Gen3 Model Development Project Update

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TPB Travel Forecasting Subcomm.

November 18, 2022

Topics

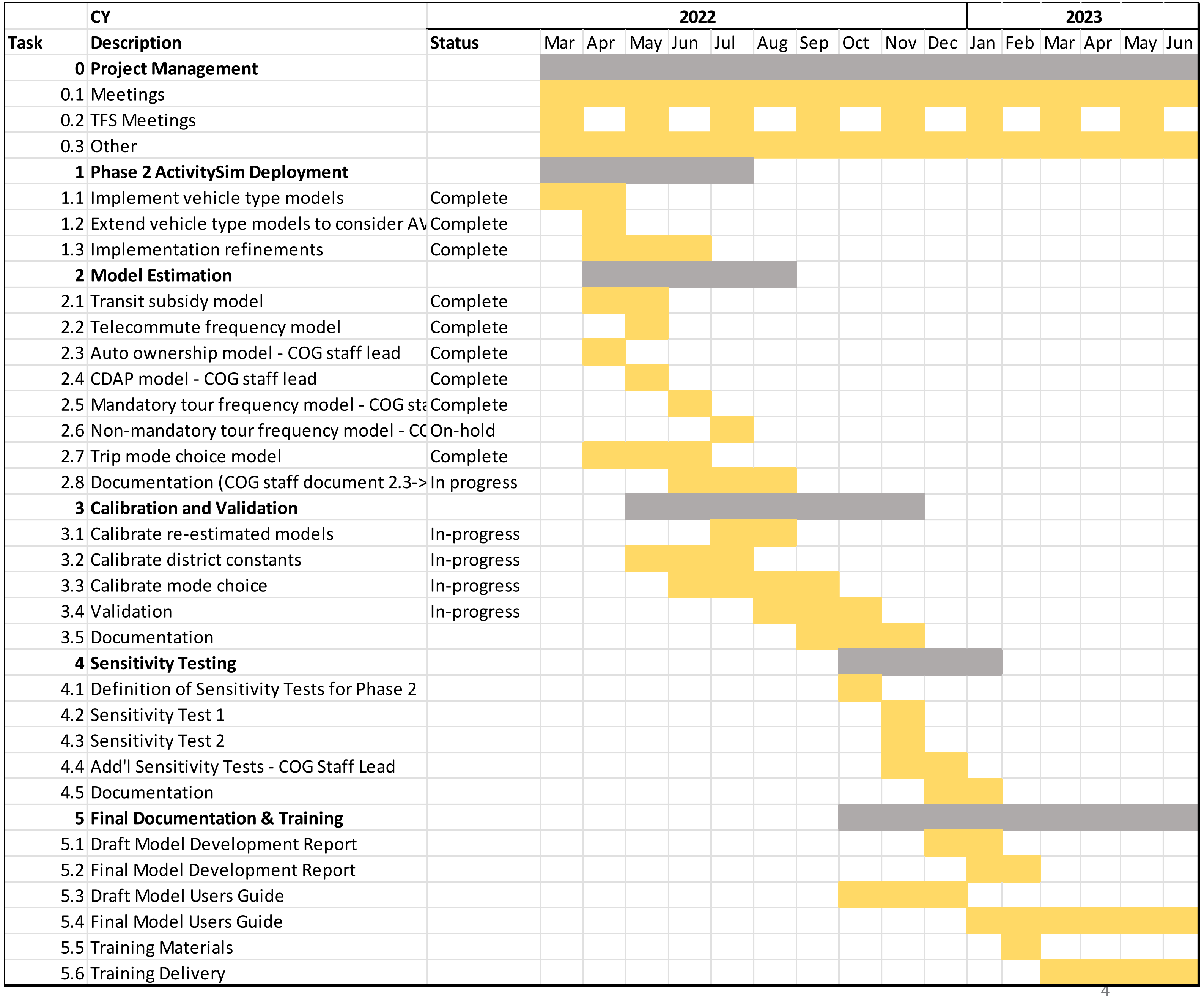
- Schedule update
- Model calibration update
- ActivitySim mandatory tour location enhancement

Gen3 Model Development Project Update

Schedule Update

Schedule Update

- Phase 2 model system implemented
- Phase 2 models estimated
- Currently in calibration; about 2 months behind schedule but catching up quickly



