Testing and Results of TMIP Exploratory Modeling and Analysis Tool (TMIP-EMAT) at the Oregon Department of Transportation (ODOT)

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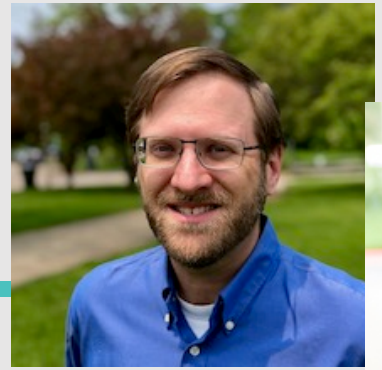
Senior Integrated Analysis Engineer, ODOT-TPAU

May 28th, 2020

Oregon Department of Transportation

Team Effort



- Jeff Newman, CS
- Rachel Copperman, CS
- Marty Milkovits
  (was CS, now Boston MPO – CTPS)
- Tom Rossi, CS
- Binny Paul, RSG
- Large group from the Oregon Modeling Steering Committee
- Sarah Sun and the System Planning Analysis Team from the Office of Planning, FHWA

Oregon Department of Transportation

OMIP
Oregon Modeling Improvement Program

Agenda - Overview

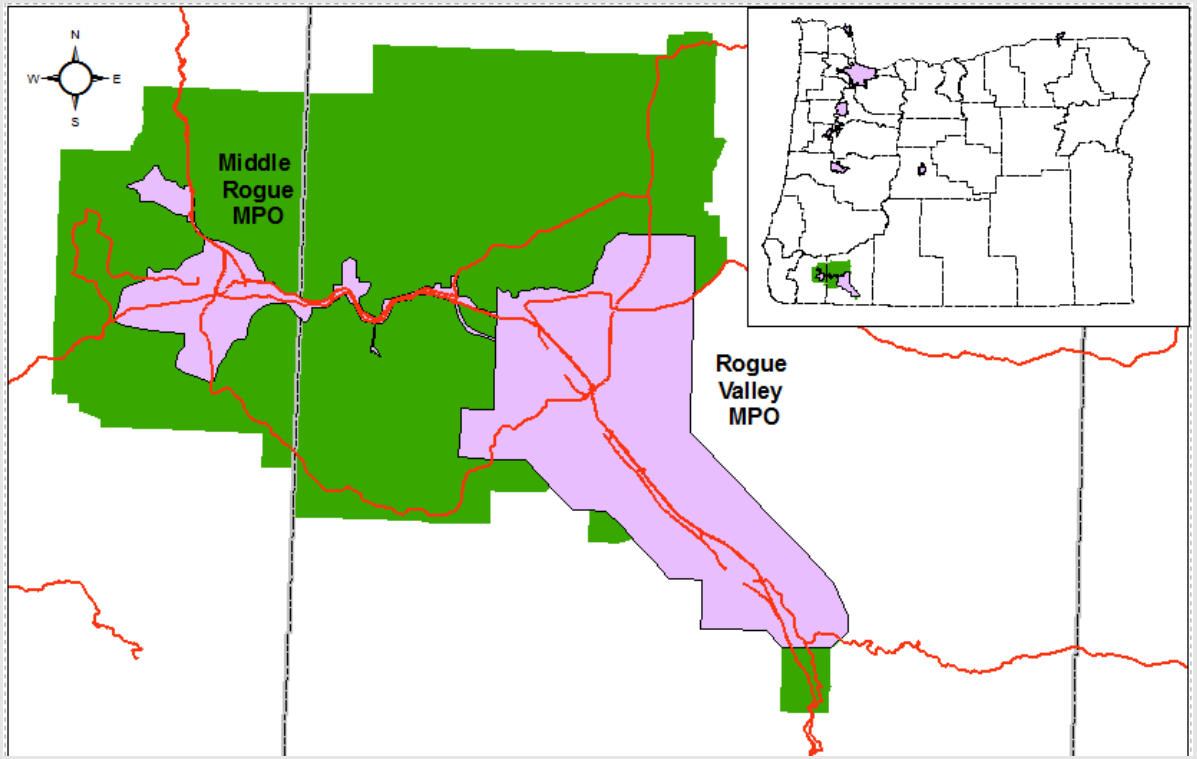
- Project Overview and Timeline
- Exploratory Modeling Motivation and Background
- Testing Scope/Design
- Model (TMIP-EMAT) Setup Steps
- Results and Lessons Learned
- Planned Future Efforts and Next Steps

Oregon Department of Transportation

Motivations

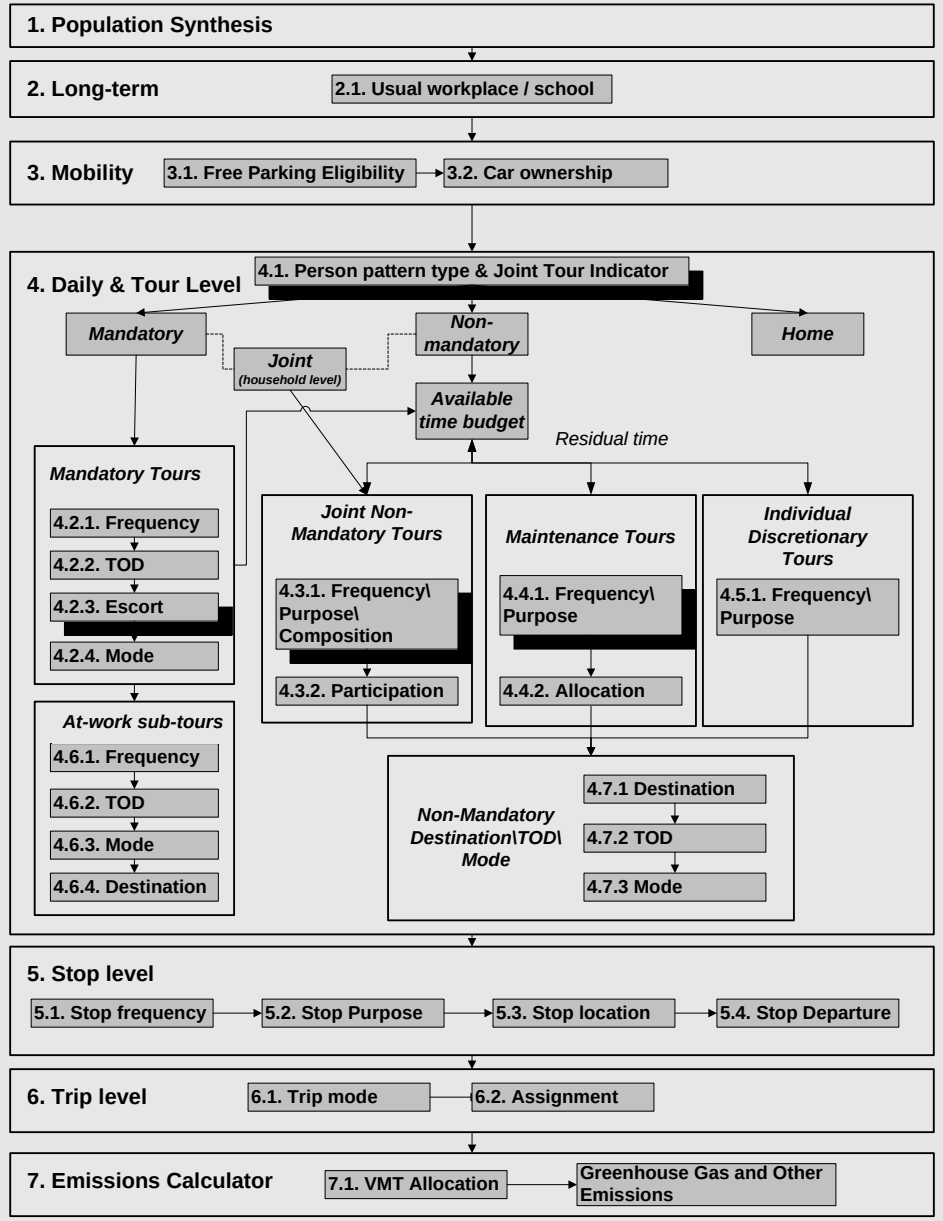
- Emerging Tech
- Uncertainty

Purpose: To test emerging tech policies with the newly deployed ABM



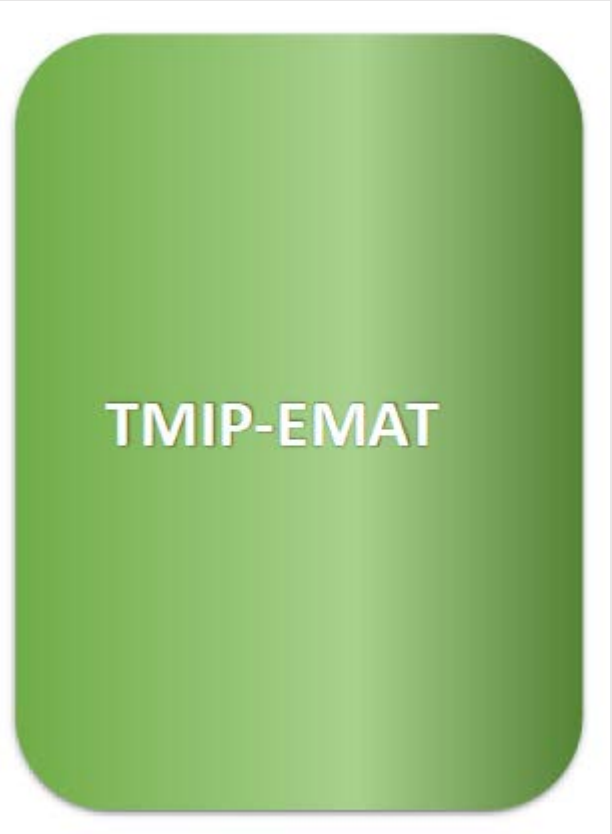
ODOT's Newly Released ABM

- CT-RAMP (pivot off of San Diego)
- Linked with Visum for Assignment
- Future Year ~500k people
  - Runs in about 4-5 hours



Enter TMIP-EMAT

- Dec 2018 TMIP-EMAT webinar
- Seemed to facilitate the exact testing OMSC wanted to complete with the ABM



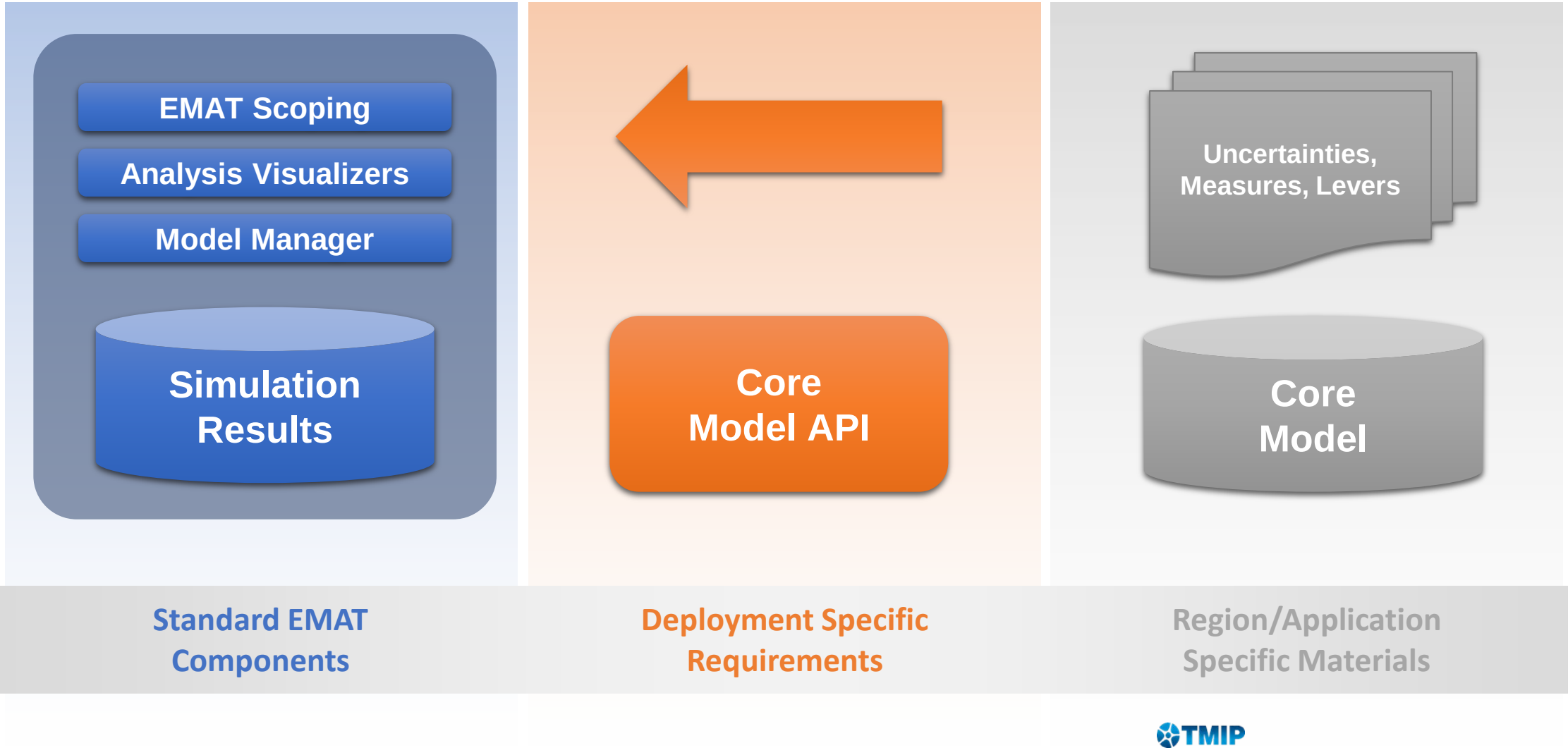
Project Timeline

- Learned of Beta Test Opportunity (Feb 2019)
- Submitted and Approved
- Official Kick-off Meeting held March 20, 2019
- Completed Beta Test September 2019
- Late 2019 / Early 2020 OMSC improved beta test design
- March 2020 update beta-test setup
- April 2020 setup and ran 100 ABM runs to complete scoped test design
- May 2020 shared and presented results

TMIP Exploratory Modeling and Analysis Tool (TMIP-EMAT)

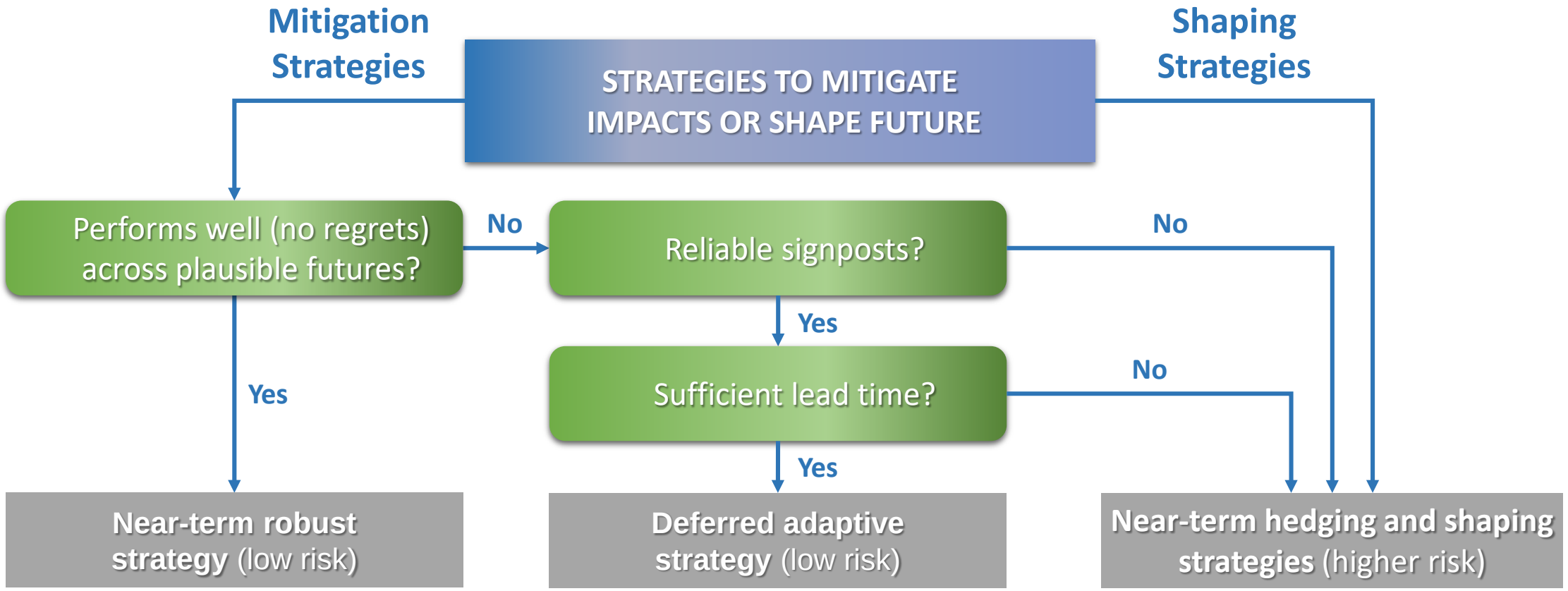
- FHWA Travel Model Improvement Program Research Project
  - Continues through Summer 2021
- Tool to support transportation planning under deep uncertainty
  - **Complements and enhances** (does not replace) existing models, visualizations, or planning tools
- More info on the Beta Testing can be found here:
  - https://www.fhwa.dot.gov/planning/tmip/publications/other_reports/emat_beta/

TMIP-EMAT Overview



TMIP
Better Methods. Better Outcomes.

Why TMIP-EMAT? **Robust** Decision-Making



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Robust Decision-Making Terminology

- **Exogenous uncertainties (X)** are factors outside the decision makers' control that may affect the ability of near-term actions to achieve decision makers' goals;
- **Policy levers (L)** are near-term actions that decision makers may want to consider;
- **Relationships (R)**, generally represented by simulation models, describe how the policy levers perform, as measured by the metrics, under the various uncertainties; and
- **Metrics (M)** are the performance standards used to evaluate whether or not a choice of policy levers achieves decision makers' goals.

