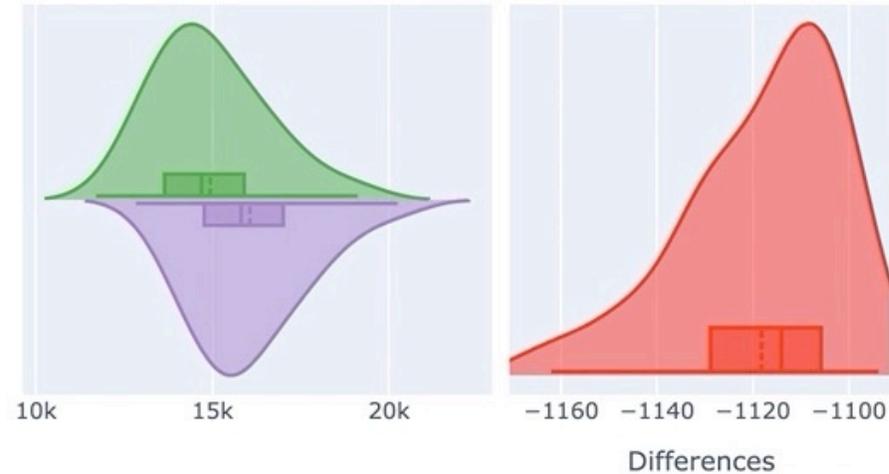


Recompute

### Annual Fuel Use



### UrbanTransitTrips



# What is EMAT?

---

- EMAT is a wrapper that goes around a travel demand model, not a model itself.
- Your core travel demand model provides the meat of the analytical relationships – “Garbage in, garbage out” definitely applies.
- EMAT includes experimental design and automatic metamodeling facilities and connects modeling results with a wider array of exploratory modeling and analysis tools.
- EMAT is not a sandwich.

# Epilog

» TMIP-EMAT documentation

**TMIP** Better Methods. Better Outcomes.

## TMIP-EMAT documentation

**Warning**

The views expressed in this documentation do not necessarily represent the opinions of FHWA, and do not constitute an endorsement, recommendation, or specification by FHWA.

TMIP-EMAT is a *methodological approach* to exploratory modeling and analysis. It provides a window to rigorous analytical methods for handling uncertainty and making well informed decisions using travel forecasting models of all types. It is designed to integrate with an existing transportation model or tool to perform exploratory analysis of a range of possible scenarios.

TMIP-EMAT provides the following features to enhance the functionality of the underlying core model:

- A structure to formalize and distill an exploratory **scope**, in a manner suitable for translating the abstraction of the “XLRM” robust decision making framework into a concrete, application-specific form,
- A systematic process for **designing experiments** to be evaluated using the core model, and support for running those experiments in an automated fashion.

to organize and store the results from a large number of

## ■ EMAT is Free and Open Source

- » EMAT Documentation <https://tmip-emat.github.io>
- » EMAT / VisionEval Interface Source Code <https://github.com/tmip-emat/tmip-emat-ve>

Send me your questions,  
comments, or anonymous  
broadside

[jeffnewman@camsys.com](mailto:jeffnewman@camsys.com)