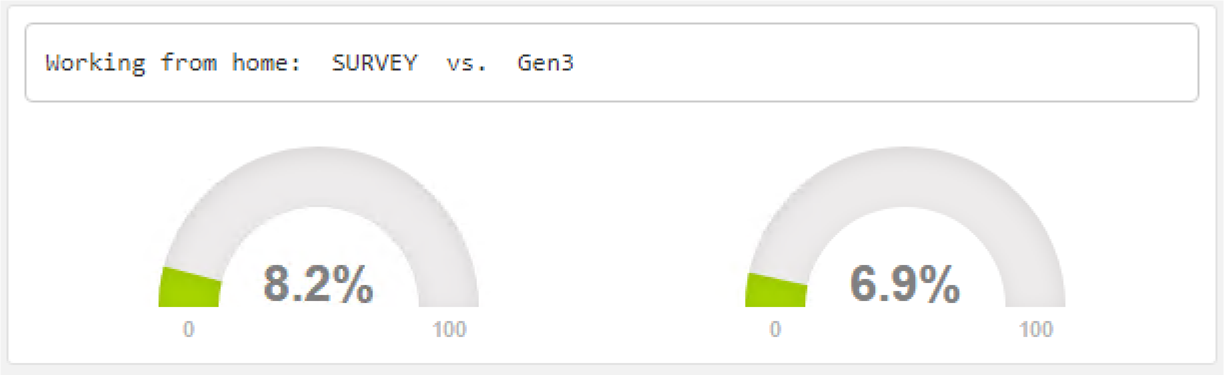
	CY		2022										2023					
Task	Description	Status	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
0	**Project Management**		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
0.1	Meetings		🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
0.2	TFS Meetings		🟨		🟨		🟨		🟨		🟨		🟨		🟨		🟨	
0.3	Other		🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
1	**Phase 2 ActivitySim Deployment**		▨	▨	▨	▨	▨											
1.1	Implement vehicle type models	Complete	🟨	🟨														
1.2	Extend vehicle type models to consider AV	Complete		🟨														
1.3	Implementation refinements	Complete		🟨	🟨	🟨												
2	**Model Estimation**			▨	▨	▨	▨	▨										
2.1	Transit subsidy model	Complete		🟨	🟨													
2.2	Telecommute frequency model	Complete			🟨													
2.3	Auto ownership model - COG staff lead	Complete		🟨														
2.4	CDAP model - COG staff lead	Complete			🟨													
2.5	Mandatory tour frequency model - COG sta	Complete				🟨												
2.6	Non-mandatory tour frequency model - C	On-hold					🟨											
2.7	Trip mode choice model	Complete		🟨	🟨	🟨												
2.8	Documentation (COG staff document 2.3->	In progress				🟨	🟨	🟨										
3	**Calibration and Validation**				▨	▨	▨	▨	▨	▨	▨							
3.1	Calibrate re-estimated models	In-progress					🟨	🟨										
3.2	Calibrate district constants	In-progress			🟨	🟨	🟨											
3.3	Calibrate mode choice	In-progress				🟨	🟨	🟨	🟨									
3.4	Validation	In-progress						🟨	🟨	🟨								
3.5	Documentation								🟨	🟨	🟨							
4	**Sensitivity Testing**									▨	▨	▨	▨					
4.1	Definition of Sensitivity Tests for Phase 2									🟨								
4.2	Sensitivity Test 1										🟨							
4.3	Sensitivity Test 2										🟨							
4.4	Add'l Sensitivity Tests - COG Staff Lead										🟨	🟨						
4.5	Documentation											🟨	🟨					
5	**Final Documentation & Training**									▨	▨	▨	▨	▨	▨	▨	▨	▨
5.1	Draft Model Development Report											🟨	🟨					
5.2	Final Model Development Report												🟨	🟨				
5.3	Draft Model Users Guide									🟨	🟨	🟨						
5.4	Final Model Users Guide												🟨	🟨	🟨	🟨	🟨	🟨
5.5	Training Materials													🟨				
5.6	Training Delivery														🟨	🟨	🟨	🟨