From Rand Robust Decision Making Glossary: https://www.rand.org/methods/rdmlab/glossary.html

RDM exercises often employ an "XLRM" framework (Lempert et al. 2003) to help guide stakeholder elicitation, data gathering, and model development. The letters X, L, R, and M refer to four categories of factors important to an RDM analysis

SCOPE

Policy lever presence and combinations *(lever combinations)*

Model input ranges/distributions/ correlations *(scenarios)*

Decision space

Uncertainty space

Model

Each unique combination of levers and scenarios is an **Experiment**

Outcome space

Outcome space is populated by a set of **Metrics** associated with each **Experiment**

The Magical Latin HyperCube

EMA Workbench

TMIP

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TMIP-EMAT Workflow

Define the uncertainty and decision space

Run model across uncertainty / decision dimensions

Risk / Exploratory analysis

SCOPE

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Great Facilitated Decision Making Process

Goals

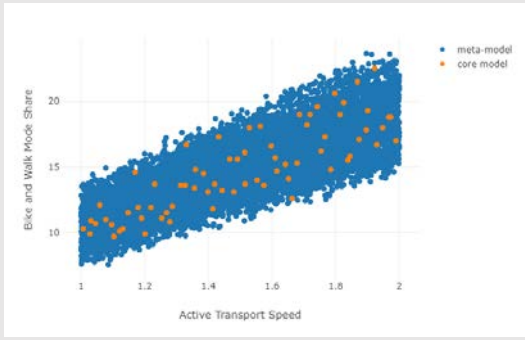
What are you trying to achieve

Policy Levers

How can you influence your goals

Uncertainties

What could impact your goals that you have no control over



Metrics

How will you know you are successful; continued monitoring

Scope Development - Goals

- “Evaluating the usefulness of the ABM for questions around Emerging Tech”
- “Determining resilient actions that work under all tested futures as opposed to actions that only work under some futures”
- “Evaluating actions with an equity lens (a more complete set of metrics)”

Scope Development - Goals

- “Evaluating the usefulness of the ABM for questions around Emerging Tech”
- “Determining resilient actions that work under all tested futures as opposed to actions that only work under some futures”
- “Evaluating actions with an equity lens (a more complete set of metrics)”

F – First

A – Attempt

I – In

L – Learning

Scope Development - Goals

- “Provide an equitable and accessible transportation system for all income groups”

Beta-Test Workshop Guided Scope

Scope Development - Goals

Refined with the OMSC

1. **Safety** – Vision Zero (reducing crashes)
2. **Equity** – Provide an equitable and accessible transportation system for all income groups
3. **Provide for economic growth and development** – Efficient movement of freight (movement of goods, long-haul and local delivery)
4. **Livability** – providing access to services and transportation options (across age and ability)
5. **Sustainability** – reducing GHG and air pollutant emissions

Scope Levers and Uncertainty

Beta-Test Workshop Guided Scope

Policy Levers

- Transit Everywhere (like public TNCs)
- Transit LOS (quality of service)
- Parking Rates ($0.50 - $20)
- Active Transport Speed (allowing various levels of micro-mobility)

Areas of Uncertainty

- Freeway Capacity
- Auto Operating Cost (grouped with Value of Travel Time)
- Economic conditions (ended up representing with income)
- ~~Household Density~~

Scope Levers and Uncertainty

Refined with the OMSC

Policy Levers

- ~~Transit Everywhere (like public TNCs)~~
- Transit LOS (quality of service)
- Parking Rates ($0.50 - $20)
- Active Transport Speed (allowing various levels of micro-mobility)
- **Urban Speed Changes**

Areas of Uncertainty

- Freeway Capacity
- Auto Operating Cost (grouped with Value of Travel Time)
- Economic conditions (ended up representing with income)
- **Household Density**
- **Age Distribution**
- **Telecommuting Adjustment**

Metrics

The dream list:

- Regional accessibility by…
- Congestion / reliability…
- Affordable Transportation
- Quality of Life
- Fiscal Sustainability
- Safety

Cold Reality (model and time limitations):

- Jobs by SOV in a time boundary
- Mode percentages
- PMT / VMT
- VHT
- V/C
- Auto ownership
- Number of Non-Mandatory Tours

The Next Phase of the Scoping Process - How the Levers are Turned into Model Inputs

Policy-Lever/Uncertainty Variable	Goal Area(s)	Minimum	Most Likely	Maximum	Distribution	Unit/Correlations/Other Notes
1. Speed Changes	Safety	0.25x	1.0x	1.25x? (do we want to test increased speeds or just decreased)	uniform	This is planned to be a multiplier on all non-interstate links. So a value of 0.75 would decrease all non-interstate speeds by 25%. Potential Measures to evaluate Safety: - % VMT by operating speed (maximize low speed bins, lower speed on non-interstates is assumed safer) - % VMT by congestion bins (maximize low congestion bins, less congestion is assumed safer) - Active mode share (maximize, high bike/walk percentage is assumed safer) *Medium or long term, using speed changes look at emissions, CO, NOX, CO2, see how those impact air quality or state GHG goals.* *On interstates and truck platooning, how is speed changed? There's an interstate capacity lever—focus on that* *Use this tool for urban areas—bring down minimum to 0.25 and max to 1.0*

Transit Level of Service Goal - Equity

- ptype: policy lever
- desc: The overall comfort, performance, and attitude toward transit has been successfully changed dtype: real
- default: 0.0
- min: **-20.0** (proxy of 20 min penalty)
- max: **20.0** (proxy of 20 min reduction)

- Measure – Accessibility by Income

Active Transport Speed Goals – Livability, Sustainability

- ptype: policy lever
- desc: Technologies that aid biking and walking may increase average speeds of these modes
- dtype: real
- default: 1
- min: 1 x current speed (3 and 12mph)
- max: 2 x current speed

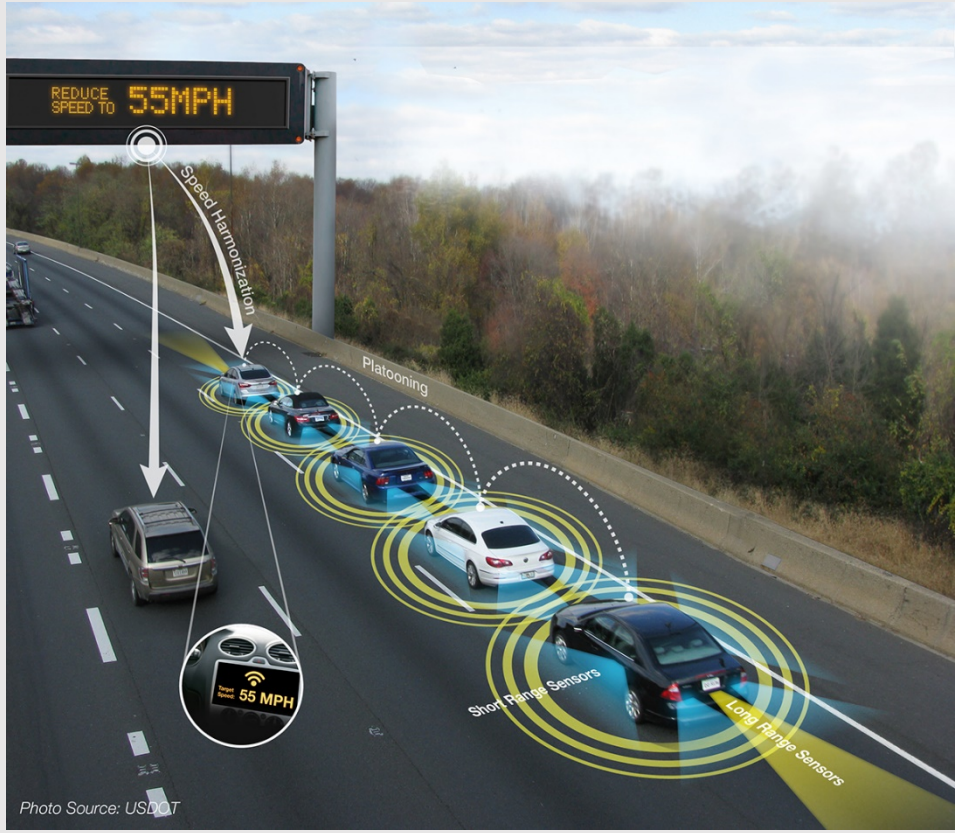
- Measures

Bike/walk mode share, Overall VMT

Freeway Capacity Goals – Equity, Economic Growth

- ptype: exogenous uncertainty
- desc: Future Tech changes how many vehicles can use a given lane of freeway
- dtype: real
- default: 1900.0
- min: 1500.0
- max: 3000.0

- Measures: VHT



Telecommuting Adjustment

Goal – None, just seemed timely

- ptype: exogenous uncertainty
- desc: How might the amount of Telecommuting change in the future
- dtype: real
- default: -0.23
- min: -1.0
- max: 0.0

Description	Filter	Formula for variable	Index	Alt1
				Mandatory
Alternative Specific Constant Adjustment for Full-time worker	fullTimeWorkerA	1		-0.230093

Great Facilitated Decision Making Process

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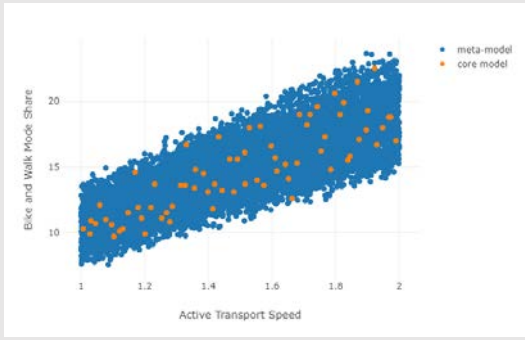

Metrics

How will you know you are successful; continued monitoring

TMIP-EMAT Workflow

2

Define the uncertainty and decision space

Run model across uncertainty / decision dimensions

Risk / Exploratory analysis

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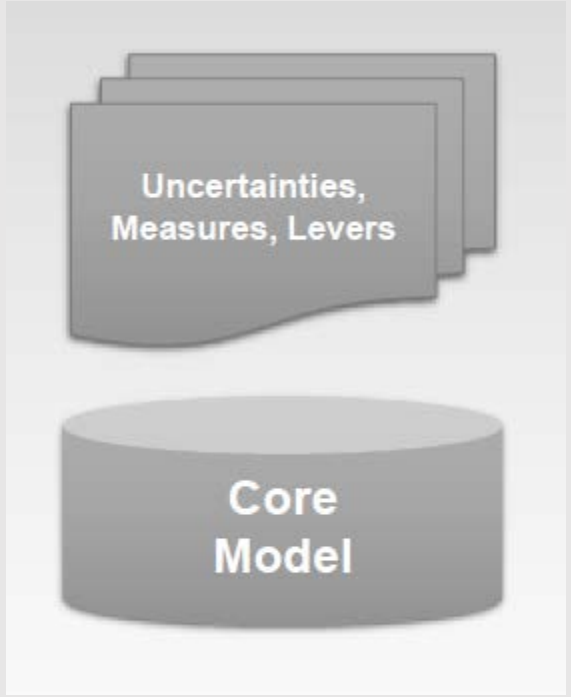
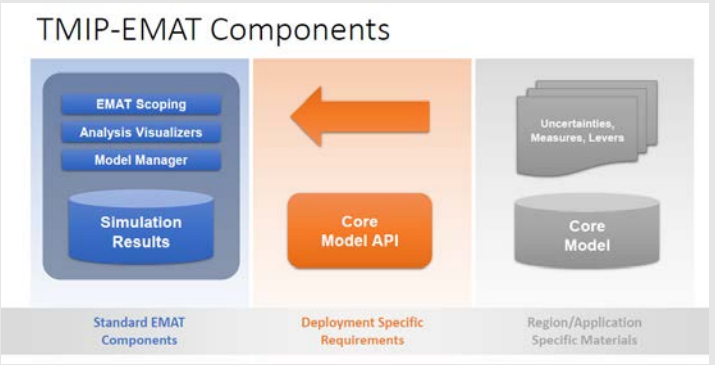
Model Setup / Configuration

Required Software
- Visum
- dependencies.zip

    - Java jdk 1.8.0_111 (and libraries)
    - Python 27 (and libraries)
    - R-3.3.1 (and libraries)

Designed so that only Visum needs to be installed.

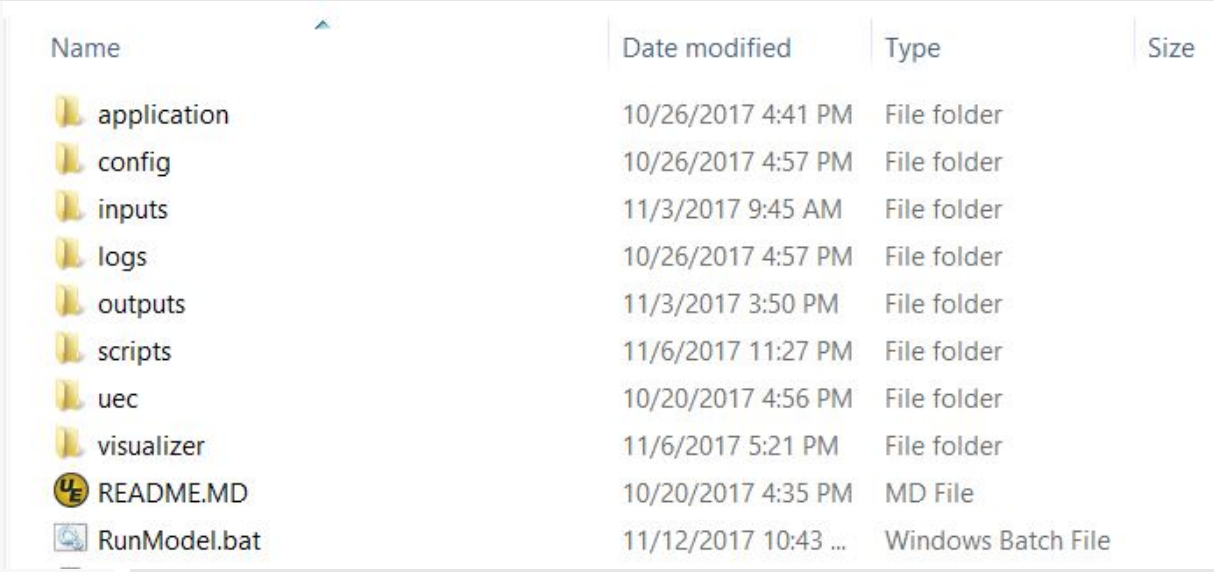


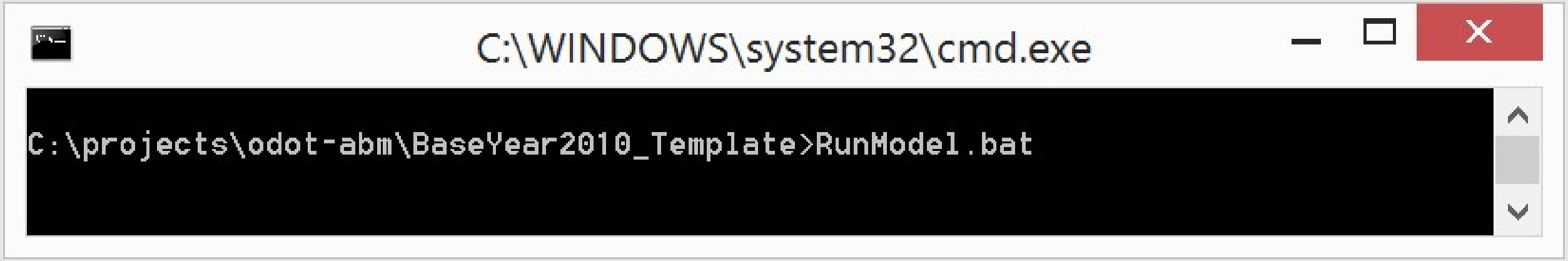


https://github.com/RSGInc/SOABM/wiki/Getting-started

Model Setup / Model Run

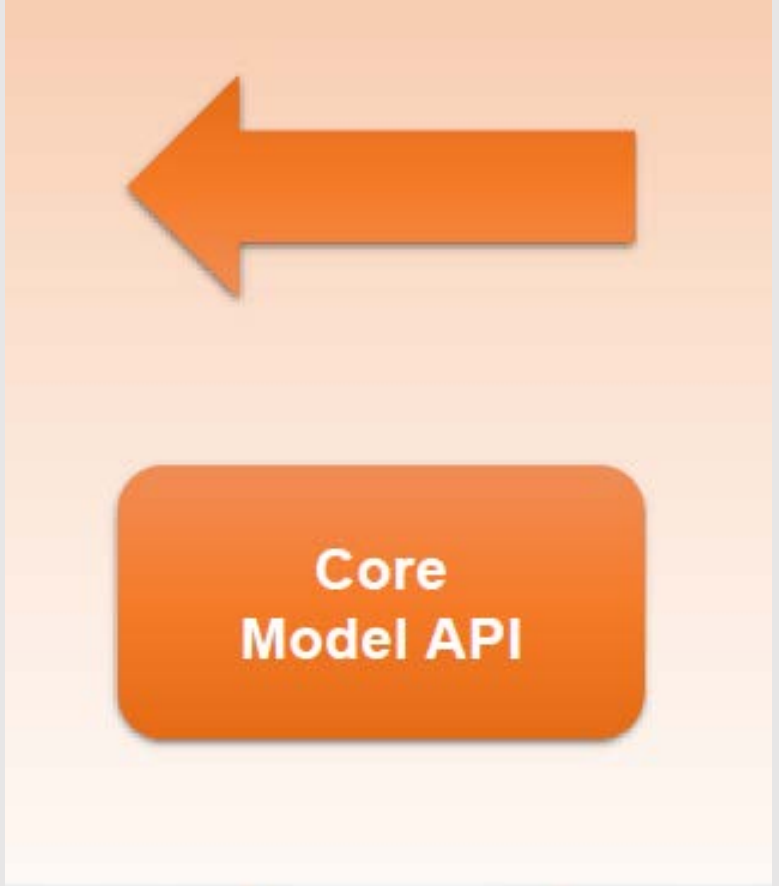
```
root/dependencies/
  jdk1.8.0_111/ - Java installation directory
  Python27/ - Python installation directory
  R-3.3.1/ - R installation directory
root/scenario_name/
  RunModel.bat - Script used to run model
  application/ - DOS batch files, Java jar file, HDF5 DLLs for OMX, VDF DLLs
  config/ - ORRAMP properties file, ORRAMP JPPF config files
    cvm/ - CVM model parameters
    visum/ - skimming procedure files
  inputs/ - Popsyn files, VISUM scenario version file, external model files, etc.
  logs/ - ORRAMP output log files
  outputs/ - other model outputs - skims, trip lists, matrices, etc.
  scripts/ - VISUM skimming, OMX reader/writer, external model, CVM
  uec/ - ORRAMP utility expression calculator (UEC) model parameter files
  visualizer/ - ORRAMP visualization tool
```



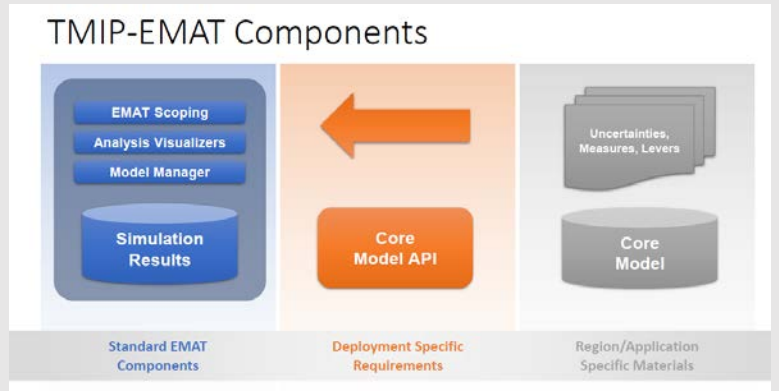


Model (API) Development

- Setup
- Run
- Post Process
- Archive
- Measure Parser Linkage



Deployment Specific Requirements



API Steps – Steps to Automated

- Setup
  - Copy blank directory
  - Write csv of scenario design values (parameters)
  - Run R script to update inputs based on design lever values
- Run
  - Simply run RunModel.bat

- Post Process
  - Runs an R script to build summary output files specific to TMIP-EMAT scope and clean/thin ABM outputs.
- Archive
  - Simply Renames the working directory with a scenario design number
- Measure Parser
  - Existing function to read measures, just needs a linkage to specific files / fields.