Gen3 Model Development Project Update

Model Calibration Update

Work from home and work location choice

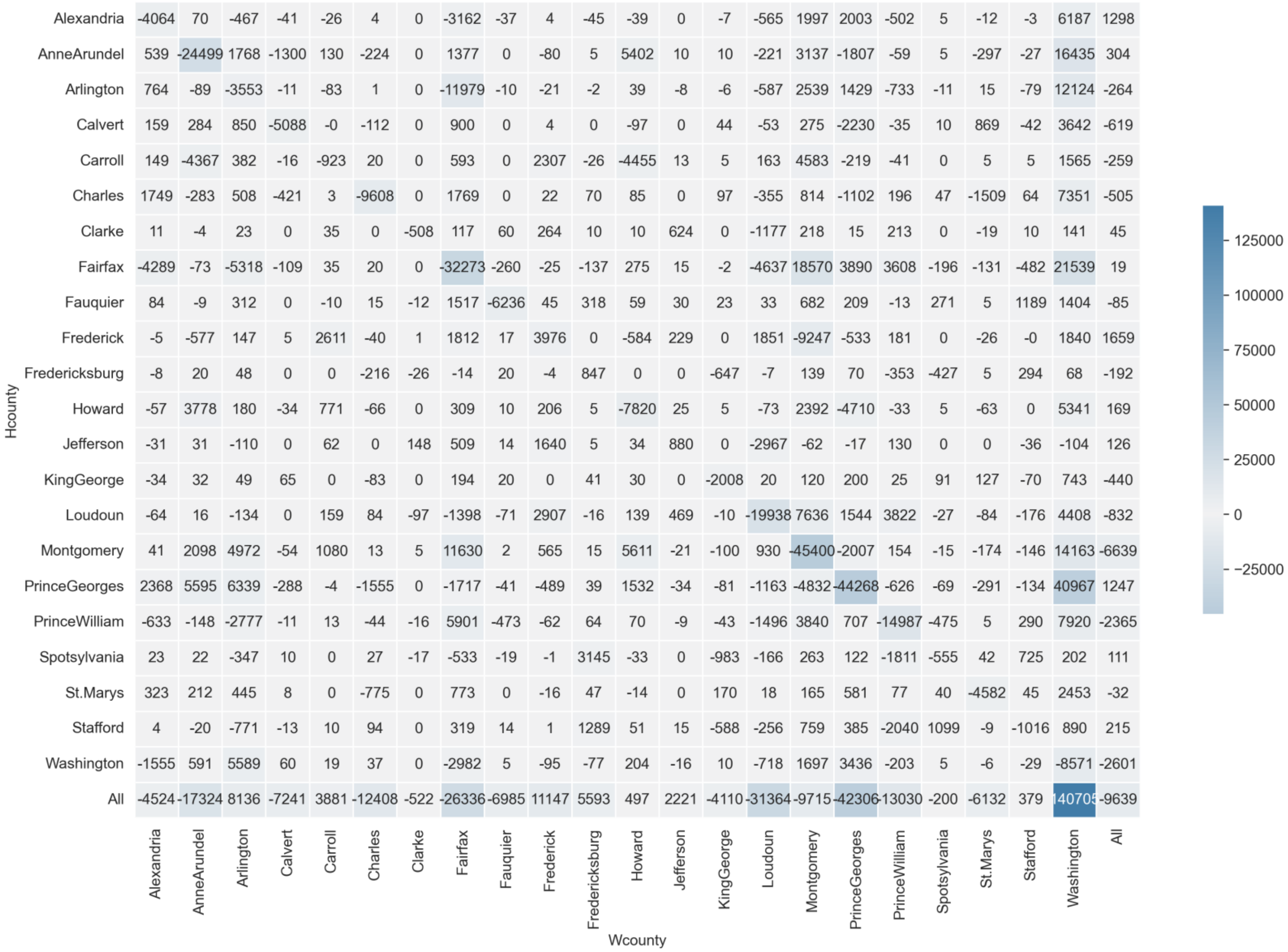
- Work from home model mostly calibrated



Working from home: SURVEY vs. Gen3

- Size terms adjusted to reduce employment for in-commuting workers and workers who work from home
- Jurisdiction level constants calibrated

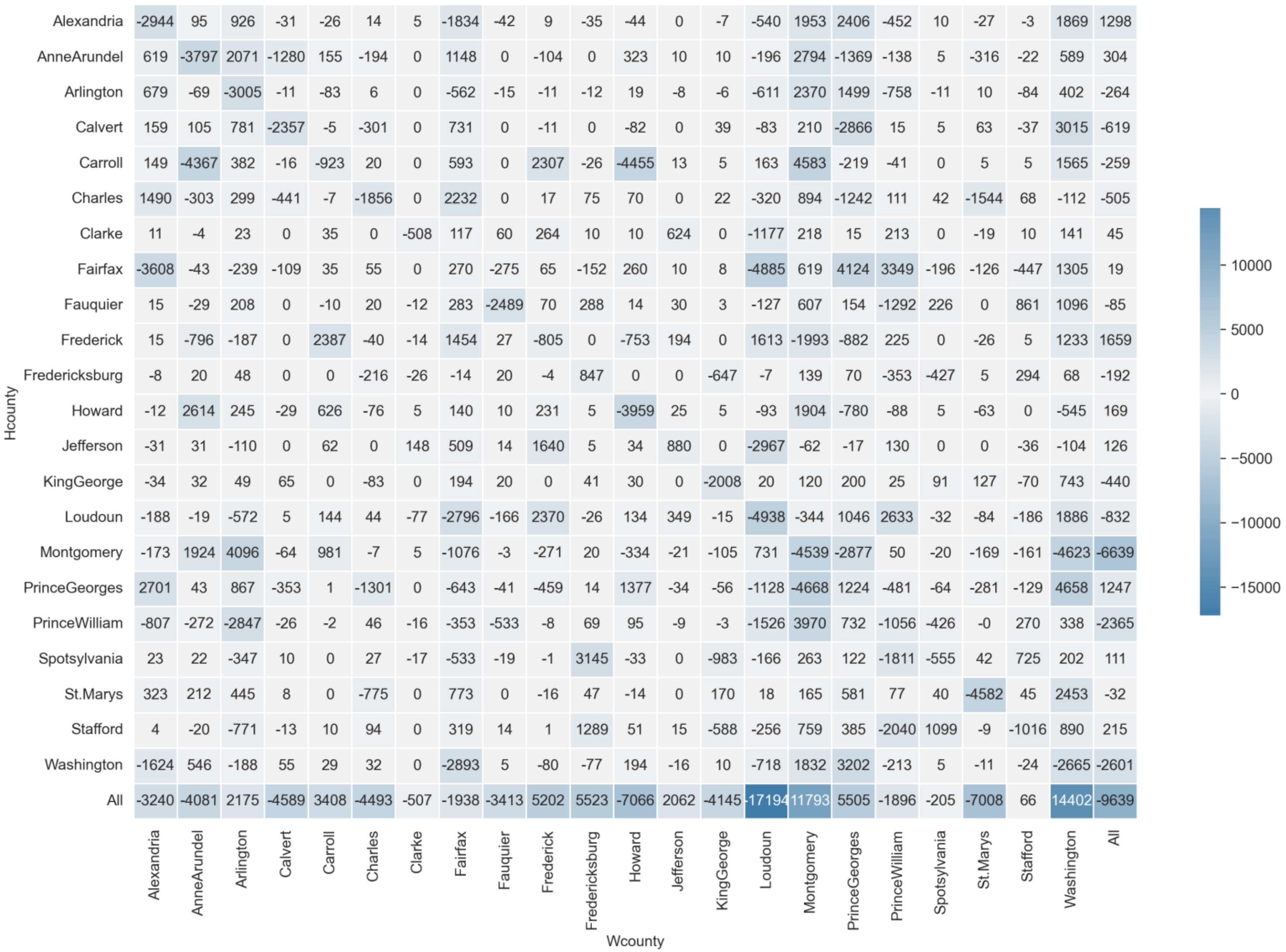
Before calibrating jurisdiction constants



	Alexandria	AnneArundel	Arlington	Calvert	Carroll	Charles	Clarke	Fairfax	Fauquier	Frederick	Fredericksburg	Howard	Jefferson	KingGeorge	Loudoun	Montgomery	PrinceGeorges	PrinceWilliam	Spotsylvania	St.Marys	Stafford	Washington	All
Alexandria	-4064	70	-467	-41	-26	4	0	-3162	-37	4	-45	-39	0	-7	-565	1997	2003	-502	5	-12	-3	6187	1298
AnneArundel	539	-24499	1768	-1300	130	-224	0	1377	0	-80	5	5402	10	10	-221	3137	-1807	-59	5	-297	-27	16435	304
Arlington	764	-89	-3553	-11	-83	1	0	-11979	-10	-21	-2	39	-8	-6	-587	2539	1429	-733	-11	15	-79	12124	-264
Calvert	159	284	850	-5088	-0	-112	0	900	0	4	0	-97	0	44	-53	275	-2230	-35	10	869	-42	3642	-619
Carroll	149	-4367	382	-16	-923	20	0	593	0	2307	-26	-4455	13	5	163	4583	-219	-41	0	5	5	1565	-259
Charles	1749	-283	508	-421	3	-9608	0	1769	0	22	70	85	0	97	-355	814	-1102	196	47	-1509	64	7351	-505
Clarke	11	-4	23	0	35	0	-508	117	60	264	10	10	624	0	-1177	218	15	213	0	-19	10	141	45
Fairfax	-4289	-73	-5318	-109	35	20	0	-32273	-260	-25	-137	275	15	-2	-4637	18570	3890	3608	-196	-131	-482	21539	19
Fauquier	84	-9	312	0	-10	15	-12	1517	-6236	45	318	59	30	23	33	682	209	-13	271	5	1189	1404	-85
Frederick	-5	-577	147	5	2611	-40	1	1812	17	3976	0	-584	229	0	1851	-9247	-533	181	0	-26	-0	1840	1659
Fredericksburg	-8	20	48	0	0	-216	-26	-14	20	-4	847	0	0	-647	-7	139	70	-353	-427	5	294	68	-192
Howard	-57	3778	180	-34	771	-66	0	309	10	206	5	-7820	25	5	-73	2392	-4710	-33	5	-63	0	5341	169
Jefferson	-31	31	-110	0	62	0	148	509	14	1640	5	34	880	0	-2967	-62	-17	130	0	0	-36	-104	126
KingGeorge	-34	32	49	65	0	-83	0	194	20	0	41	30	0	-2008	20	120	200	25	91	127	-70	743	-440
Loudoun	-64	16	-134	0	159	84	-97	-1398	-71	2907	-16	139	469	-10	-19938	7636	1544	3822	-27	-84	-176	4408	-832
Montgomery	41	2098	4972	-54	1080	13	5	11630	2	565	15	5611	-21	-100	930	-45400	-2007	154	-15	-174	-146	14163	-6639
PrinceGeorges	2368	5595	6339	-288	-4	-1555	0	-1717	-41	-489	39	1532	-34	-81	-1163	-4832	-44268	-626	-69	-291	-134	40967	1247
PrinceWilliam	-633	-148	-2777	-11	13	-44	-16	5901	-473	-62	64	70	-9	-43	-1496	3840	707	-14987	-475	5	290	7920	-2365
Spotsylvania	23	22	-347	10	0	27	-17	-533	-19	-1	3145	-33	0	-983	-166	263	122	-1811	-555	42	725	202	111
St.Marys	323	212	445	8	0	-775	0	773	0	-16	47	-14	0	170	18	165	581	77	40	-4582	45	2453	-32
Stafford	4	-20	-771	-13	10	94	0	319	14	1	1289	51	15	-588	-256	759	385	-2040	1099	-9	-1016	890	215
Washington	-1555	591	5589	60	19	37	0	-2982	5	-95	-77	204	-16	10	-718	1697	3436	-203	5	-6	-29	-8571	-2601
All	-4524	-17324	8136	-7241	3881	-12408	-522	-26336	-6985	11147	5593	497	2221	-4110	-31364	-9715	-42306	-13030	-200	-6132	379	140705	-9639