Stepping Through Experiments Picked through Latin HyperCube Sampling (LHS)

	A	B	C	D	E	F	G	H	I	J	K
1	experimen	Age Distrib	Freeway C	Auto Oper	Household	Incomes	Telecomm	Urban Spe	Transit Qu	Parking Ra	Active Trai
2	1	1	2990.295	29.60209	1.150815	0.850791	-0.22775	0.768183	-19.8382	6.929721	1.4069
3	2	1	2381.115	28.56786	1.475727	0.716642	-0.2571	0.501646	0.055293	14.65021	1.359906
4	3	0	2462.716	43.35553	1.081207	1.115233	-0.49151	0.994397	9.266163	2.935176	1.816905
5	4	0	2534.59	22.77353	0.57	0.534464	-0.77256	1.113665	-8.57205	9.063079	1.619481
6	5	1	2910.674	6.189827	0.719974	1.123068	-0.94668	0.450658	9.771106	8.661325	1.985836
7	6	0	2266.073	5.768483	0.896947	0.640173	-0.29433	0.467878	8.987703	1.263957	1.685316
8	7	0	2769.798	6.419524	1.323739	0.762935	-0.733	1.135124	17.23701	7.582203	1.851687
9	8	1	1722.445	18.8165	1.034015	1.292678	-0.51908	1.021768	-10.2227	10.81765	1.271588
10	9	1	2113.225	27.56329	1.389251	0.990367	-0.66946	0.875208	3.442242	3.595876	1.39938
11	10	1	1898.409	27.19734	1.332449	0.70804	-0.46137	0.47591	15.72764	5.595487	1.427183
12	11	0	2879.102	21.53144	1.26664	1.303338	-0.6537	0.284445	-16.6887	4.045752	1.334765
13	12	0	2755.642	16.82275	0.784812	1.168919	-0.4113	0.42143	2.855455	3.33417	1.598837

The Magical Latin HyperCube

Oregon Department of Transportation

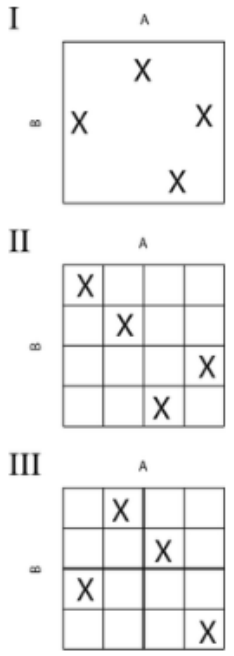
$$x_{ik} = D_{X_i}^{-1}(U_{ik}); i = 1, 2, \ldots, N; k = 1, 2, \ldots, M$$

Looking Behind the Curtain

In two dimensions the difference between random sampling, Latin Hypercube sampling, and orthogonal sampling can be explained as follows:

1. In **random sampling** new sample points are generated without taking into account the previously generated sample points. One does not necessarily need to know beforehand how many sample points are needed.
2. In **Latin Hypercube sampling** one must first decide how many sample points to use and for each sample point remember in which row and column the sample point was taken. Such configuration is similar to having N rooks on a chess board without threatening each other.
3. In **Orthogonal sampling**, the sample space is divided into equally probable subspaces. All sample points are then chosen simultaneously making sure that the total set of sample points is a Latin Hypercube sample and that each subspace is sampled with the same density.

Thus, orthogonal sampling ensures that the set of random numbers is a very good representative of the real variability, LHS ensures that the set of random numbers is representative of the real variability whereas traditional random sampling (sometimes called brute force) is just a set of random numbers without any guarantees.



https://en.wikipedia.org/wiki/Latin_hypercube_sampling

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TMIP-EMAT Workflow

Define the uncertainty and decision space

SCOPE

Run model across uncertainty / decision dimensions

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Analyze

EMA Workbench

3

Results Based on:

10 Levers x

10 Core Model Runs/Lever =

100 Full ABM Scenarios Completed

Results look good ☺

Inputs

Outputs

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	experimen	Age Distrib	Freeway C	Auto Oper	Household	Incomes	Telecomm	Urban Spe	Transit Qu	Parking Ra	Active Tra	Percentag	Percentag	Percentag	Bike and W	Transit wit	Millions of	Millions of	Millions of	Percentag	Percentag	Millions of	Millions
2	1	1	2990.295	29.60209	1.150815	0.850791	-0.22775	0.768183	-19.8382	6.929721	1.4069	57.7	57.1	50.6	20.5	0.4	9.107283	1.439026	9.423766	27.63	25.97	1.393578	
3	2	1	2381.115	28.56786	1.475727	0.716642	-0.2571	0.501646	0.055293	14.65021	1.359906	42.3	43.5	37.5	20.3	0.6	9.256025	1.434554	9.444295	24.33	0	1.798979	
4	3	0	2462.716	43.35553	1.081207	1.115233	-0.49151	0.994397	9.266163	2.935176	1.816905	65.2	63	59.4	25	0.6	8.888536	1.414079	9.212635	23.36	14.47	0.734623	
5	4	0	2534.59	22.77353	0.57	0.534464	-0.77256	1.113665	-8.57205	9.063079	1.619481	69.1	68.2	64	29.1	0.5	7.639745	1.235658	8.35917	29.6	9.44	2.137671	
6	5	1	2910.674	6.189827	0.719974	1.123068	-0.94668	0.450658	9.771106	8.661325	1.985836	40.3	39.2	32.7	26.6	0.6	9.215978	1.445871	9.458455	25.07	0	0.965189	
7	6	0	2266.073	5.768483	0.896947	0.640173	-0.29433	0.467878	8.987703	1.263957	1.685316	40.7	41.4	34.1	22.3	0.5	9.338048	1.491837	9.863796	20.51	0	2.307668	
8	7	0	2769.798	6.419524	1.323739	0.762935	-0.733	1.135124	17.23701	7.582203	1.851687	69.2	67.8	63.9	19.8	0.6	11.00529	1.687972	11.02184	21.45	9.77	2.095184	
9	8	1	1722.445	18.8165	1.034015	1.292678	-0.51908	1.021768	-10.2227	10.81765	1.271588	64.3	60.6	57.5	17.1	0.4	10.06814	1.595638	10.28664	17.14	9.72	0.861222	
10	9	1	2113.225	27.56329	1.389251	0.990367	-0.66946	0.875208	3.442242	3.595876	1.39938	61.3	60.4	53.8	17	0.4	9.916914	1.547022	10.05783	19.55	14.7	1.225322	
11	10	1	1898.409	27.19734	1.332449	0.70804	-0.46137	0.47591	15.72764	5.595487	1.427183	40.5	41.4	36.2	20.8	0.6	8.950802	1.393502	9.237808	22.18	0	1.776632	
12	11	0	2879.102	21.53144	1.26664	1.303338	-0.6537	0.284445	-16.6887	4.045752	1.334765	8	9.1	7.5	18.6	0.4	9.450731	1.52615	9.945275	23.52	0	0.747073	
13	12	0	2755.642	16.82275	0.784812	1.168919	-0.4113	0.42143	2.855455	3.33417	1.598837	36	36	28.5	23.1	0.5	8.961433	1.478447	9.55773	21.94	0	0.811499	
14	13	1	2838.991	5.313701	1.280349	0.798104	-0.89912	0.529613	-9.07294	10.54116	1.634042	44.5	45	38.5	19.7	0.4	10.47907	1.590194	10.45967	22.51	0	1.959463	
15	14	1	1562.089	15.41093	1.181109	0.729641	-0.07134	0.354178	-6.10785	3.941863	1.941715	21.9	23.4	17	26.1	0.4	8.954437	1.368701	9.147839	21.74	0	1.720373	
16	15	1	1812.36	18.42476	0.628954	0.519577	-0.47959	0.5413	-1.48158	17.98416	1.561318	46.7	46.6	40.4	29.2	0.6	7.686411	1.218645	8.259875	22.86	0	2.293373	
17	16	0	2571.303	39.36912	0.758921	0.835912	-0.91042	0.81651	-0.02515	11.41228	1.874119	58.5	58.3	53.7	30.8	0.6	7.804177	1.239037	8.26454	27.95	24.99	0.997924	
18	17	0	2075.389	31.55195	0.809152	1.183115	-0.90773	1.205879	-15.1371	13.1226	1.960249	70.2	68.3	65	27.5	0.4	8.799369	1.401623	9.167418	21.29	9.35	0.676055	

Uncertainties ⟷ Policy Levers

	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0257042	0.0471329	0.0482821	0.0427327	0.0394827	0.0469136	0.575288	0.0830295	0.0499987	0.0414359
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0234979	0.0499328	0.0493246	0.0442336	0.0408537	0.040682	0.596777	0.0649377	0.0433008	0.0464599
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0345267	0.0474496	0.0571037	0.0489444	0.0496779	0.0508438	0.549025	0.0687977	0.0483799	0.045251
Bike and Walk Mode Share	0.033724	0.0423424	0.103598	0.219507	0.0976348	0.0475395	0.060642	0.0449326	0.0615405	0.288539
Transit with PNR and KNR Mode Share	0.0518717	0.0607869	0.0985202	0.102784	0.0630194	0.0621766	0.0626623	0.285781	0.132873	0.0795259
Millions of Person Miles Traveled	0.0299699	0.0499768	0.277401	0.253783	0.106957	0.0526466	0.071374	0.0473575	0.0524723	0.0580622
Millions of Vehicle Miles Traveled in PM	0.053534	0.0544239	0.215353	0.210532	0.136135	0.056859	0.0705601	0.0588674	0.0593232	0.0844129
Millions of Vehicle Miles Traveled	0.0498665	0.058043	0.251724	0.196376	0.133795	0.058649	0.0627319	0.0512195	0.0616796	0.0759166
Percentage VMT in Light Congestion	0.0364048	0.234016	0.201634	0.0908841	0.128056	0.0505795	0.0648447	0.0544634	0.0521241	0.0869938
Percentage VMT Below 30mph	0.0502436	0.0535798	0.0560773	0.0551734	0.036801	0.0475183	0.537732	0.0618359	0.0511332	0.0499056
Millions of VMT for Households Below 25k	0.0437598	0.0403332	0.148943	0.080555	0.450928	0.041935	0.0470797	0.0570167	0.0420312	0.0474184
Thousands of Vehicle Hours Traveled in PM	0.0335604	0.043294	0.092757	0.0960732	0.0807504	0.0481221	0.433884	0.0719388	0.0460428	0.0535773
Thousands of Vehicle Hours Traveled	0.0322245	0.0425234	0.0870913	0.0970584	0.0626658	0.0380097	0.484289	0.0653856	0.04563	0.0451228
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.0397044	0.361928	0.107273	0.0619916	0.0821684	0.0603525	0.0784758	0.0669003	0.0693283	0.0718778
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.0497205	0.0576368	0.205628	0.208003	0.115218	0.0526535	0.0933104	0.0602442	0.061335	0.0962499
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.0428661	0.0690728	0.231316	0.165513	0.120517	0.058904	0.0716019	0.0574372	0.0662083	0.116564
Number of Autos Owned Per Household	0.0564055	0.0409718	0.0344932	0.354303	0.259628	0.0566757	0.0476873	0.0450454	0.0512366	0.0535528
Percent of Non-Mandatory Tours	0.599835	0.0320252	0.0278261	0.030058	0.0737975	0.102413	0.0391967	0.0298901	0.0332597	0.0316986

Feature Scoring – With machine learning

0.575288

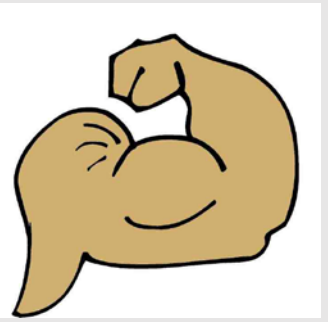
Yellow = most important input to an output

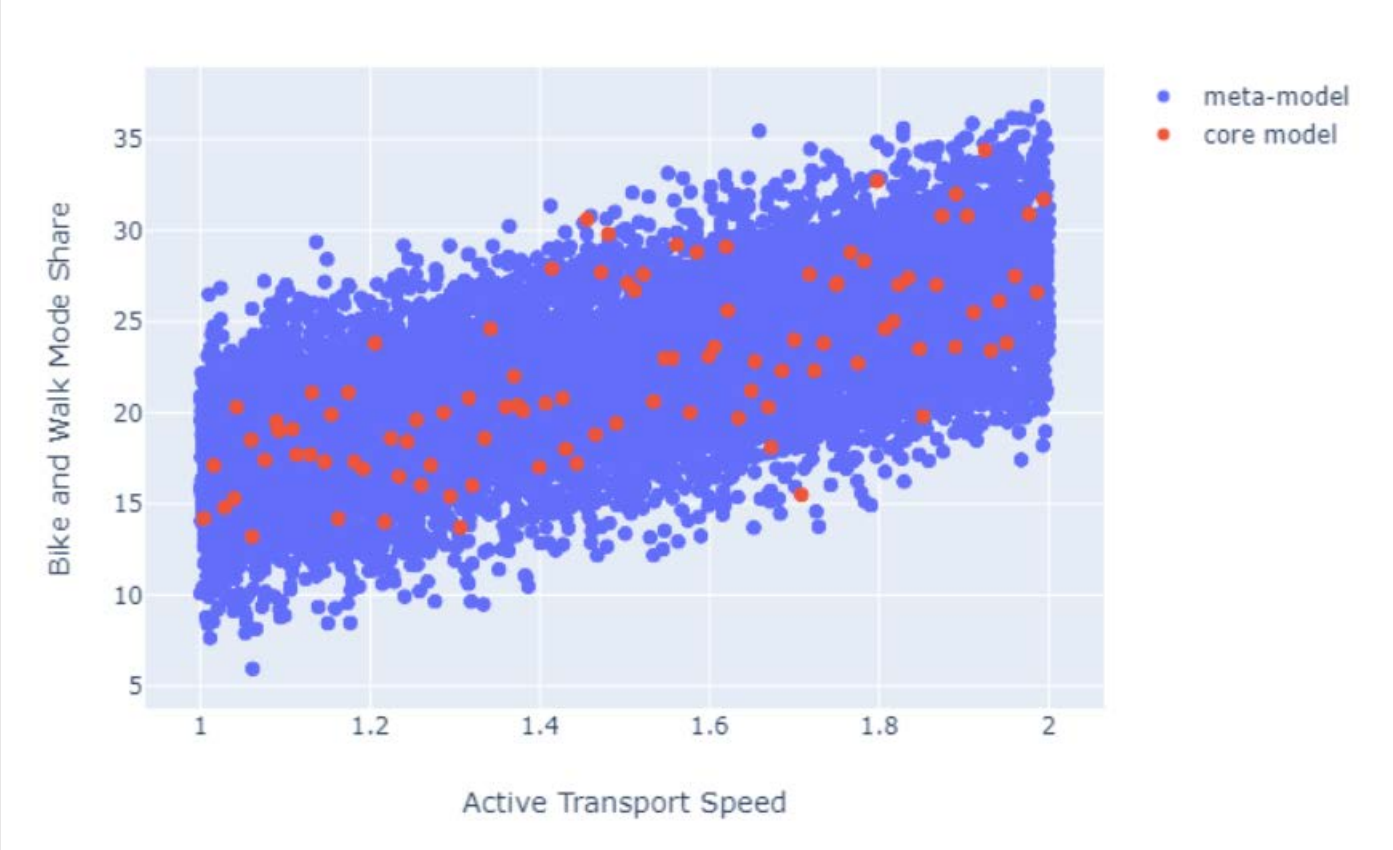
Numbers are relative to each measure

0.0257042

Purpose = least important input to an output

The Strength of the Meta Model





Oregon Department of Transportation

Active Transport Speed Goals – Livability, Sustainability

- ptype: policy lever
- desc: Technologies that aid biking and walking may increase average speeds of these modes
- dtype: real
- default: 1
- min: 1 x current speed (3 and 12mph)
- max: 2 x current speed

- Measures

Bike/walk mode share, Overall VMT

	Active Transport Speed
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0414359
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0464599
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.045251
Bike and Walk Mode Share	0.288539
Transit with PNR and KNR Mode Share	0.0795259
Millions of Person Miles Traveled	0.0580622
Millions of Vehicle Miles Traveled in PM	0.0844129
Millions of Vehicle Miles Traveled	0.0759166
Percentage VMT in Light Congestion	0.0869938
Percentage VMT Below 30mph	0.0499056
Millions of VMT for Households Below 25k	0.0474184
Thousands of Vehicle Hours Traveled in PM	0.0535773
Thousands of Vehicle Hours Traveled	0.0451228
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.0718778
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.0962499
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.116564
Number of Autos Owned Per Household	0.0535528
Percent of Non-Mandatory Tours	0.0316986

	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Bike and Walk Mode Share	0.033724	0.0423424	0.103598	0.219507	0.0976348	0.0475395	0.060642	0.0449326	0.0615405	0.288539
Millions of Vehicle Miles Traveled	0.0498665	0.058043	0.251724	0.196376	0.133795	0.058649	0.0627319	0.0512195	0.0616796	0.0759166

Measures: Bike/walk mode share, Overall VMT

Urban Speed Goal - Safety

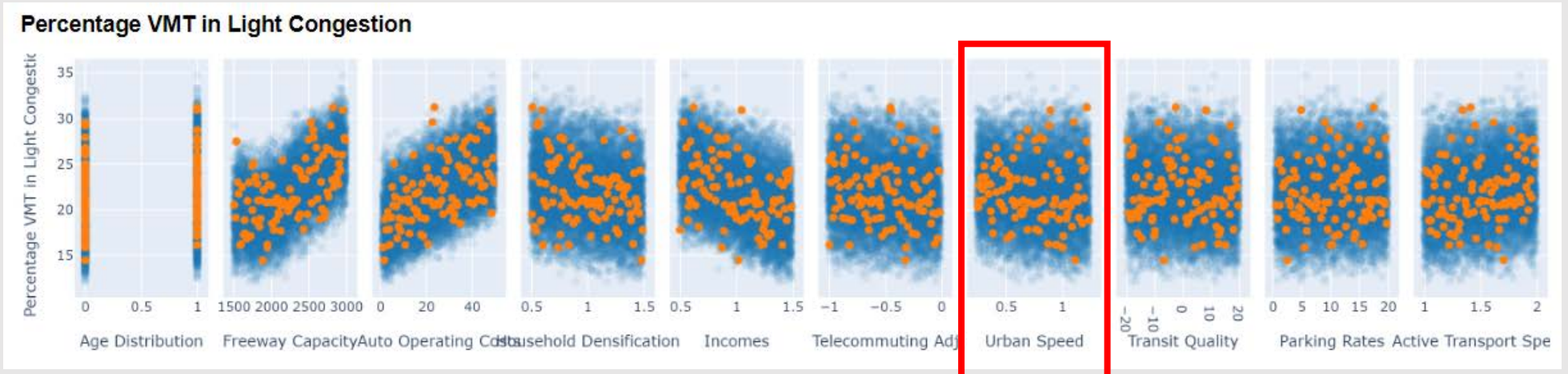
- ptype: policy lever
- desc: A multiplier on Urban (non-interstate) speedsdtype: real
- default: 1.0
- min: 0.25
- max: 1.25

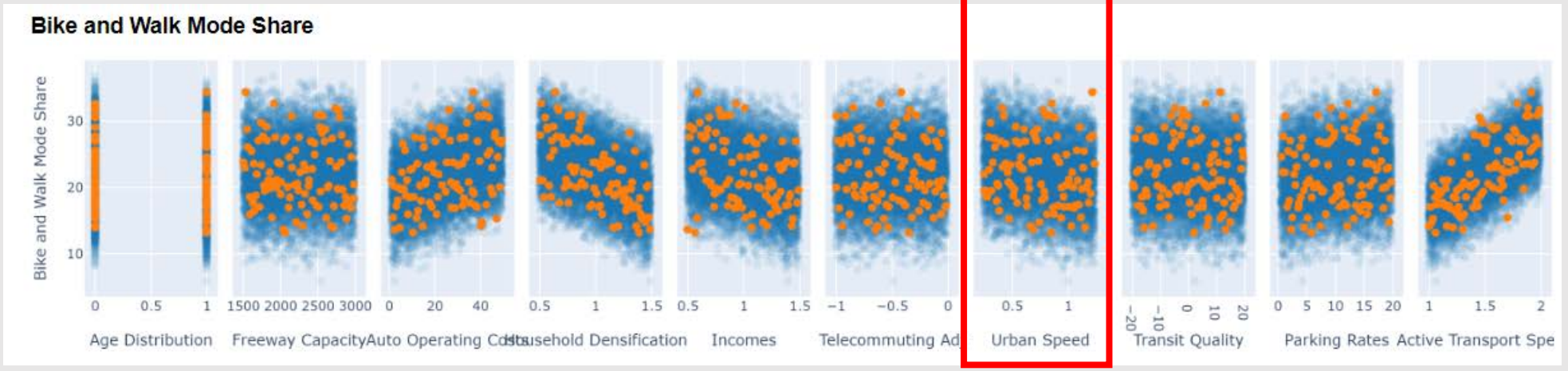
- Measures:

VMT by Speed (lower speed), VMT by V/C (lower V/C), Active Mode Share

	Urban Speed
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.575288
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.596777
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.549025
Bike and Walk Mode Share	0.060642
Transit with PNR and KNR Mode Share	0.0626623
Millions of Person Miles Traveled	0.071374
Millions of Vehicle Miles Traveled in PM	0.0705601
Millions of Vehicle Miles Traveled	0.0627319
Percentage VMT in Light Congestion	0.0648447
Percentage VMT Below 30mph	0.537732
Millions of VMT for Households Below 25k	0.0470797
Thousands of Vehicle Hours Traveled in PM	0.433884
Thousands of Vehicle Hours Traveled	0.484289
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.0784758
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.0933104
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.0716019
Number of Autos Owned Per Household	0.0476873
Percent of Non-Mandatory Tours	0.0391967

	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Percentage VMT in Light Congestion	0.0364048	0.234016	0.201634	0.0908841	0.128056	0.0505795	0.0648447	0.0544634	0.0521241	0.0869938
Bike and Walk Mode Share	0.033724	0.0423424	0.103598	0.219507	0.0976348	0.0475395	0.060642	0.0449326	0.0615405	0.288539





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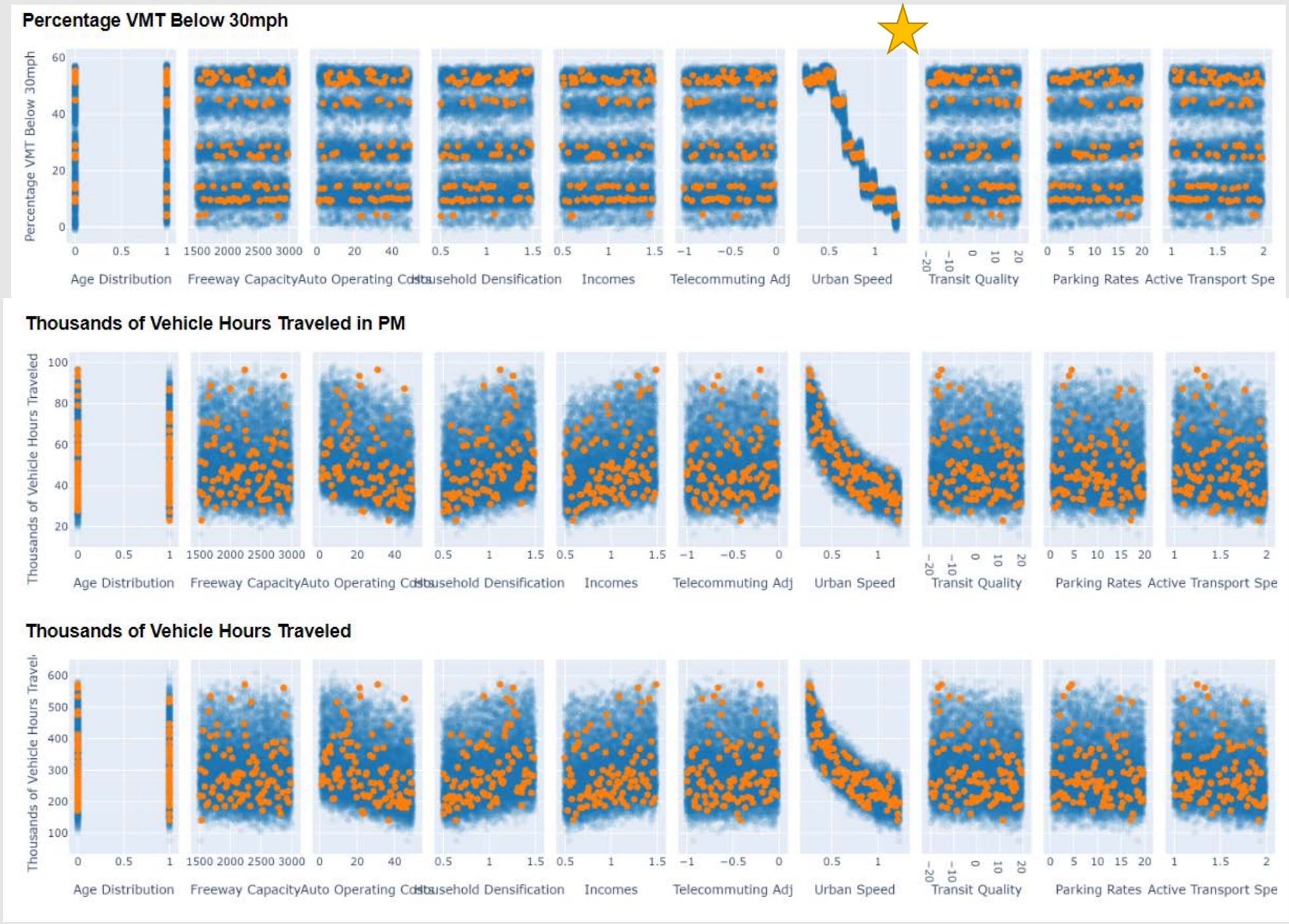
Percent of Non-Mandatory Tours	0.0391967



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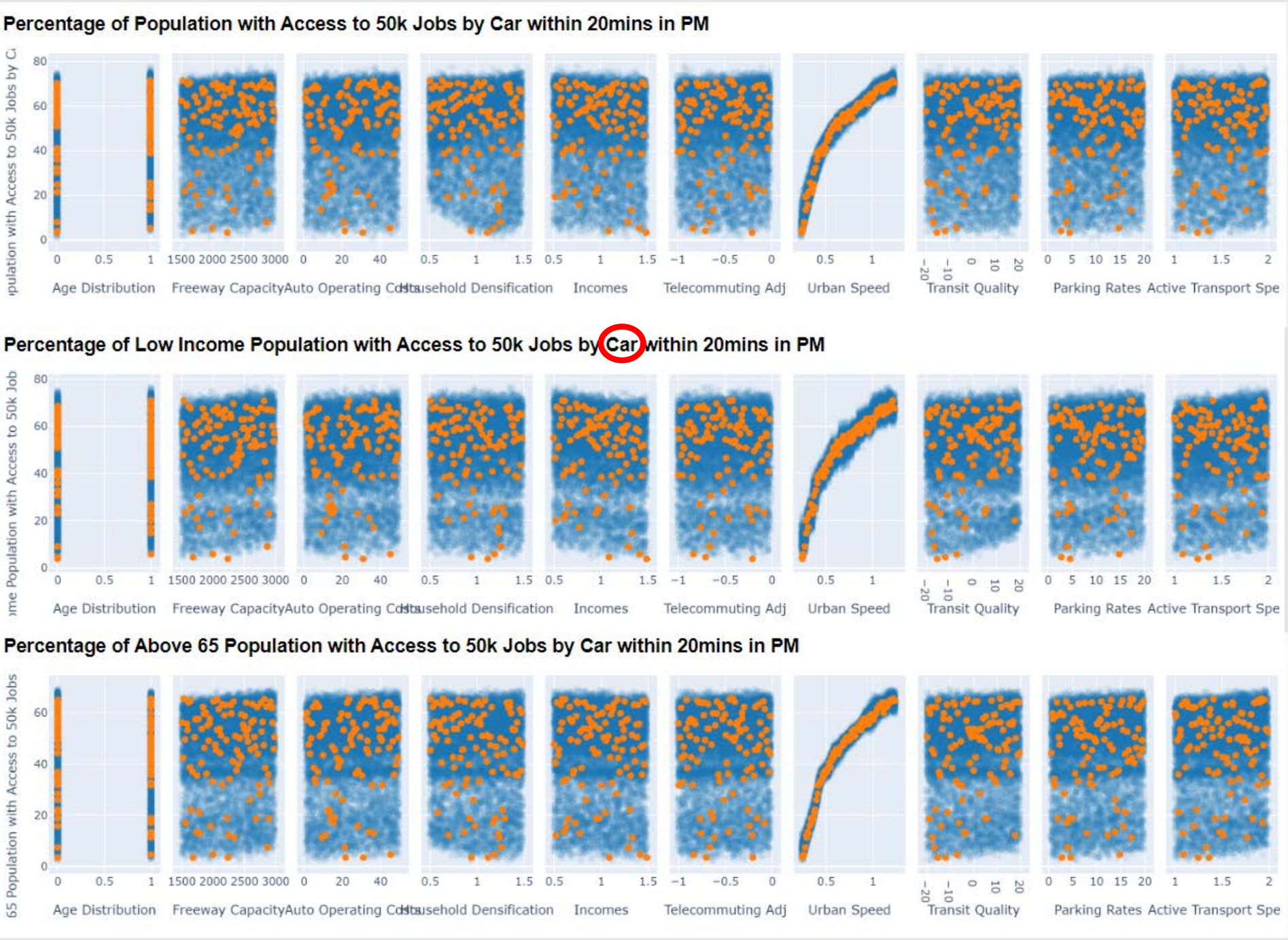
Percent of Non-Mandatory Tours	0.0391967

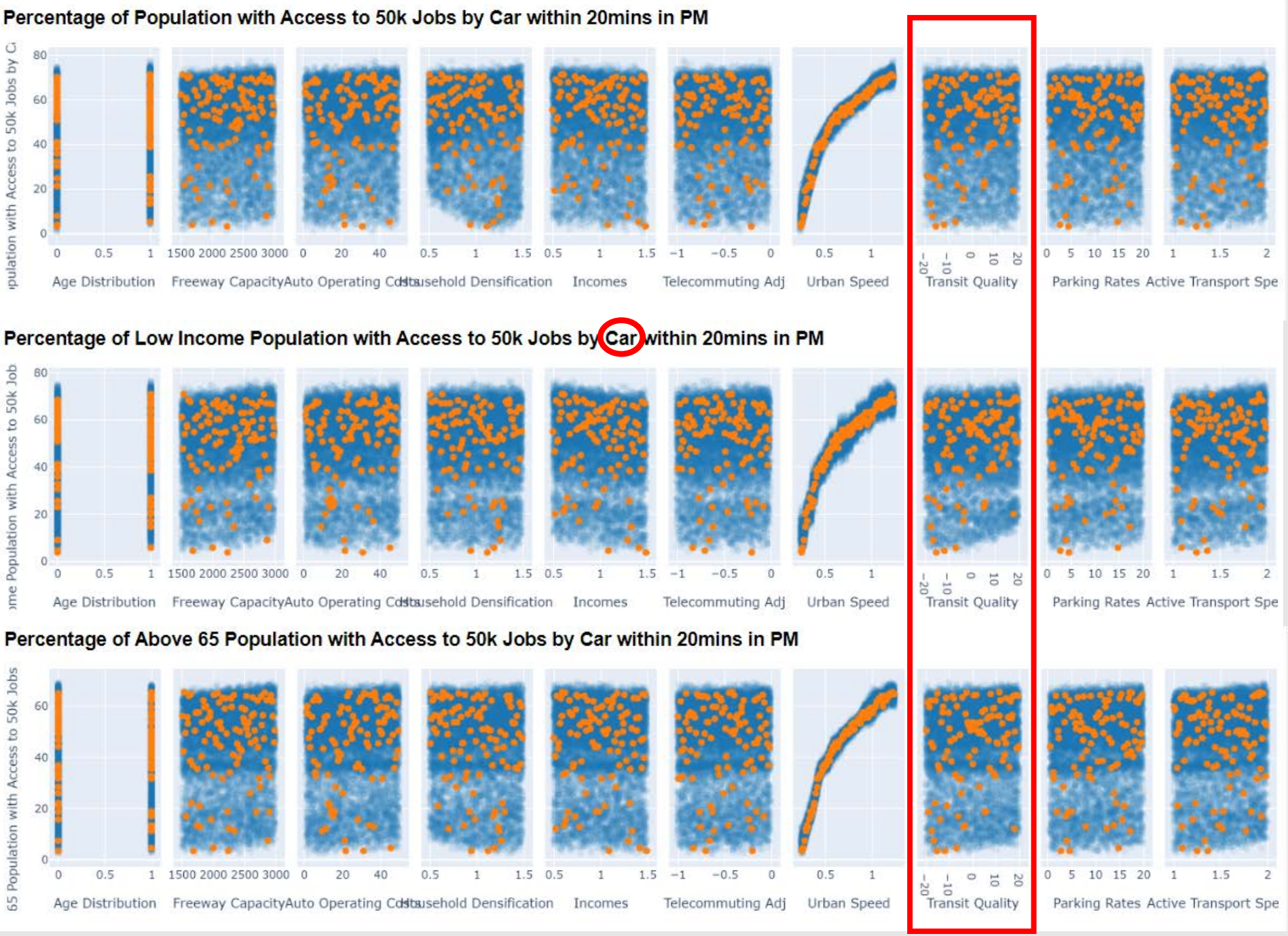


Transit Level of Service Goal - Equity

- ptype: policy lever
- desc: The overall comfort, performance, and attitude toward transit has been successfully changed dtype: real
- default: 0.0
- min: **-20.0** (proxy of 20 min penalty)
- max: **20.0** (proxy of 20 min reduction)

- Measure – Accessibility by Income

	Transit Quality
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0830295
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0649377
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0687977
Bike and Walk Mode Share	0.0449326
Transit with PNR and KNR Mode Share	0.285781
Millions of Person Miles Traveled	0.0473575
Millions of Vehicle Miles Traveled in PM	0.0588674
Millions of Vehicle Miles Traveled	0.0512195
Percentage VMT in Light Congestion	0.0544634
Percentage VMT Below 30mph	0.0618359
Millions of VMT for Households Below 25k	0.0570167
Thousands of Vehicle Hours Traveled in PM	0.0719388
Thousands of Vehicle Hours Traveled	0.0653856
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.0669003
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.0602442
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.0574372
Number of Autos Owned Per Household	0.0450454
Percent of Non-Mandatory Tours	0.0298901



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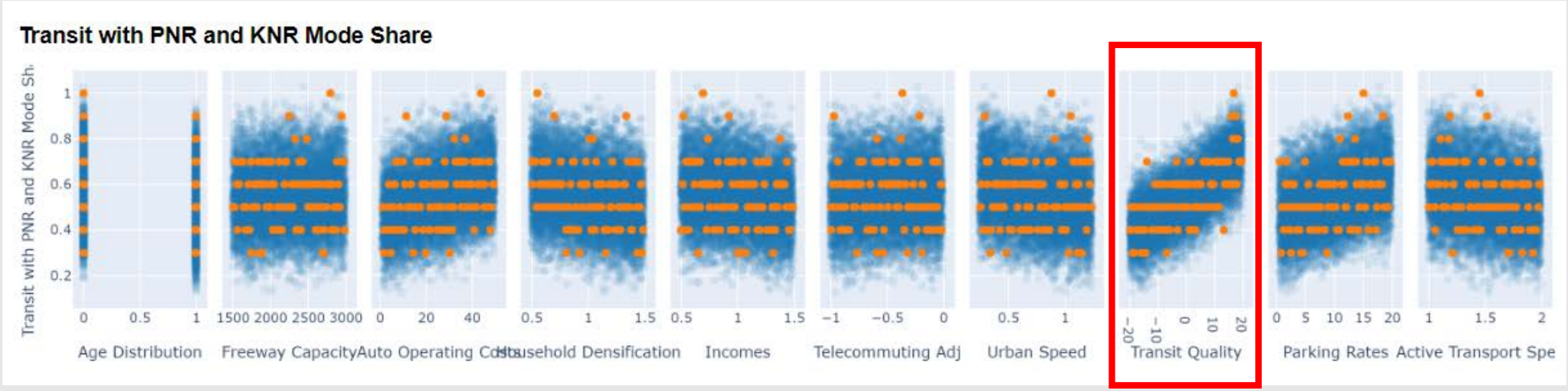
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.0574372
Number of Autos Owned Per Household	0.0450454
Percent of Non-Mandatory Tours	0.0298901

	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Transit with PNR and KNR Mode Share	0.0518717	0.0607869	0.0985202	0.102784	0.0630194	0.0621766	0.0626623	0.285781	0.132873	0.0795259

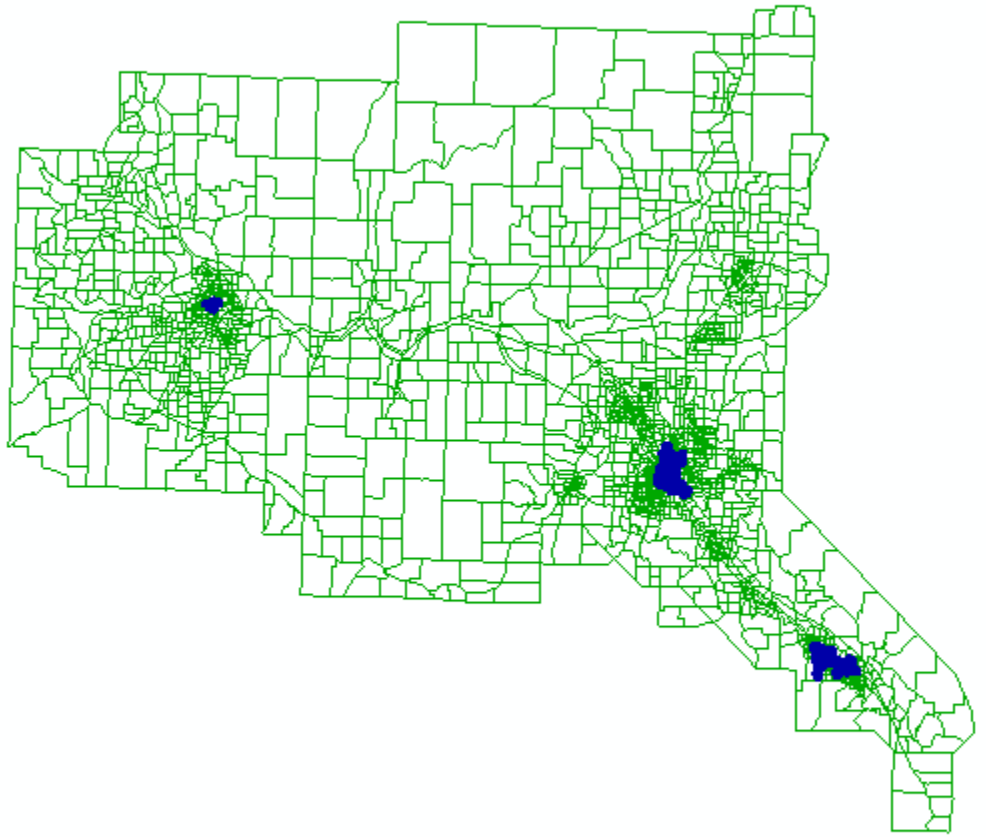


Parking Rates Goals – Equity, Sustainability

- ptype: policy lever
- desc: Varies the cost of Parking in Parking Zones
- dtype: real
- default: 1.0
- min: 0.5 $/hr
- max: 20 $/hr