After calibrating jurisdiction constants

Note: Target is <5k difference for each jurisdiction OD



	Alexandria	AnneArundel	Arlington	Calvert	Carroll	Charles	Clarke	Fairfax	Fauquier	Frederick	Fredericksburg	Howard	Jefferson	KingGeorge	Loudoun	Montgomery	PrinceGeorges	PrinceWilliam	Spotsylvania	St.Marys	Stafford	Washington	All
Alexandria	-2944	95	926	-31	-26	14	5	-1834	-42	9	-35	-44	0	-7	-540	1953	2406	-452	10	-27	-3	1869	1298
AnneArundel	619	-3797	2071	-1280	155	-194	0	1148	0	-104	0	323	10	10	-196	2794	-1369	-138	5	-316	-22	589	304
Arlington	679	-69	-3005	-11	-83	6	0	-562	-15	-11	-12	19	-8	-6	-611	2370	1499	-758	-11	10	-84	402	-264
Calvert	159	105	781	-2357	-5	-301	0	731	0	-11	0	-82	0	39	-83	210	-2866	15	5	63	-37	3015	-619
Carroll	149	-4367	382	-16	-923	20	0	593	0	2307	-26	-4455	13	5	163	4583	-219	-41	0	5	5	1565	-259
Charles	1490	-303	299	-441	-7	-1856	0	2232	0	17	75	70	0	22	-320	894	-1242	111	42	-1544	68	-112	-505
Clarke	11	-4	23	0	35	0	-508	117	60	264	10	10	624	0	-1177	218	15	213	0	-19	10	141	45
Fairfax	-3608	-43	-239	-109	35	55	0	270	-275	65	-152	260	10	8	-4885	619	4124	3349	-196	-126	-447	1305	19
Fauquier	15	-29	208	0	-10	20	-12	283	-2489	70	288	14	30	3	-127	607	154	-1292	226	0	861	1096	-85
Frederick	15	-796	-187	0	2387	-40	-14	1454	27	-805	0	-753	194	0	1613	-1993	-882	225	0	-26	5	1233	1659
Fredericksburg	-8	20	48	0	0	-216	-26	-14	20	-4	847	0	0	-647	-7	139	70	-353	-427	5	294	68	-192
Howard	-12	2614	245	-29	626	-76	5	140	10	231	5	-3959	25	5	-93	1904	-780	-88	5	-63	0	-545	169
Jefferson	-31	31	-110	0	62	0	148	509	14	1640	5	34	880	0	-2967	-62	-17	130	0	0	-36	-104	126
KingGeorge	-34	32	49	65	0	-83	0	194	20	0	41	30	0	-2008	20	120	200	25	91	127	-70	743	-440
Loudoun	-188	-19	-572	5	144	44	-77	-2796	-166	2370	-26	134	349	-15	-4938	-344	1046	2633	-32	-84	-186	1886	-832
Montgomery	-173	1924	4096	-64	981	-7	5	-1076	-3	-271	20	-334	-21	-105	731	-4539	-2877	50	-20	-169	-161	-4623	-6639
PrinceGeorges	2701	43	867	-353	1	-1301	0	-643	-41	-459	14	1377	-34	-56	-1128	-4668	1224	-481	-64	-281	-129	4658	1247
PrinceWilliam	-807	-272	-2847	-26	-2	46	-16	-353	-533	-8	69	95	-9	-3	-1526	3970	732	-1056	-426	-0	270	338	-2365
Spotsylvania	23	22	-347	10	0	27	-17	-533	-19	-1	3145	-33	0	-983	-166	263	122	-1811	-555	42	725	202	111
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Washington	-1624	546	-188	55	29	32	0	-2893	5	-80	-77	194	-16	10	-718	1832	3202	-213	5	-11	-24	-2665	-2601
All	-3240	-4081	2175	-4589	3408	-4493	-507	-1938	-3413	5202	5523	-7066	2062	-4145	-17194	11793	5505	-1896	-205	-7008	66	14402	-9639

Note: Scale changes.