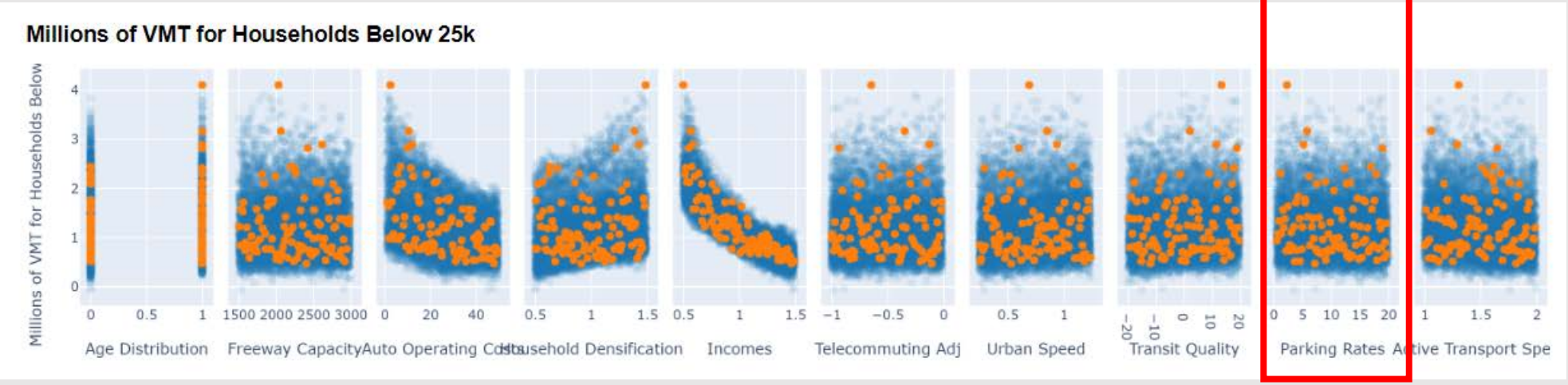
- Measures:

Overall VMT, VMT by income group (low)



	Parking Rates
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0499987
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0433008
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0483799
Bike and Walk Mode Share	0.0615405
Transit with PNR and KNR Mode Share	0.132873
Millions of Person Miles Traveled	0.0524723
Millions of Vehicle Miles Traveled in PM	0.0593232
Millions of Vehicle Miles Traveled	0.0616796
Percentage VMT in Light Congestion	0.0521241
Percentage VMT Below 30mph	0.0511332
Millions of VMT for Households Below 25k	0.0420312
Thousands of Vehicle Hours Traveled in PM	0.0460428
Thousands of Vehicle Hours Traveled	0.04563
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.0693283
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.061335
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.0662083
Number of Autos Owned Per Household	0.0512366
Percent of Non-Mandatory Tours	0.0332597

	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Millions of Vehicle Miles Traveled	0.0498665	0.058043	0.251724	0.196376	0.133795	0.058649	0.0627319	0.0512195	0.0616796	0.0759166
Millions of VMT for Households Below 25k	0.0437598	0.0403332	0.148943	0.080555	0.450928	0.041935	0.0470797	0.0570167	0.0420312	0.0474184



Measures: Overall VMT, VMT by income group (low)

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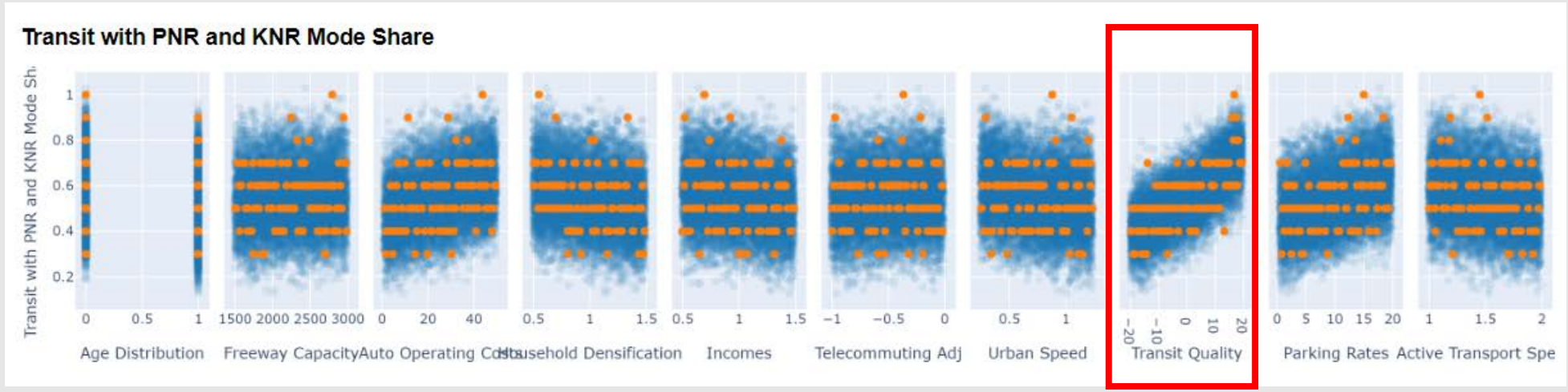
	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Transit with PNR and KNR Mode Share	0.0518717	0.0607869	0.0985202	0.102784	0.0630194	0.0621766	0.0626623	0.285781	0.132873	0.0795259



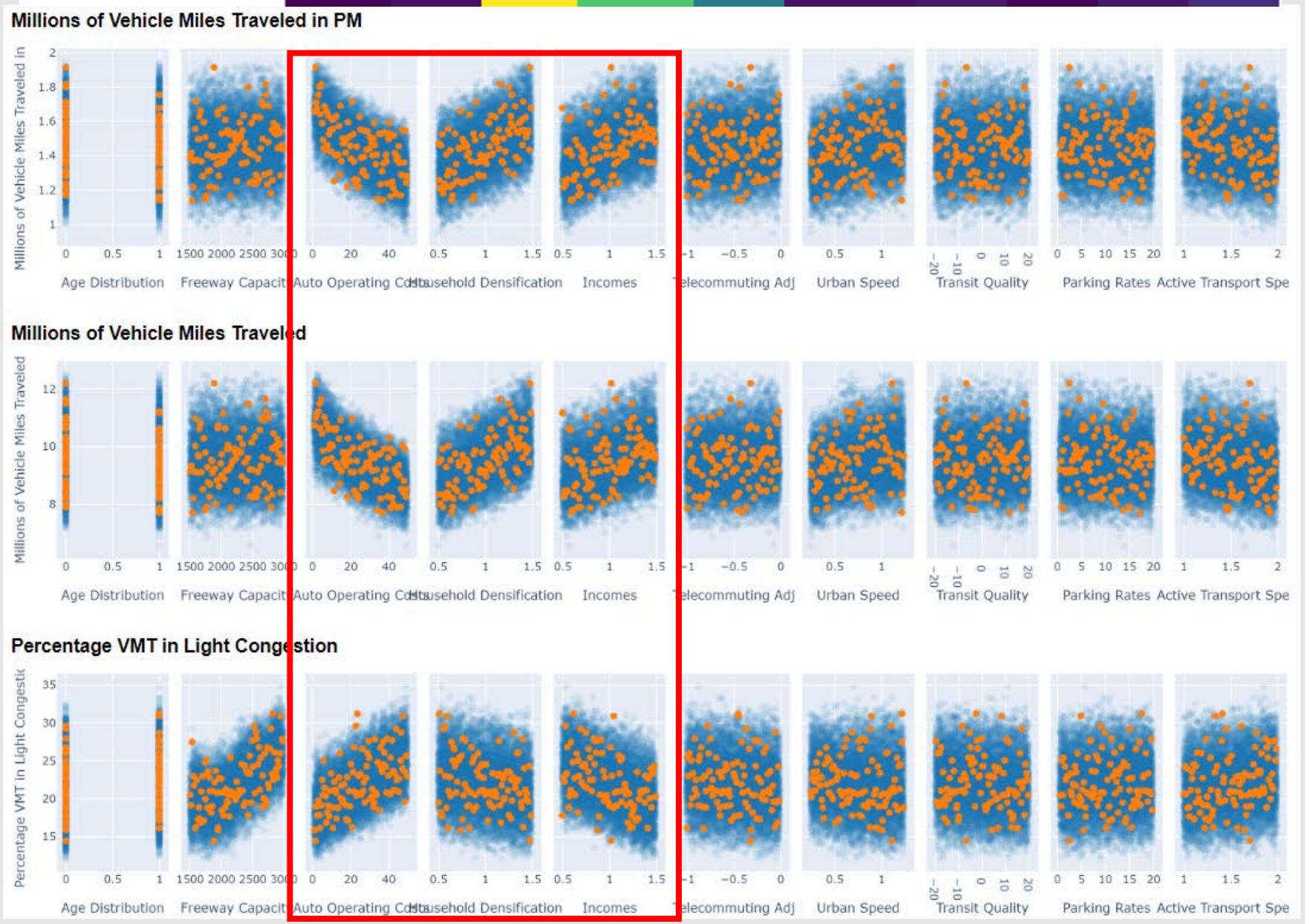
Auto Operating Goals – Sustainability Costs

- ptype: exogenous uncertainty
- desc: Change vehicle fuel cost
- dtype: real
- default: 12.4
- min: 1.0 # auto operating cost is what the user sees not actual costs, so a low cost could be subsidized by ad-rev, also home solar power…
- max: **50.0** # max represents higher tax scenarios and carbon fees and PAYD
- **Also assumed to cover value of travel time and road use charges**

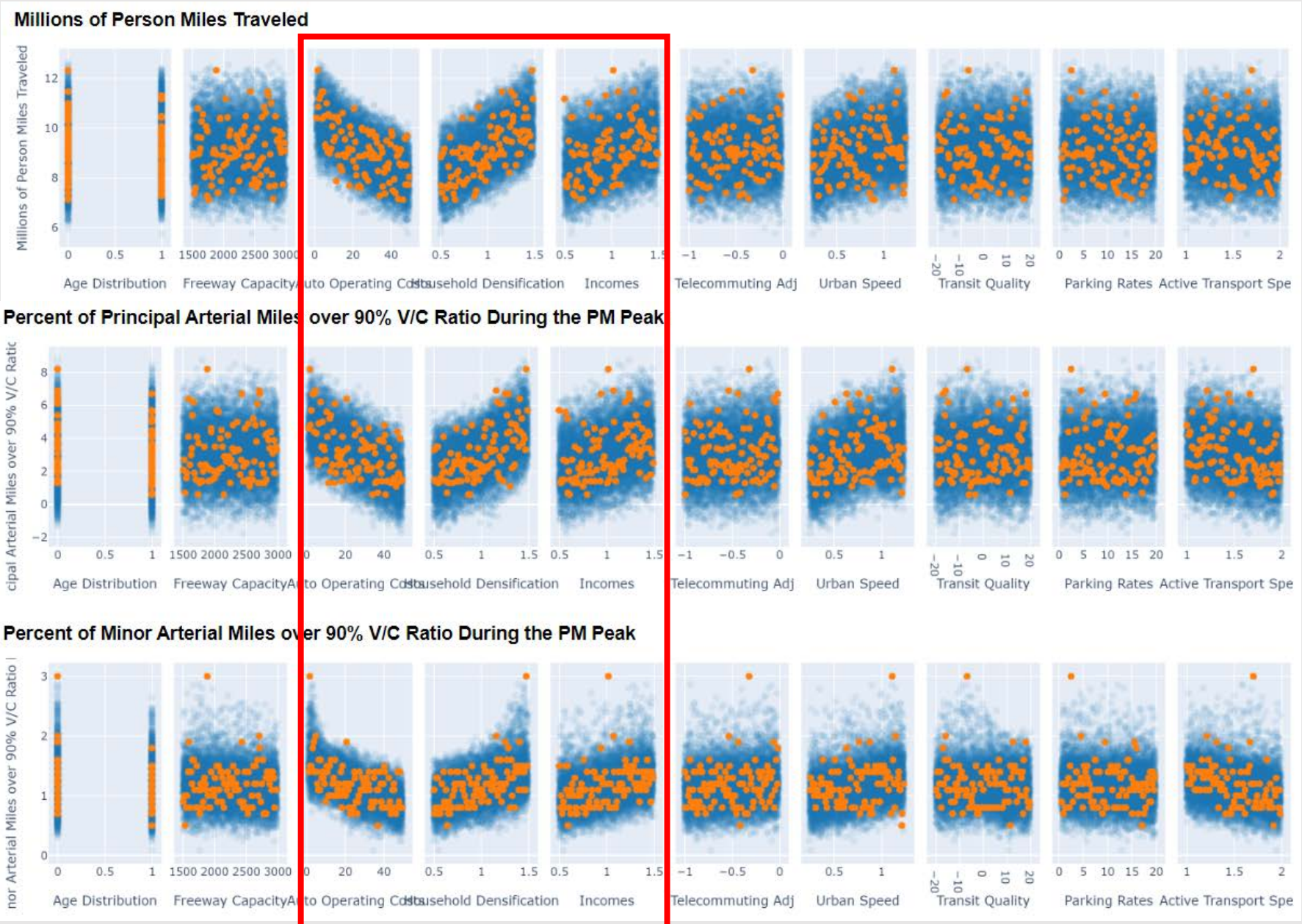
- Measures: Overall VMT (assuming proxy for GhG)

	Auto Operating Costs	Household Densification	Incomes
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0482821	0.0427327	0.0394827
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0493246	0.0442336	0.0408537
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0571037	0.0489444	0.0496779
Bike and Walk Mode Share	0.103598	0.219507	0.0976348
Transit with PNR and KNR Mode Share	0.0985202	0.102784	0.0630194
Millions of Person Miles Traveled	0.277401	0.253783	0.106957
Millions of Vehicle Miles Traveled in PM	0.215353	0.210532	0.136135
Millions of Vehicle Miles Traveled	0.251724	0.196376	0.133795
Percentage VMT in Light Congestion	0.201634	0.0908841	0.128056
Percentage VMT Below 30mph	0.0560773	0.0551734	0.036801
Millions of VMT for Households Below 25k	0.148943	0.080555	0.450928
Thousands of Vehicle Hours Traveled in PM	0.092757	0.0960732	0.0807504
Thousands of Vehicle Hours Traveled	0.0870913	0.0970584	0.0626658
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.107273	0.0619916	0.0821684
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.205628	0.208003	0.115218
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.231316	0.165513	0.120517
Number of Autos Owned Per Household	0.0344932	0.354303	0.259628
Percent of Non-Mandatory Tours	0.0278261	0.030058	0.0737975

	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Millions of Vehicle Miles Traveled	0.0498665	0.058043	0.251724	0.196376	0.133795	0.058649	0.0627319	0.0512195	0.0616796	0.0759166



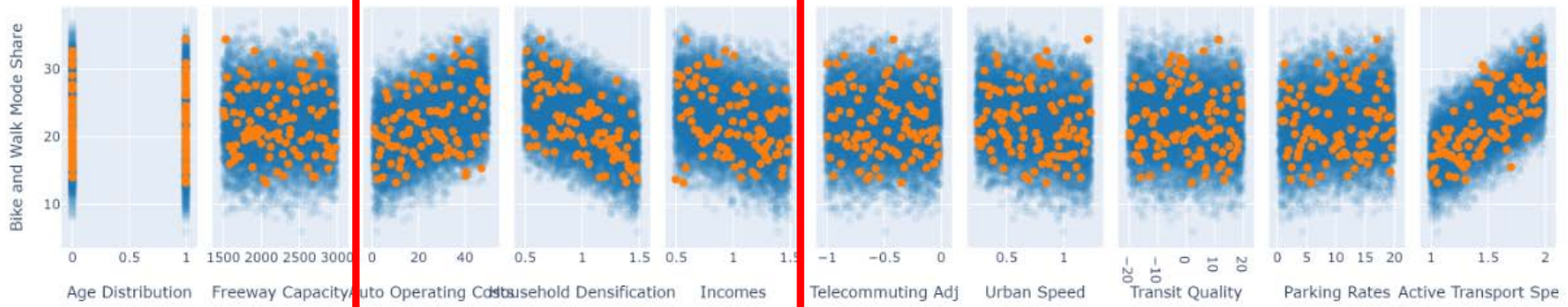
	Auto Operating Costs	Household Densification	Incomes
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0482821	0.0427327	0.0394827
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0493246	0.0442336	0.0408537
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0571037	0.0489444	0.0496779
Bike and Walk Mode Share	0.103598	0.219507	0.0976348
Transit with PNR and KNR Mode Share	0.0985202	0.102784	0.0630194
Millions of Person Miles Traveled	0.277401	0.253783	0.106957
Millions of Vehicle Miles Traveled in PM	0.215353	0.210532	0.136135
Millions of Vehicle Miles Traveled	0.251724	0.196376	0.133795
Percentage VMT in Light Congestion	0.201634	0.0908841	0.128056
Percentage VMT Below 30mph	0.0560773	0.0551734	0.036801
Millions of VMT for Households Below 25k	0.148943	0.080555	0.450928
Thousands of Vehicle Hours Traveled in PM	0.092757	0.0960732	0.0807504
Thousands of Vehicle Hours Traveled	0.0870913	0.0970584	0.0626658
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.107273	0.0619916	0.0821684
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.205628	0.208003	0.115218
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.231316	0.165513	0.120517
Number of Autos Owned Per Household	0.0344932	0.354303	0.259628
Percent of Non-Mandatory Tours	0.0278261	0.030058	0.0737975



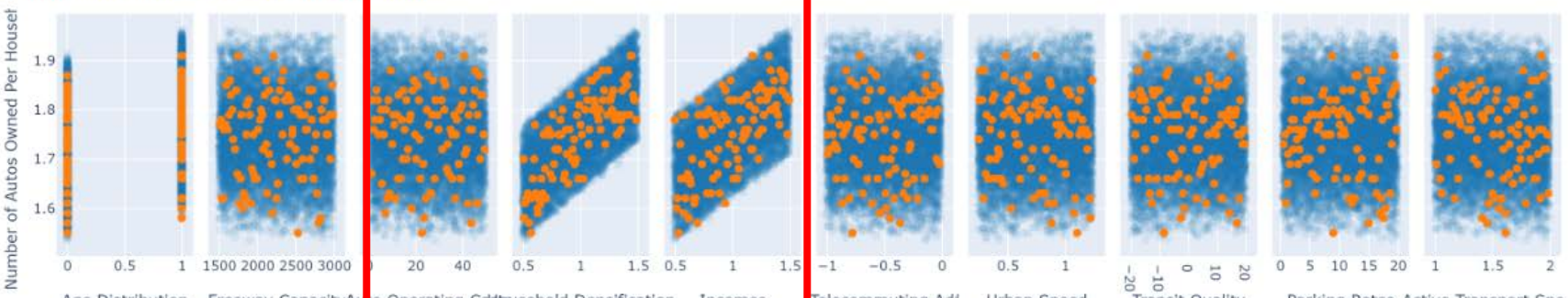
	Auto Operating Costs	Household Densification	Incomes
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0482821	0.0427327	0.0394827
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0493246	0.0442336	0.0408537
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0571037	0.0489444	0.0496779
Bike and Walk Mode Share	0.103598	0.219507	0.0976348
Transit with PNR and KNR Mode Share	0.0985202	0.102784	0.0630194
Millions of Person Miles Traveled	0.277401	0.253783	0.106957
Millions of Vehicle Miles Traveled in PM	0.215353	0.210532	0.136135
Millions of Vehicle Miles Traveled	0.251724	0.196376	0.133795
Percentage VMT in Light Congestion	0.201634	0.0908841	0.128056
Percentage VMT Below 30mph	0.0560773	0.0551734	0.036801
Millions of VMT for Households Below 25k	0.148943	0.080555	0.450928
Thousands of Vehicle Hours Traveled in PM	0.092757	0.0960732	0.0807504
Thousands of Vehicle Hours Traveled	0.0870913	0.0970584	0.0626658
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.107273	0.0619916	0.0821684
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.205628	0.208003	0.115218
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.231316	0.165513	0.120517
Number of Autos Owned Per Household	0.0344932	0.354303	0.259628
Percent of Non-Mandatory Tours	0.0278261	0.030058	0.0737975

	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Bike and Walk Mode Share	0.033724	0.0423424	0.103598	0.219507	0.0976348	0.0475395	0.060642	0.0449326	0.0615405	0.288539
Number of Autos Owned Per Household	0.0564055	0.0409718	0.0344932	0.354303	0.259628	0.0566757	0.0476873	0.0450454	0.0512366	0.0535528

Bike and Walk Mode Share

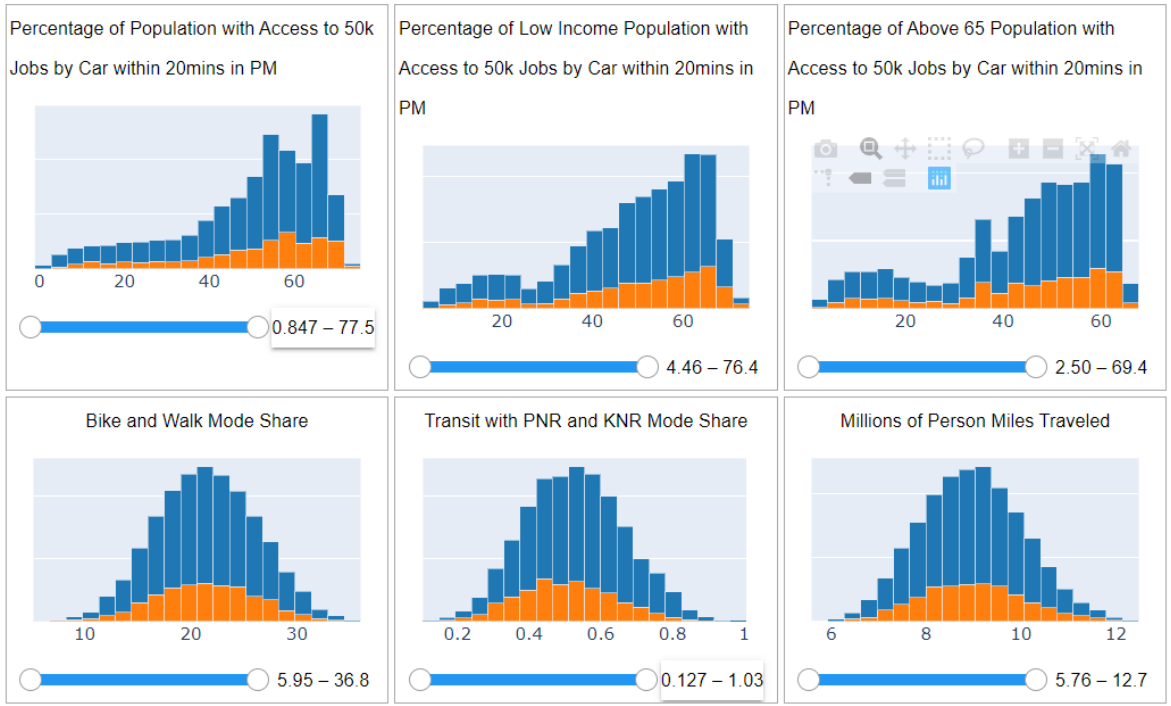


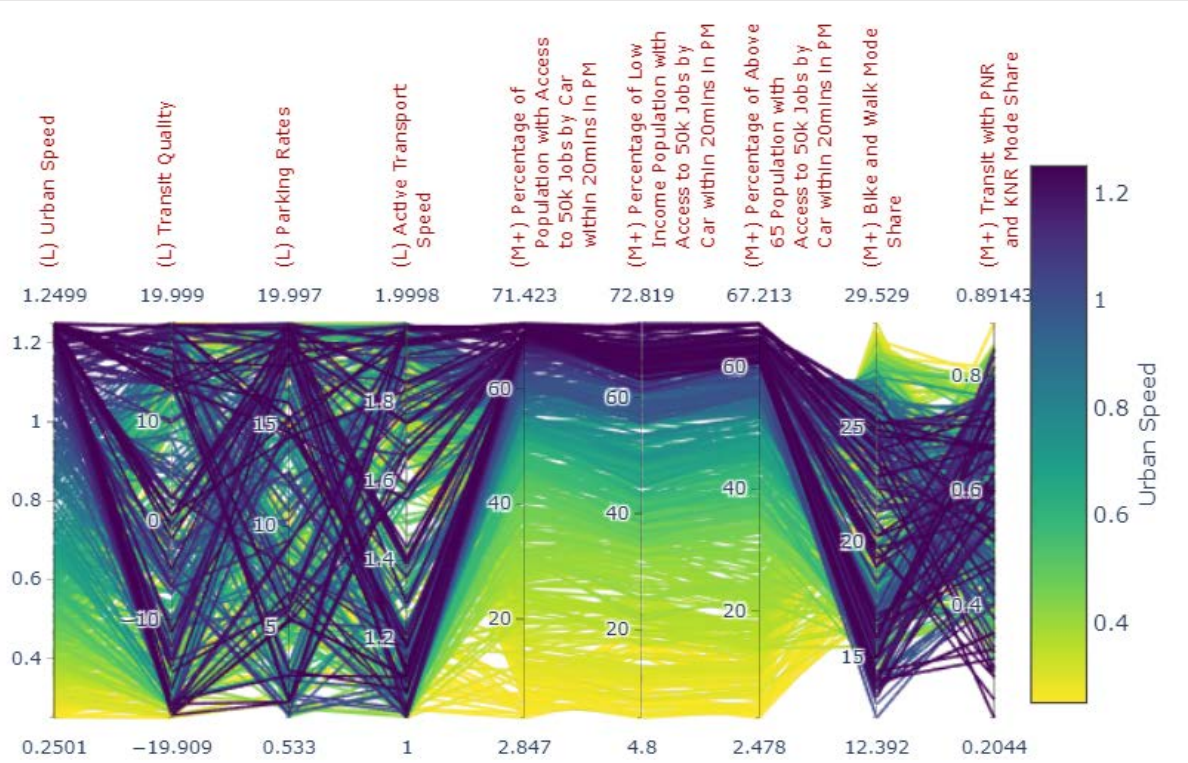
Number of Autos Owned Per Household

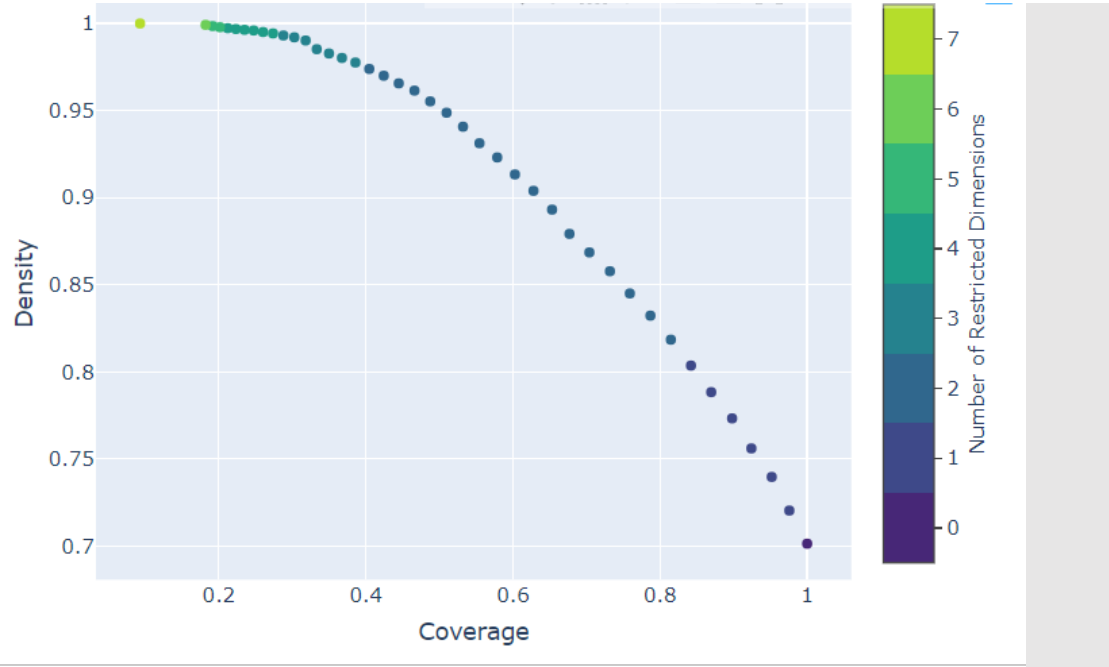


Next Steps – Exploring the Data

The **blue** bars depict the unconditional frequency of performance measures in the data across all cases, while the **orange** bars depict the freque measures conditional on the constraints.







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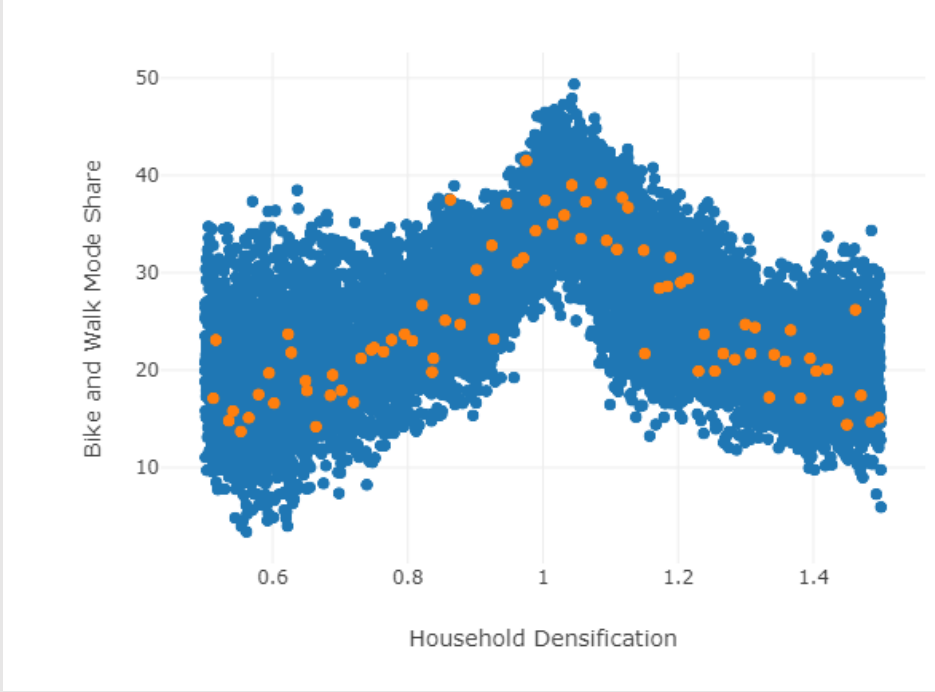
Lessons Learned - Great Testing of the Model Before Official Use

Model Runs – a Lesson Each Time

3 Beta Test Rounds in 2019

1. issues found with v/c calculations and reference scenario setup/inputs
2. Household Densification
3. Clear that Transit Everywhere had Issues



	Transit Everywhere
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.301319
Bike and Walk Mode Share	0.107464
Transit with PNR and KNR Mode Share	0.746386
Millions of Person Miles Traveled	0.04692
Millions of Vehicle Miles Traveled in PM	0.226638
Millions of Auto Miles Traveled	0.206412
Millions of Truck Miles Traveled	0.0792662
Millions of Vehicle Miles Traveled	0.214569
Thousands of Vehicle Hours Traveled in PM	0.225438
Thousands of Auto Hours Traveled	0.223072
Thousands of Truck Hours Traveled	0.152221
Thousands of Vehicle Hours Traveled	0.233678

Output Design Matters !!!!!!!!!!!!

Assumption was made that shifting to ABM would give a wider array of outputs to help tell the story…

Yes, **BUT**

In order to get access to those results and information, the ABM design needs to anticipate and export the outputs in an easy to use format (ideally a travel survey format).

Metrics

The dream list:	Cold Reality (model and time limitations):
• Regional accessibility by…	• Jobs by SOV in a time boundary
• Congestion / reliability…	• Mode percentages
• Affordable Transportation	• PMT / VMT
• Quality of Life	• VHT
• Fiscal Sustainability	• V/C
• Safety	• Auto ownership
	• Number of Non-Mandatory Tours

Model Runs – Still More Lessons

Lessons from 2020 re-run

- Tolling not setup as user anticipated.
- Tolling methodology was inconsistent across modules (commercial vehicle and externals
- Accessibility is a key/important measure that needs to be better defined.

Final Thoughts:

How do you summarize all this?

1. Uncertainties seem much more impactful than Levers
2. Further model enhancements needed to fully test all the levers like MaaS
3. Lots more to learn – specifically around accessibility

Uncertainties ← → Policy Levers

	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0257042	0.0471329	0.0482821	0.0427327	0.0394827	0.0469136	0.575288	0.0830295	0.0499987	0.0414359
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0234979	0.0499328	0.0493246	0.0442336	0.0408537	0.040682	0.596777	0.0649377	0.0433008	0.0464599
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0345267	0.0474496	0.0571037	0.0489444	0.0496779	0.0508438	0.549025	0.0687977	0.0483799	0.045251
Bike and Walk Mode Share	0.033724	0.0423424	0.103598	0.219507	0.0976348	0.0475395	0.060642	0.0449326	0.0615405	0.288539
Transit with PNR and KNR Mode Share	0.0518717	0.0607869	0.0985202	0.102784	0.0630194	0.0621766	0.0626623	0.285781	0.132873	0.0795259
Millions of Person Miles Traveled	0.0299699	0.0499768	0.277401	0.253783	0.106957	0.0526466	0.071374	0.0473575	0.0524723	0.0580622
Millions of Vehicle Miles Traveled in PM	0.053534	0.0544239	0.215353	0.210532	0.136135	0.056859	0.0705601	0.0588674	0.0593232	0.0844129
Millions of Vehicle Miles Traveled	0.0498665	0.058043	0.251724	0.196376	0.133795	0.058649	0.0627319	0.0512195	0.0616796	0.0759166
Percentage VMT in Light Congestion	0.0364048	0.234016	0.201634	0.0908841	0.128056	0.0505795	0.0648447	0.0544634	0.0521241	0.0869938
Percentage VMT Below 30mph	0.0502436	0.0535798	0.0560773	0.0551734	0.036801	0.0475183	0.537732	0.0618359	0.0511332	0.0499056
Millions of VMT for Households Below 25k	0.0437598	0.0403332	0.148943	0.080555	0.450928	0.041935	0.0470797	0.0570167	0.0420312	0.0474184
Thousands of Vehicle Hours Traveled in PM	0.0335604	0.043294	0.092757	0.0960732	0.0807504	0.0481221	0.433884	0.0719388	0.0460428	0.0535773
Thousands of Vehicle Hours Traveled	0.0322245	0.0425234	0.0870913	0.0970584	0.0626658	0.0380097	0.484289	0.0653856	0.04563	0.0451228
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.0397044	0.361928	0.107273	0.0619916	0.0821684	0.0603525	0.0784758	0.0669003	0.0693283	0.0718778
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.0497205	0.0576368	0.205628	0.208003	0.115218	0.0526535	0.0933104	0.0602442	0.061335	0.0962499
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.0428661	0.0690728	0.231316	0.165513	0.120517	0.058904	0.0716019	0.0574372	0.0662083	0.116564
Number of Autos Owned Per Household	0.0564055	0.0409718	0.0344932	0.354303	0.259628	0.0566757	0.0476873	0.0450454	0.0512366	0.0535528
Percent of Non-Mandatory Tours	0.599835	0.0320252	0.0278261	0.030058	0.0737975	0.102413	0.0391967	0.0298901	0.0332597	0.0316986

Next Steps – Model Development

These lessons are helping to guide model improvement:

- Telecommuting
- Vehicle Representation
- Vehicle Tracking
- Tolling Improvements
- Output Access / Formatting
- Better Measures
  - https://github.com/RSGInc/bca4abm

The Magic of TMIP-EMAT

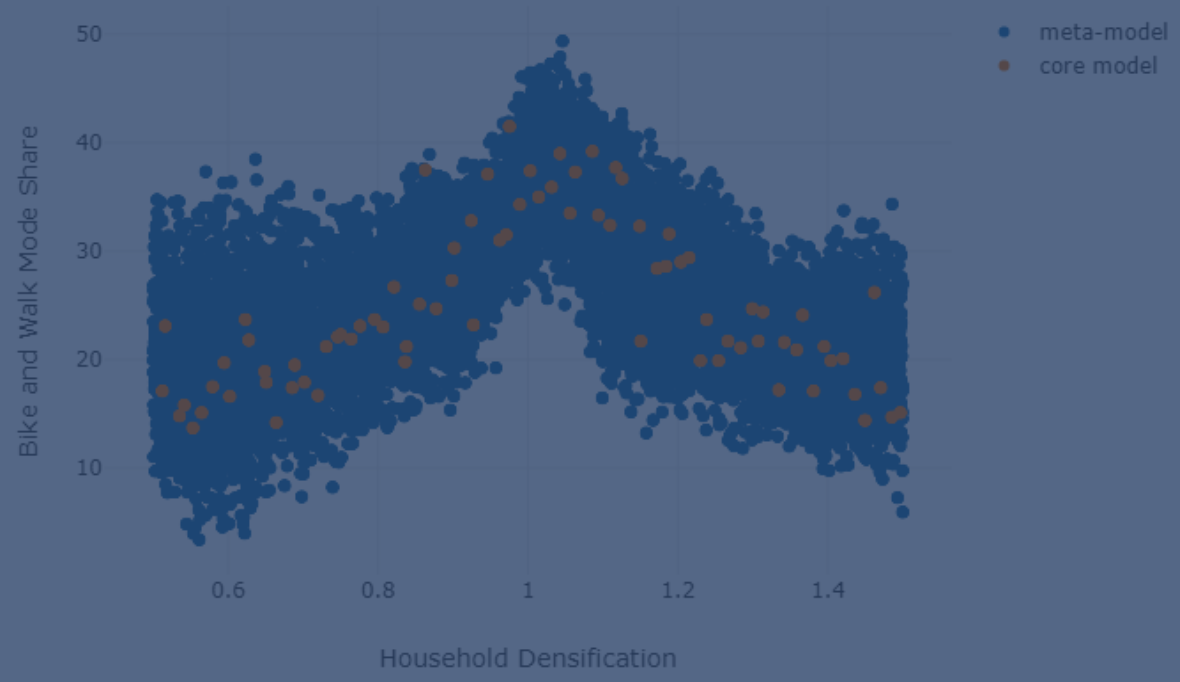
1. Robust Decision Making (RDM) Problem Design and Scoping

2. (2.5 words) Latin HyperCube

3. Exploratory Model and Analysis (EMA) Workbench
   https://emaworkbench.readthedocs.io/en/latest/

The rest is just automating your core model

Any Questions?