Was -25k to +125k.

Now +/- 15k

Jurisdiction Level Origin-Destination Constants

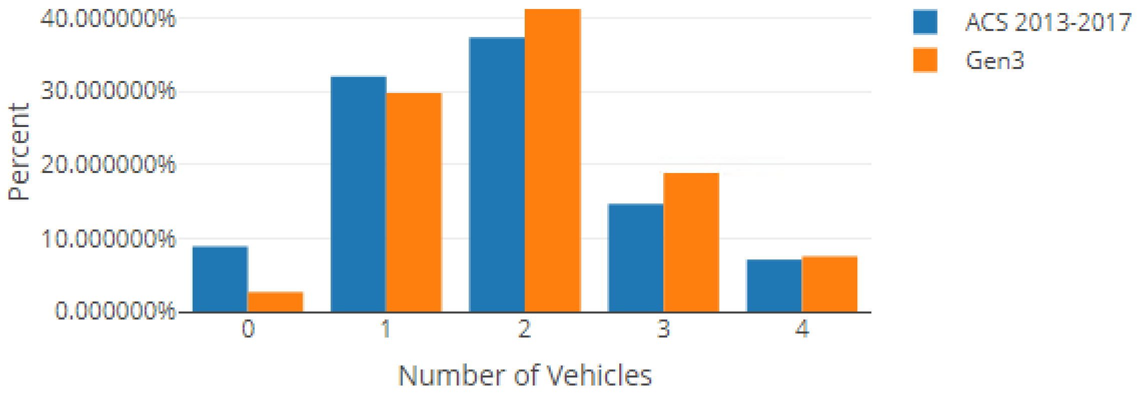
- 34 jurisdiction-level origin-destination (OD) constants

- Minimum constant = -1.0776
- Maximum constant = 0.6687

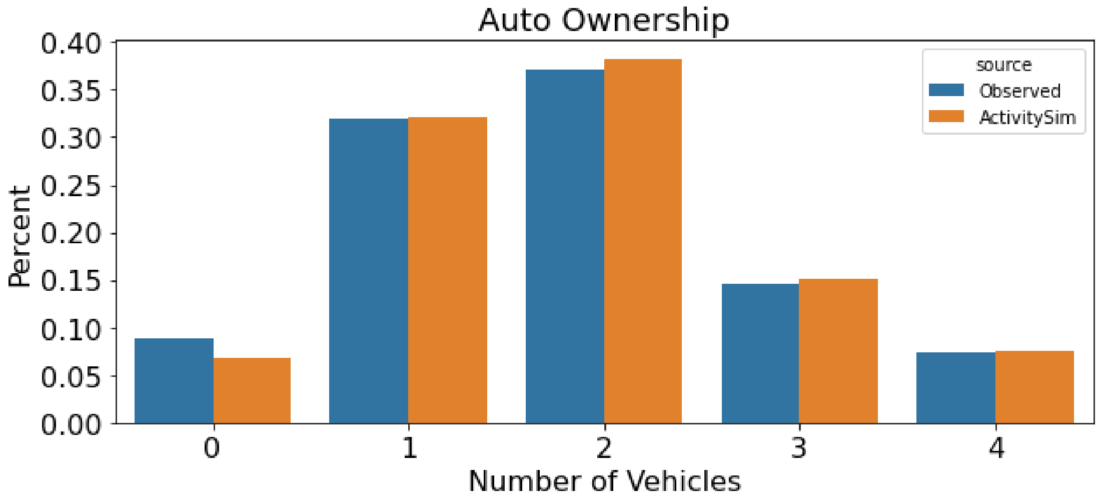
- A constant is added to the destination choice utility equation if the zone OD pair belongs to jurisdiction-level OD pair for which a constant has been calculated.

Residence Jurisdiction	Work Jurisdiction	Constant
Washington	Washington	0.03165
Washington	Arlington	-0.2292
Montgomery	Washington	-0.1119
Montgomery	Montgomery	0.20863
Montgomery	Fairfax	-0.361
Montgomery	Howard	-0.4923
PrinceGeorges	Washington	-0.2448
PrinceGeorges	PrinceGeorges	0.28689
PrinceGeorges	Arlington	-0.2878
PrinceGeorges	AnneArundel	-0.3001
Arlington	Washington	-0.2159
Arlington	Fairfax	0.4332
Alexandria	Washington	-0.205
Fairfax	Washington	-0.205
Fairfax	Montgomery	-0.7743
Fairfax	Arlington	0.10208
Fairfax	Fairfax	0.09414
Loudoun	Montgomery	-1.0776
Loudoun	Fairfax	0.15389
Loudoun	Loudoun	0.34886
PrinceWilliam	Washington	-0.3036
PrinceWilliam	Fairfax	-0.0705
PrinceWilliam	PrinceWilliam	0.14003
Frederick	Montgomery	0.31946
Howard	Washington	-0.3425
Howard	PrinceGeorges	0.28349
Howard	Howard	0.10316
AnneArundel	Washington	-0.5265
AnneArundel	Howard	-0.2065
AnneArundel	AnneArundel	0.14006
Charles	Washington	-0.3846
Charles	Charles	0.36901
Calvert	Calvert	0.31611
Fauquier	Fauquier	0.6687