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Appendix

Next slides are extra lever (input) context

Urban Speed Goal - Safety

- ptype: policy lever
- desc: A multiplier on Urban (non-interstate) speedsdtype: real
- default: 1.0
- min: 0.25
- max: 1.25

- Measures:

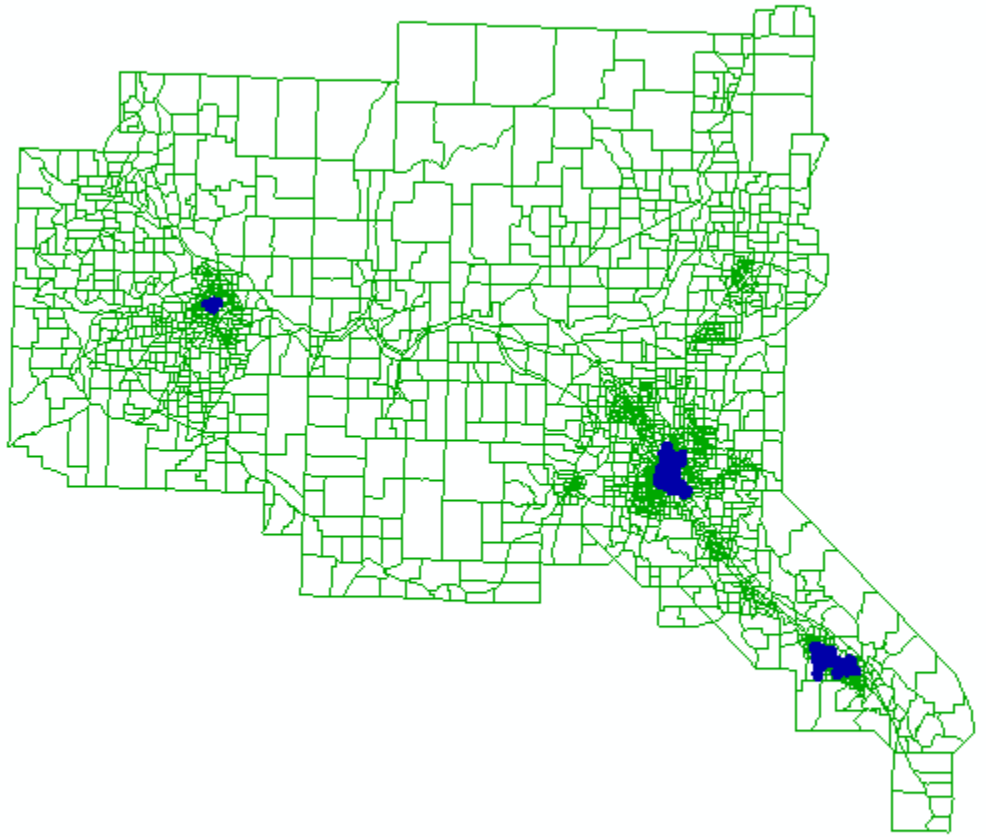
VMT by Speed (lower speed), VMT by V/C (lower V/C), Active Mode Share

Parking Rates Goals – Equity, Sustainability

- ptype: policy lever
- desc: Varies the cost of Parking in Parking Zones
- dtype: real
- default: 1.0
- min: 0.5 $/hr
- max: 20 $/hr

- Measures:

Overall VMT, VMT by income group (low)



Auto Operating Costs Goals ility

First Attempt in Learning

- ptype: exogenou
- desc: Char cost
- dtype
- # auto operating cost is what the user not actual costs, so a low cost could be ubsidized by ad-rev, also home solar power…
- max: 50.0 # max represents higher tax scenarios and carbon fees and PAYD
- **Also assumed to cover value of travel time and road use charges**

- Measures: Overall VMT (assuming proxy for GhG)

Personal Income

Goal - Equity

- ptype: exogenous uncertainty
- desc: How have incomes (purchasing power) changed moving into the future
- dtype: real
- default: 1.0
- min: 0.5 x current income
- Max 1.5 x current income

- Measures – unclear how best to monitor

Easier than to try to model the overall economic conditions (jobs, job type, occupation, household mix…)

Household Densification Goal - Livability

- ptype: exogenous uncertainty
- desc: Shifting Households closer to or father away from urban cores to represent different land use scenarios
- dtype: real
- default: 1.0
- min: 0.5 (half the distance to the urban core)
- max: 1.5 (1.5x farther from the core)

- Measures?:

VMT for Low Income, VMT Overall

Age Distribution

- ptype: exogenous uncertainty
- desc: Two populations indicating whether the population ages or not.
- dtype: boolean
- default: False (projected older)

- Measures:

Accessibility by Low Income and by Older Populations

The population is anticipated to age (get older on average), but what if climate migration pushed the demographics younger – like today.

~~Transit Everywhere~~

- ptype: policy lever
- desc: Allows transit everywhere to approximate a public TNC ve… typical routed and sche… service
- dtype: bool
- defau…
- …u transit
- …public TNC

First Attempt in Learning

Extra results slides

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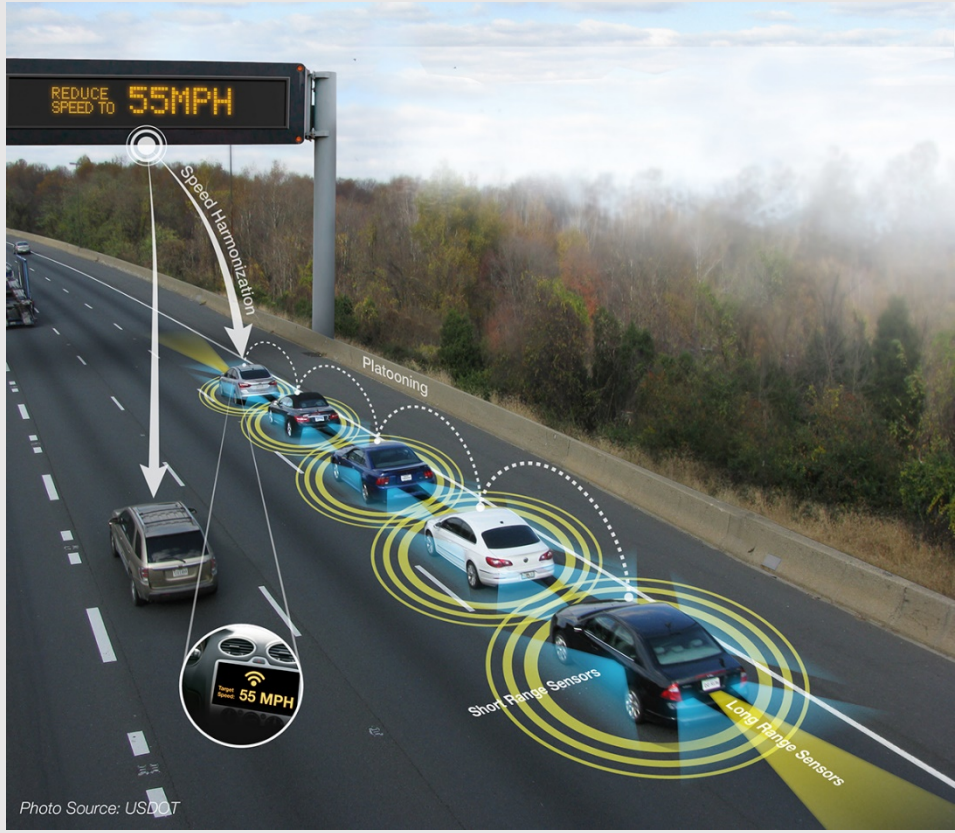
Freeway Capacity Goals – Equity, Economic Growth

- ptype: exogenous uncertainty
- desc: Future Tech changes how many vehicles can use a given lane of freeway
- dtype: real
- default: 1900.0
- min: 1500.0
- max: 3000.0

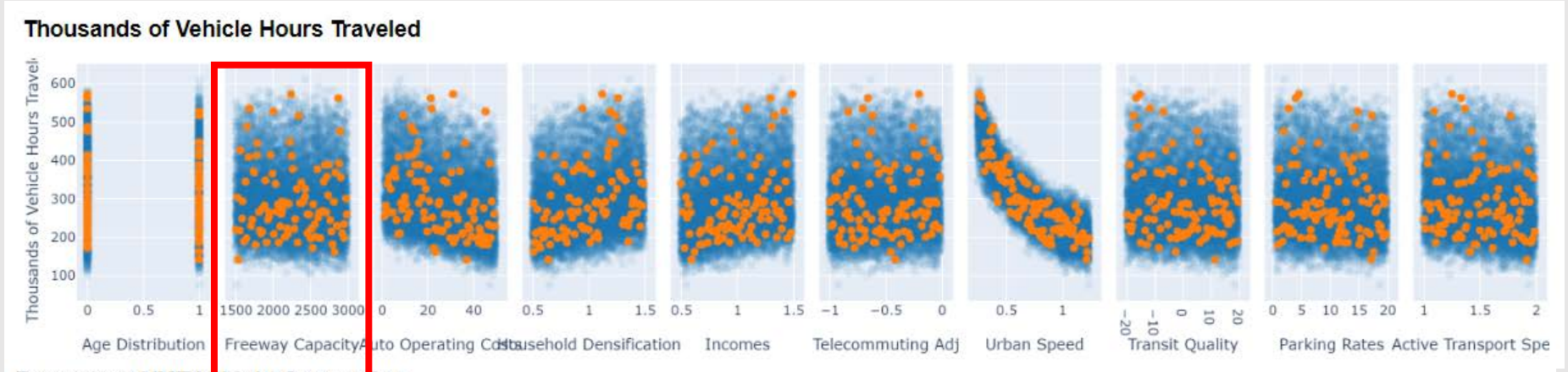
- Measures: VHT

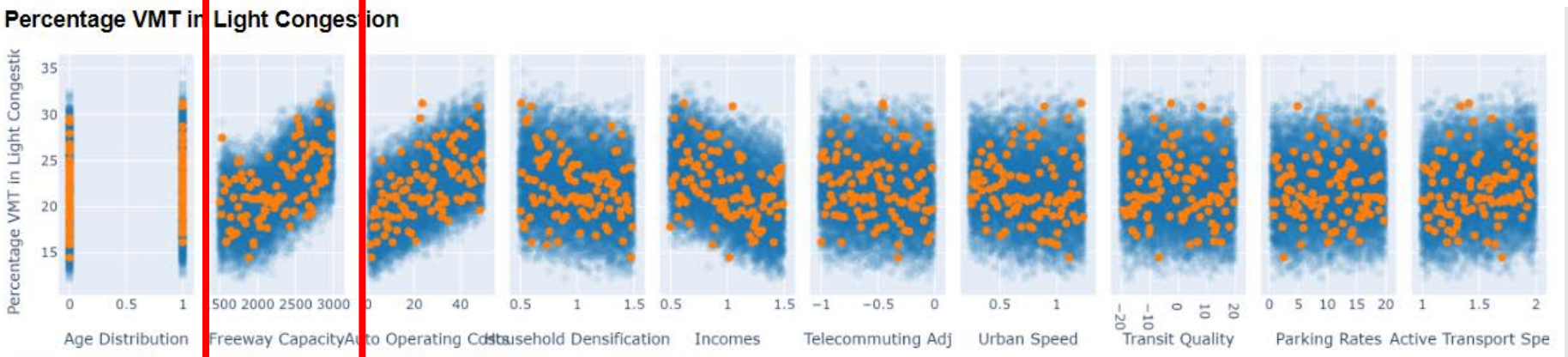


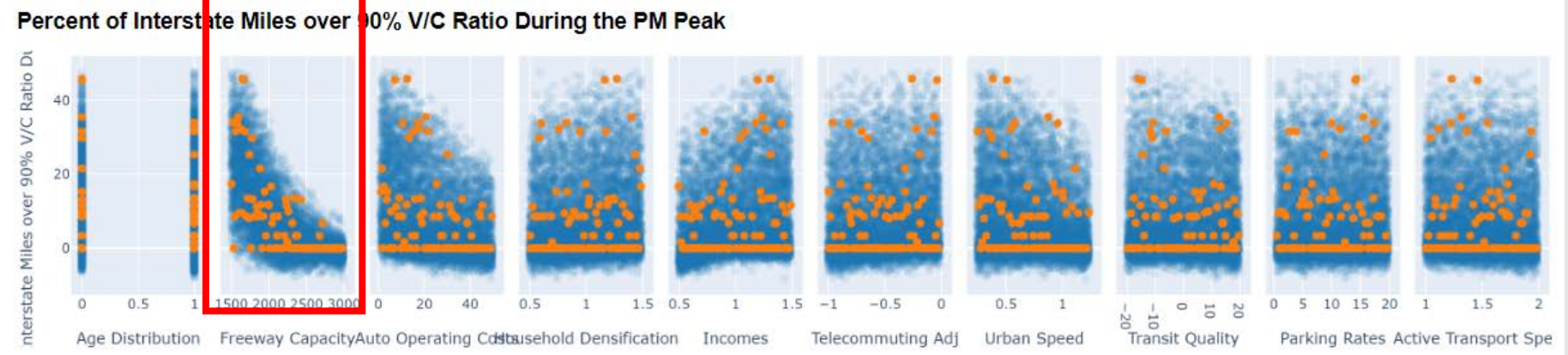
	Freeway Capacity
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0471329
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0499328
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0474496
Bike and Walk Mode Share	0.0423424
Transit with PNR and KNR Mode Share	0.0607869
Millions of Person Miles Traveled	0.0499768
Millions of Vehicle Miles Traveled in PM	0.0544239
Millions of Vehicle Miles Traveled	0.058043
Percentage VMT in Light Congestion	0.234016
Percentage VMT Below 30mph	0.0535798
Millions of VMT for Households Below 25k	0.0403332
Thousands of Vehicle Hours Traveled in PM	0.043294
Thousands of Vehicle Hours Traveled	0.0425234
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.361928
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.0576368
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.0690728
Number of Autos Owned Per Household	0.0409718
Percent of Non-Mandatory Tours	0.0320252

	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Thousands of Vehicle Hours Traveled	0.0322245	0.0425234	0.0870913	0.0970584	0.0626658	0.0380097	0.484289	0.0653856	0.04563	0.0451228

Measures:
VHT







Auto Operating Goals – Sustainability Costs

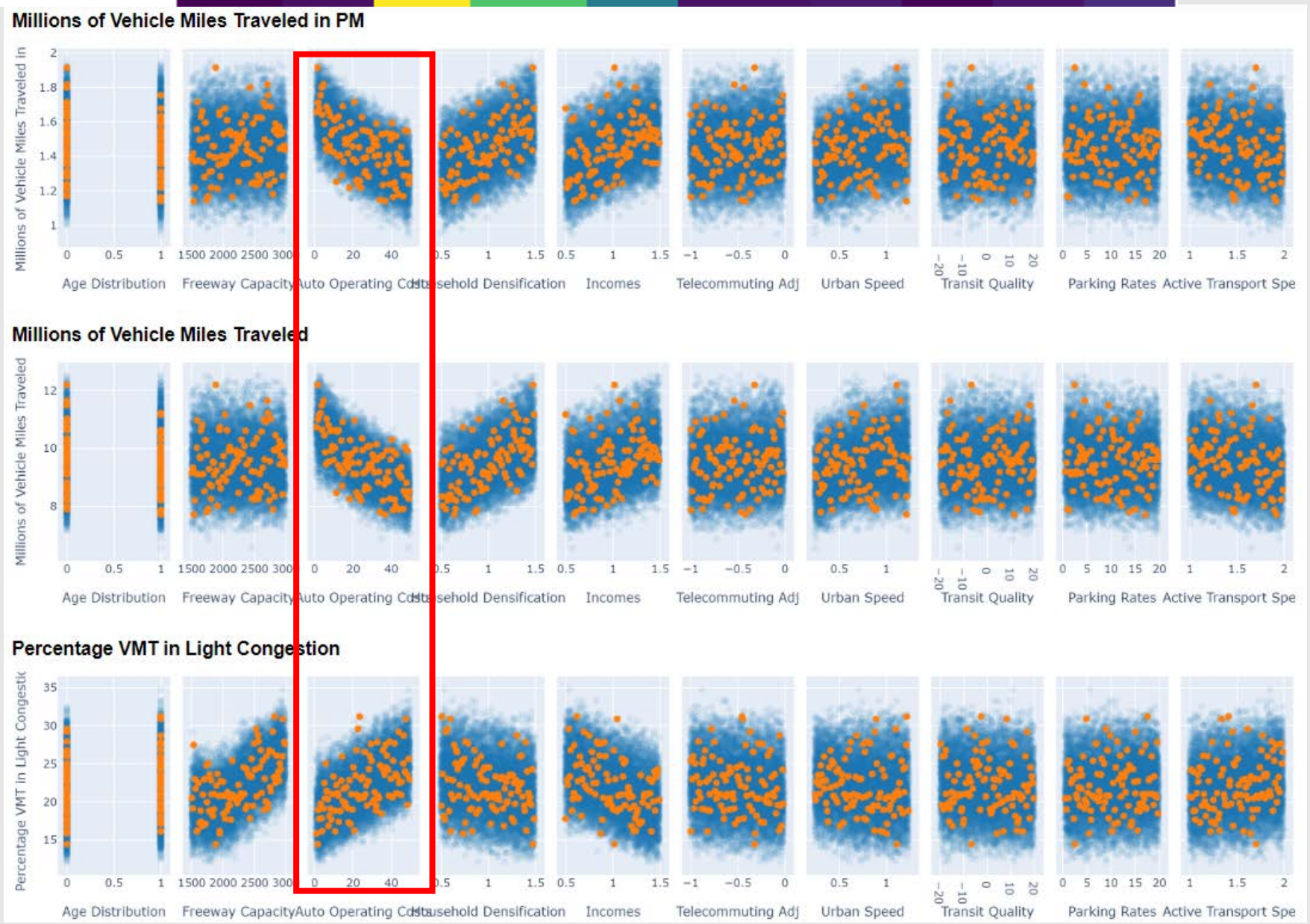
- ptype: exogenous uncertainty
- desc: Change vehicle fuel cost
- dtype: real
- default: 12.4
- min: 1.0 # auto operating cost is what the user sees not actual costs, so a low cost could be subsidized by ad-rev, also home solar power…
- max: **50.0** # max represents higher tax scenarios and carbon fees and PAYD
- **Also assumed to cover value of travel time and road use charges**

- Measures: Overall VMT (assuming proxy for GhG)

	Auto Operating Costs
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0482821
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0493246
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0571037
Bike and Walk Mode Share	0.103598
Transit with PNR and KNR Mode Share	0.0985202
Millions of Person Miles Traveled	0.277401
Millions of Vehicle Miles Traveled in PM	0.215353
Millions of Vehicle Miles Traveled	0.251724
Percentage VMT in Light Congestion	0.201634
Percentage VMT Below 30mph	0.0560773
Millions of VMT for Households Below 25k	0.148943
Thousands of Vehicle Hours Traveled in PM	0.092757
Thousands of Vehicle Hours Traveled	0.0870913
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.107273
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.205628
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.231316
Number of Autos Owned Per Household	0.0344932
Percent of Non-Mandatory Tours	0.0278261

	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Millions of Vehicle Miles Traveled	0.0498665	0.058043	0.251724	0.196376	0.133795	0.058649	0.0627319	0.0512195	0.0616796	0.0759166

Measures:
Overall VMT



	Auto Operating Costs
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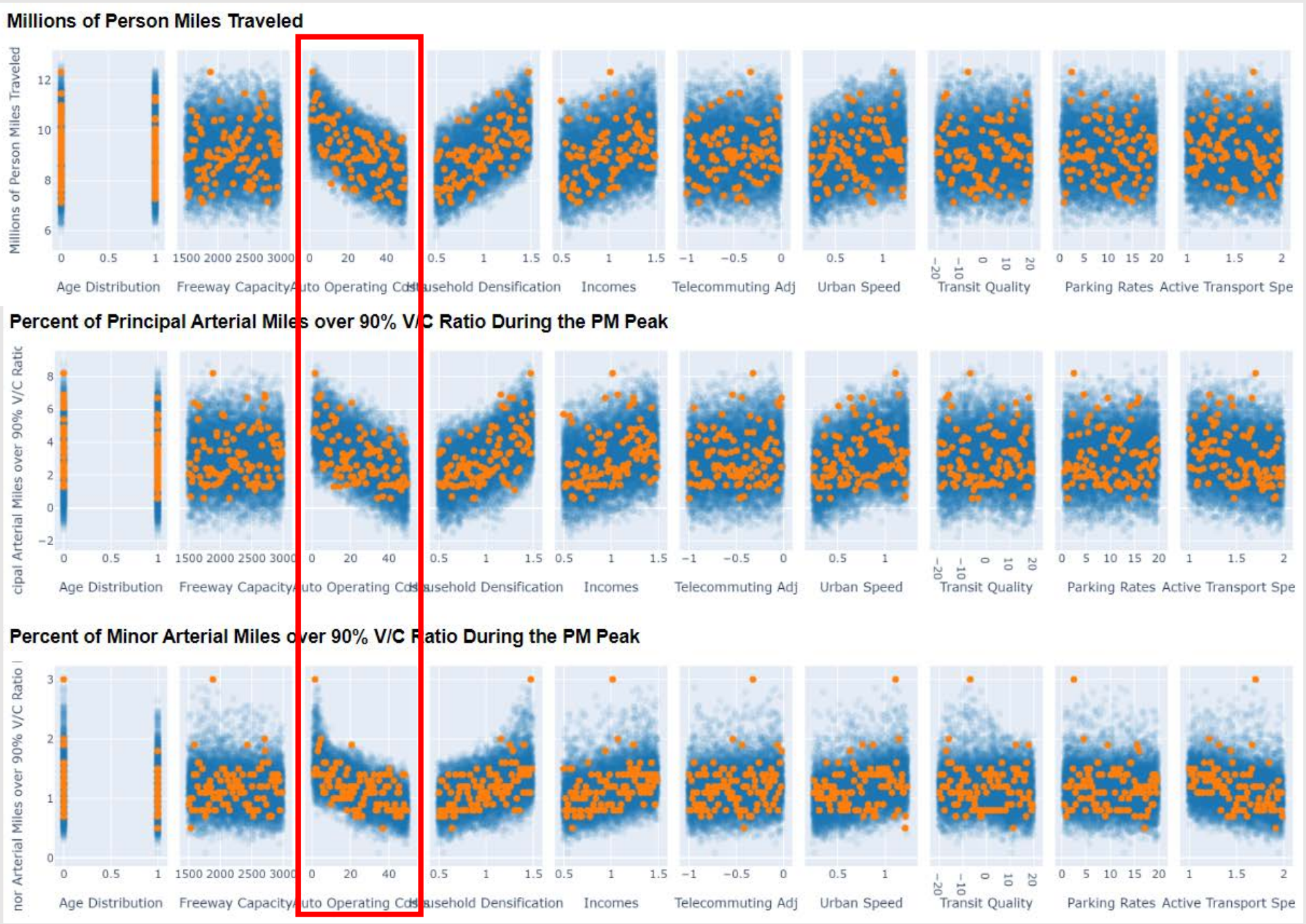
Number of Autos Owned Per Household	0.0344932
Percent of Non-Mandatory Tours	0.0278261



Personal Income

Goal - Equity

- ptype: exogenous uncertainty
- desc: How have incomes (purchasing power) changed moving into the future
- dtype: real
- default: 1.0
- min: 0.5 x current income
- Max 1.5 x current income

- Measures – unclear how best to monitor

Easier than to try to model the overall economic conditions (jobs, job type, occupation, household mix…)

	Auto Operating Costs	Household Densification	Incomes
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0482821	0.0427327	0.0394827
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0493246	0.0442336	0.0408537
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0571037	0.0489444	0.0496779
Bike and Walk Mode Share	0.103598	0.219507	0.0976348
Transit with PNR and KNR Mode Share	0.0985202	0.102784	0.0630194
Millions of Person Miles Traveled	0.277401	0.253783	0.106957
Millions of Vehicle Miles Traveled in PM	0.215353	0.210532	0.136135
Millions of Vehicle Miles Traveled	0.251724	0.196376	0.133795
Percentage VMT in Light Congestion	0.201634	0.0908841	0.128056
Percentage VMT Below 30mph	0.0560773	0.0551734	0.036801
Millions of VMT for Households Below 25k	0.148943	0.080555	0.450928
Thousands of Vehicle Hours Traveled in PM	0.092757	0.0960732	0.0807504
Thousands of Vehicle Hours Traveled	0.0870913	0.0970584	0.0626658
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.107273	0.0619916	0.0821684
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.205628	0.208003	0.115218
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.231316	0.165513	0.120517
Number of Autos Owned Per Household	0.0344932	0.354303	0.259628
Percent of Non-Mandatory Tours	0.0278261	0.030058	0.0737975

	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Millions of VMT for Households Below 25k	0.0437598	0.0403332	0.148943	0.080555	0.450928	0.041935	0.0470797	0.0570167	0.0420312	0.0474184

Household Densification Goal - Livability

- ptype: exogenous uncertainty
- desc: Shifting Households closer to or father away from urban cores to represent different land use scenarios
- dtype: real
- default: 1.0
- min: 0.5 (half the distance to the urban core)
- max: 1.5 (1.5x farther from the core)

- Measures?:

VMT for Low Income, VMT Overall

	Auto Operating Costs	Household Densification	Incomes
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0482821	0.0427327	0.0394827
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0493246	0.0442336	0.0408537
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0571037	0.0489444	0.0496779
Bike and Walk Mode Share	0.103598	0.219507	0.0976348
Transit with PNR and KNR Mode Share	0.0985202	0.102784	0.0630194
Millions of Person Miles Traveled	0.277401	0.253783	0.106957
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Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.107273	0.0619916	0.0821684
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.205628	0.208003	0.115218
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.231316	0.165513	0.120517
Number of Autos Owned Per Household	0.0344932	0.354303	0.259628
Percent of Non-Mandatory Tours	0.0278261	0.030058	0.0737975

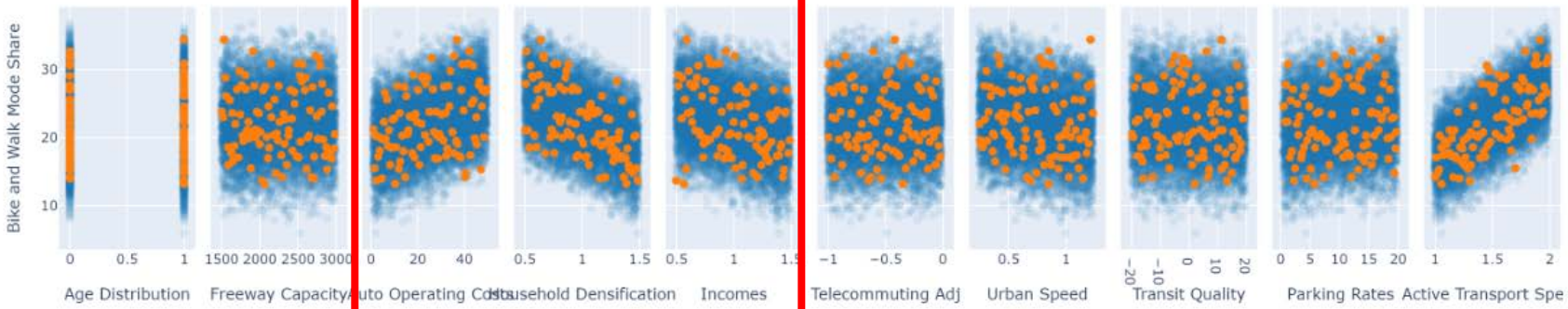
	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Millions of Vehicle Miles Traveled	0.0498665	0.058043	0.251724	0.196376	0.133795	0.058649	0.0627319	0.0512195	0.0616796	0.0759166
Millions of VMT for Households Below 25k	0.0437598	0.0403332	0.148943	0.080555	0.450928	0.041935	0.0470797	0.0570167	0.0420312	0.0474184

Measures?: VMT for Low Income, VMT Overall

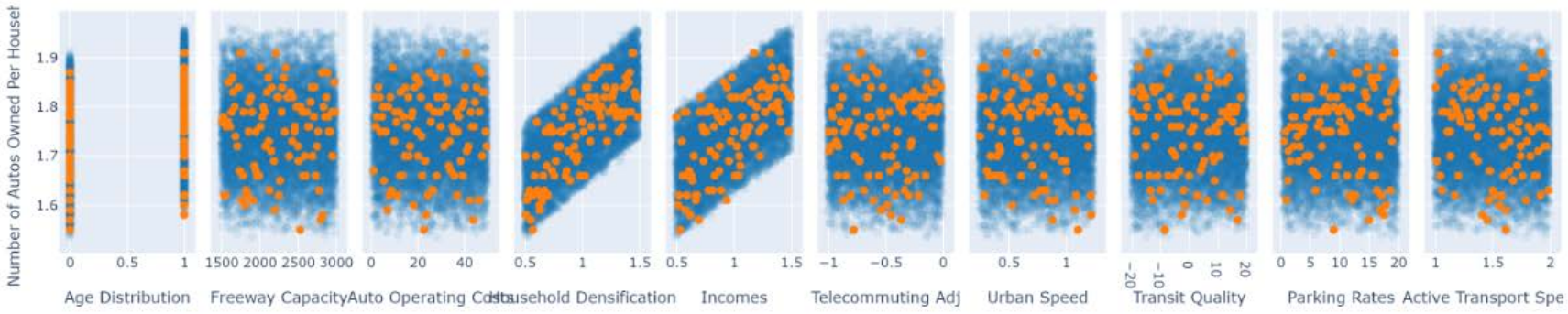
	Auto Operating Costs	Household Densification	Incomes
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0482821	0.0427327	0.0394827
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0493246	0.0442336	0.0408537
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0571037	0.0489444	0.0496779
Bike and Walk Mode Share	0.103598	0.219507	0.0976348
Transit with PNR and KNR Mode Share	0.0985202	0.102784	0.0630194
Millions of Person Miles Traveled	0.277401	0.253783	0.106957
Millions of Vehicle Miles Traveled in PM	0.215353	0.210532	0.136135
Millions of Vehicle Miles Traveled	0.251724	0.196376	0.133795
Percentage VMT in Light Congestion	0.201634	0.0908841	0.128056
Percentage VMT Below 30mph	0.0560773	0.0551734	0.036801
Millions of VMT for Households Below 25k	0.148943	0.080555	0.450928
Thousands of Vehicle Hours Traveled in PM	0.092757	0.0960732	0.0807504
Thousands of Vehicle Hours Traveled	0.0870913	0.0970584	0.0626658
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.107273	0.0619916	0.0821684
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.205628	0.208003	0.115218
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.231316	0.165513	0.120517
Number of Autos Owned Per Household	0.0344932	0.354303	0.259628
Percent of Non-Mandatory Tours	0.0278261	0.030058	0.0737975

	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Bike and Walk Mode Share	0.033724	0.0423424	0.103598	0.219507	0.0976348	0.0475395	0.060642	0.0449326	0.0615405	0.288539
Number of Autos Owned Per Household	0.0564055	0.0409718	0.0344932	0.354303	0.259628	0.0566757	0.0476873	0.0450454	0.0512366	0.0535528

Bike and Walk Mode Share



Number of Autos Owned Per Household



Age Distribution

- ptype: exogenous uncertainty
- desc: Two populations indicating whether the population ages or not.
- dtype: boolean
- default: False (projected older)

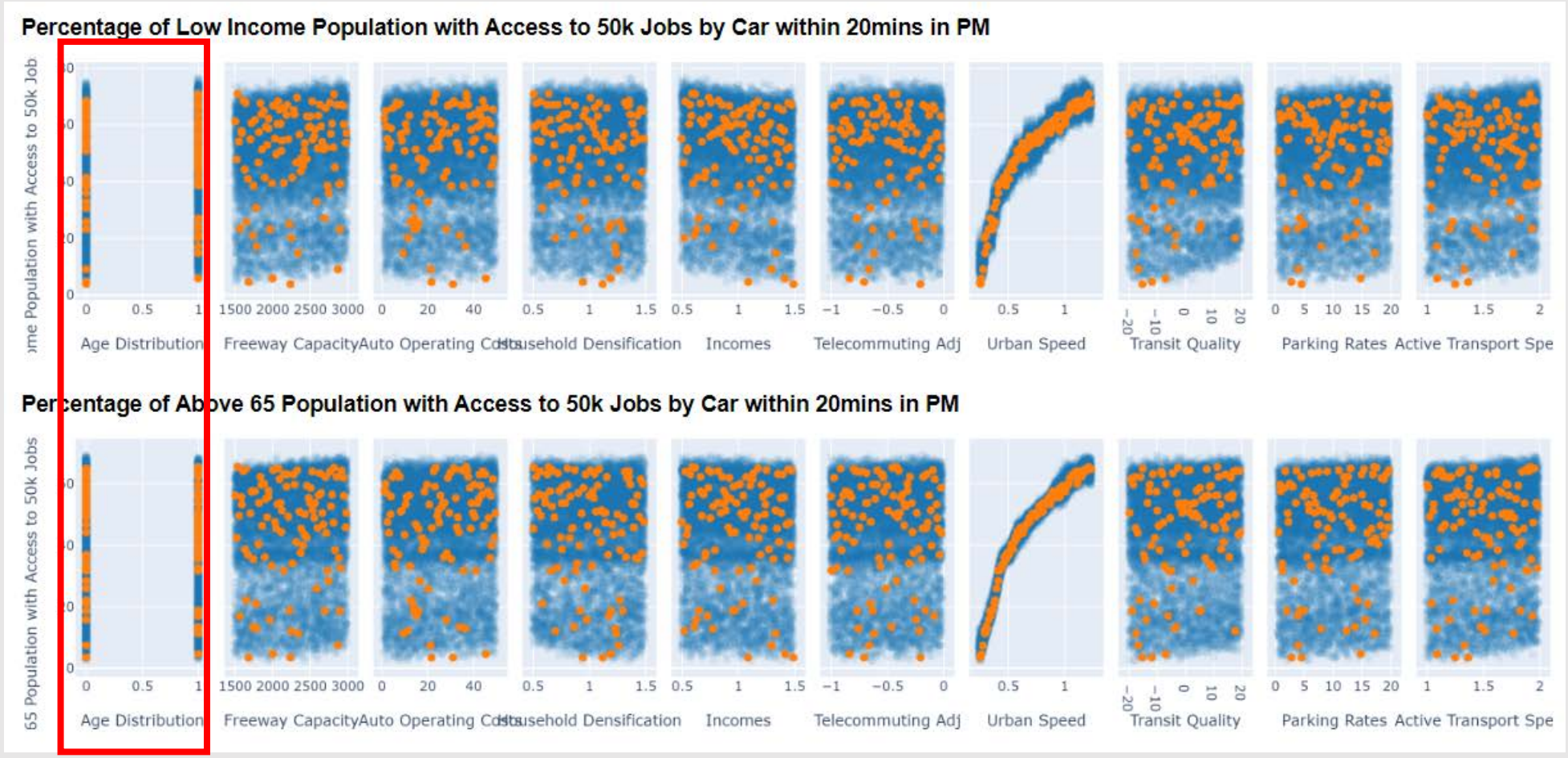
- Measures:

Accessibility by Low Income and by Older Populations

The population is anticipated to age (get older on average), but what if climate migration pushed the demographics younger – like today.

	Age Distribution
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0257042
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0234979
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0345267
Bike and Walk Mode Share	0.033724
Transit with PNR and KNR Mode Share	0.0518717
Millions of Person Miles Traveled	0.0299699
Millions of Vehicle Miles Traveled in PM	0.053534
Millions of Vehicle Miles Traveled	0.0498665
Percentage VMT in Light Congestion	0.0364048
Percentage VMT Below 30mph	0.0502436
Millions of VMT for Households Below 25k	0.0437598
Thousands of Vehicle Hours Traveled in PM	0.0335604
Thousands of Vehicle Hours Traveled	0.0322245
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.0397044
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.0497205
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.0428661
Number of Autos Owned Per Household	0.0564055
Percent of Non-Mandatory Tours	0.599835

	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0234979	0.0499328	0.0493246	0.0442336	0.0408537	0.040682	0.596777	0.0649377	0.0433008	0.0464599
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0345267	0.0474496	0.0571037	0.0489444	0.0496779	0.0508438	0.549025	0.0687977	0.0483799	0.045251



Measures - Accessibility by Low Income and by Older Populations

Telecommuting Adjustment

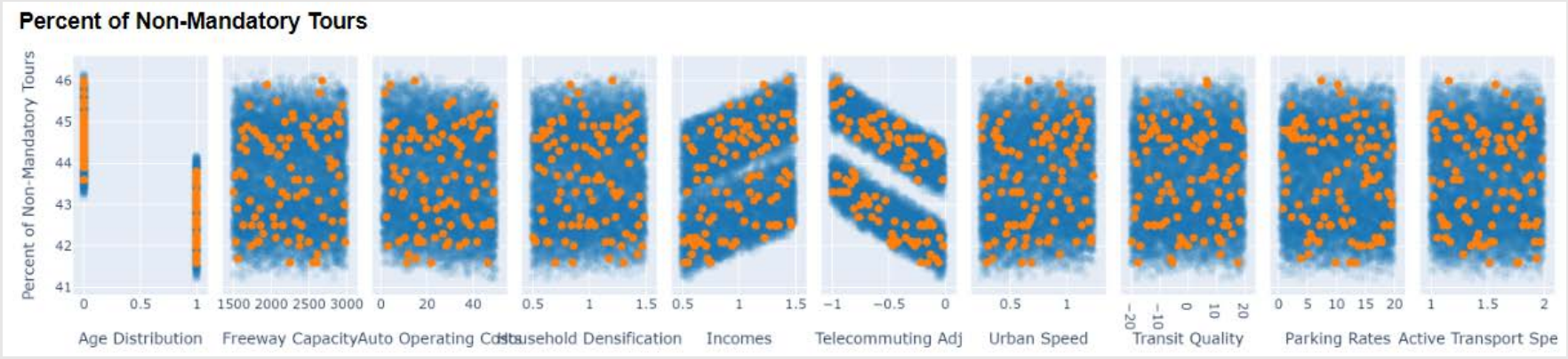
Goal – None, just an extra COVID test

- ptype: exogenous uncertainty
- desc: How might the amount of Telecommuting change in the future
- dtype: real
- default: -0.23
- min: -1.0
- max: 0.0

Description	Filter	Formula for variable	Index	Alt1
				Mandatory
Alternative Specific Constant Adjustment for Full-time worker	fullTimeWorkerA	1		-0.230093

	Age Distribution	Telecommuting Adj
Percentage of Population with Access to 50k Jobs by Car within 20mins in PM	0.0257042	0.0469136
Percentage of Low Income Population with Access to 50k Jobs by Car within 20mins in PM	0.0234979	0.040682
Percentage of Above 65 Population with Access to 50k Jobs by Car within 20mins in PM	0.0345267	0.0508438
Bike and Walk Mode Share	0.033724	0.0475395
Transit with PNR and KNR Mode Share	0.0518717	0.0621766
Millions of Person Miles Traveled	0.0299699	0.0526466
Millions of Vehicle Miles Traveled in PM	0.053534	0.056859
Millions of Vehicle Miles Traveled	0.0498665	0.058649
Percentage VMT in Light Congestion	0.0364048	0.0505795
Percentage VMT Below 30mph	0.0502436	0.0475183
Millions of VMT for Households Below 25k	0.0437598	0.041935
Thousands of Vehicle Hours Traveled in PM	0.0335604	0.0481221
Thousands of Vehicle Hours Traveled	0.0322245	0.0380097
Percent of Interstate Miles over 90% V/C Ratio During the PM Peak	0.0397044	0.0603525
Percent of Principal Arterial Miles over 90% V/C Ratio During the PM Peak	0.0497205	0.0526535
Percent of Minor Arterial Miles over 90% V/C Ratio During the PM Peak	0.0428661	0.058904
Number of Autos Owned Per Household	0.0564055	0.0566757
Percent of Non-Mandatory Tours	0.599835	0.102413

	Age Distribution	Freeway Capacity	Auto Operating Costs	Household Densification	Incomes	Telecommuting Adj	Urban Speed	Transit Quality	Parking Rates	Active Transport Speed
Percent of Non-Mandatory Tours	0.599835	0.0320252	0.0278261	0.030058	0.0737975	0.102413	0.0391967	0.0298901	0.0332597	0.0316986



Measure would need to be changed to really see how Telecommuting was impacting trips, but from other measures it seems like the telecommuting adjustment is not having much overall impact, and the modeling approach should likely be reviewed and improved.