Auto Ownership Calibration

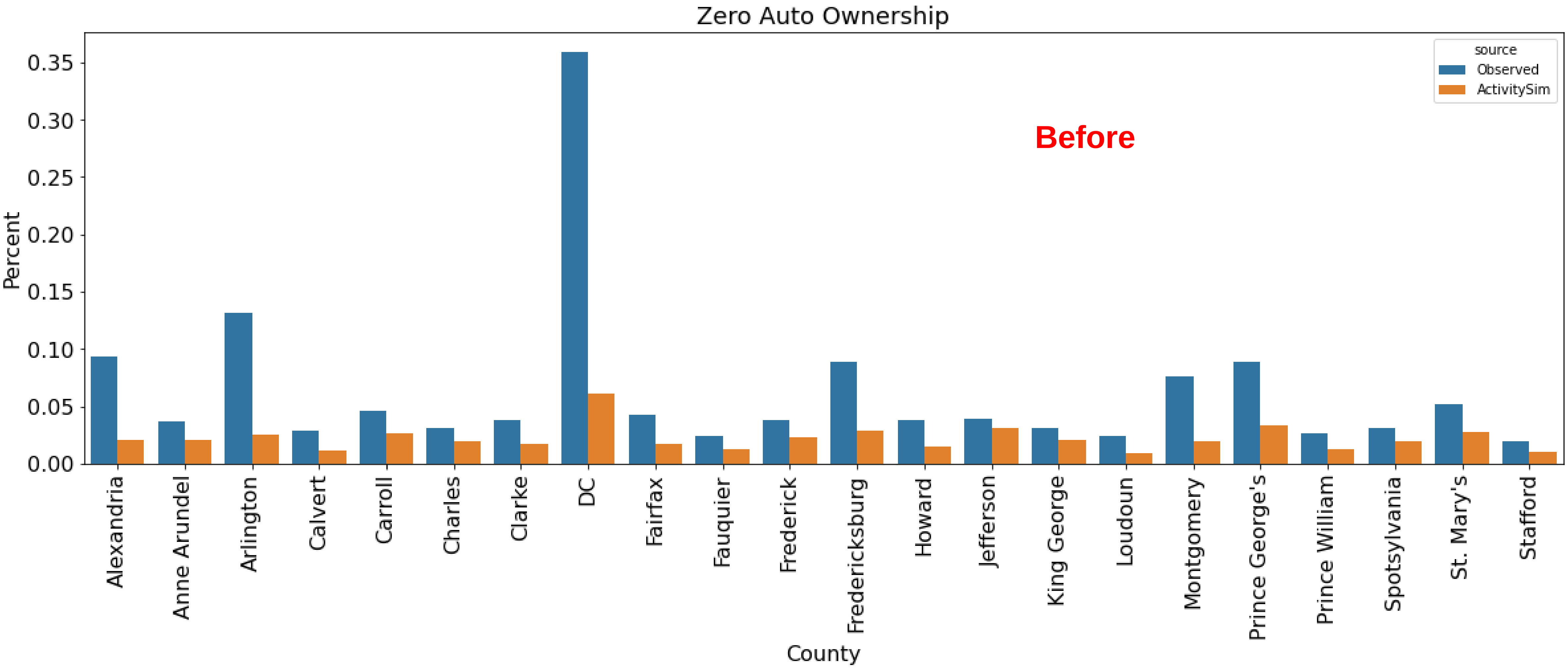


Before

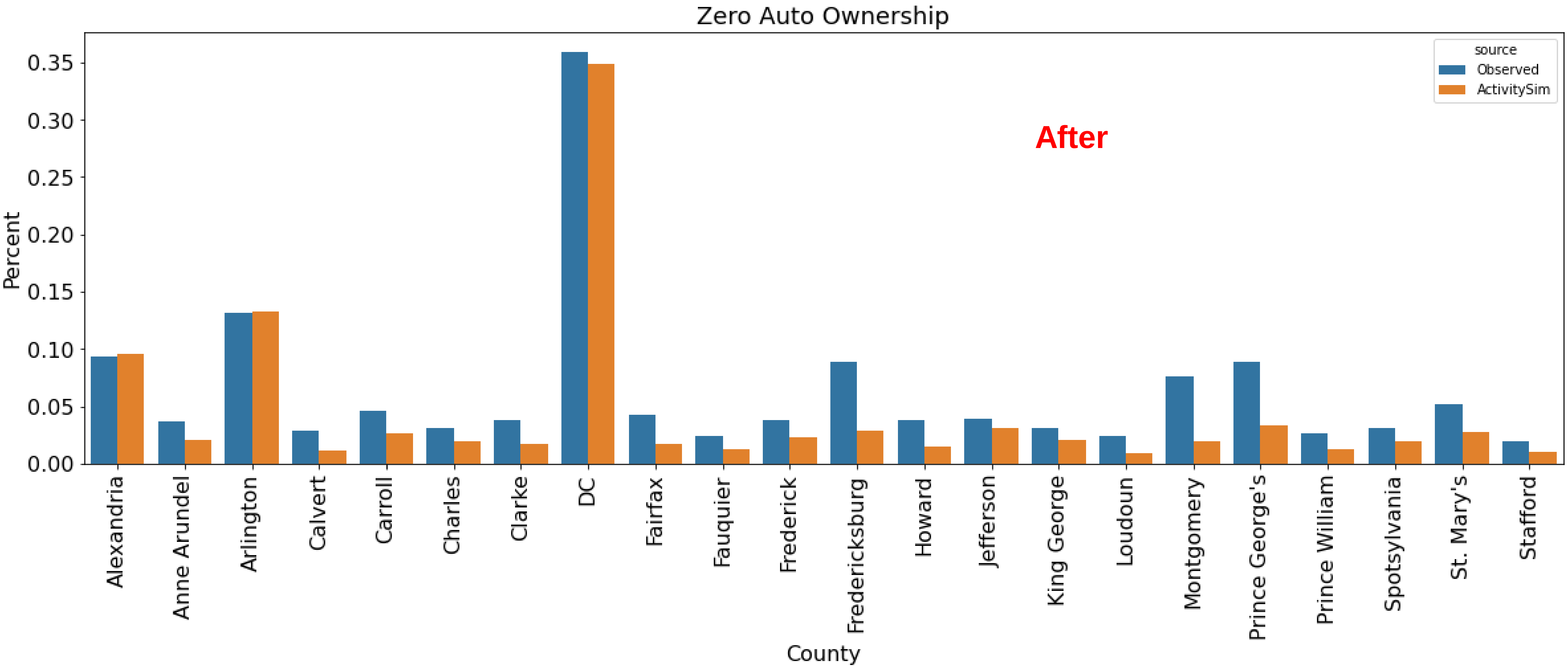


After

Auto Ownership Calibration



Auto Ownership Calibration



Auto Ownership Constants

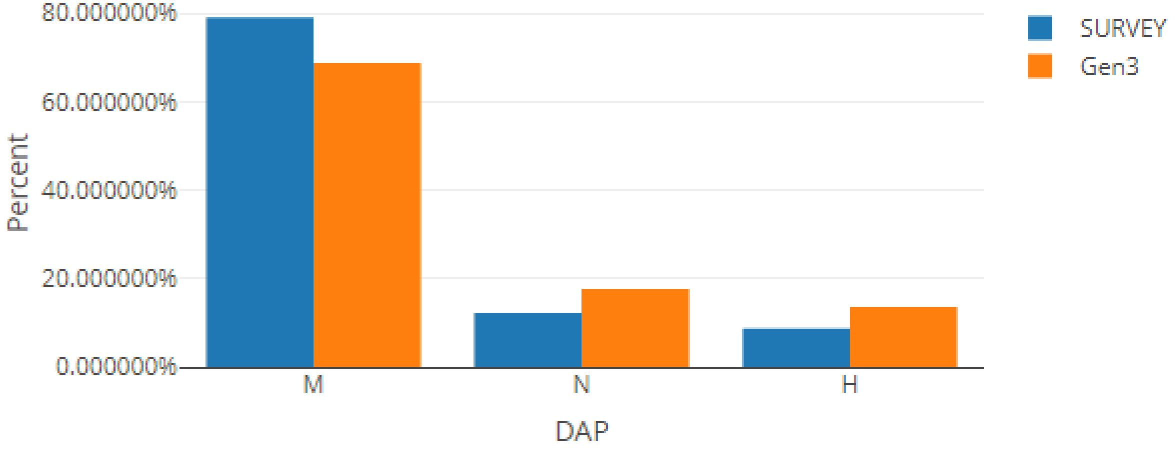
	0	1	2	3	4+
Region		1.25	-0.79	-3.19	-4.67
Alexandria	3.12	1.33			
Arlington	3.53	1.33			
DC	4.93	2.05			

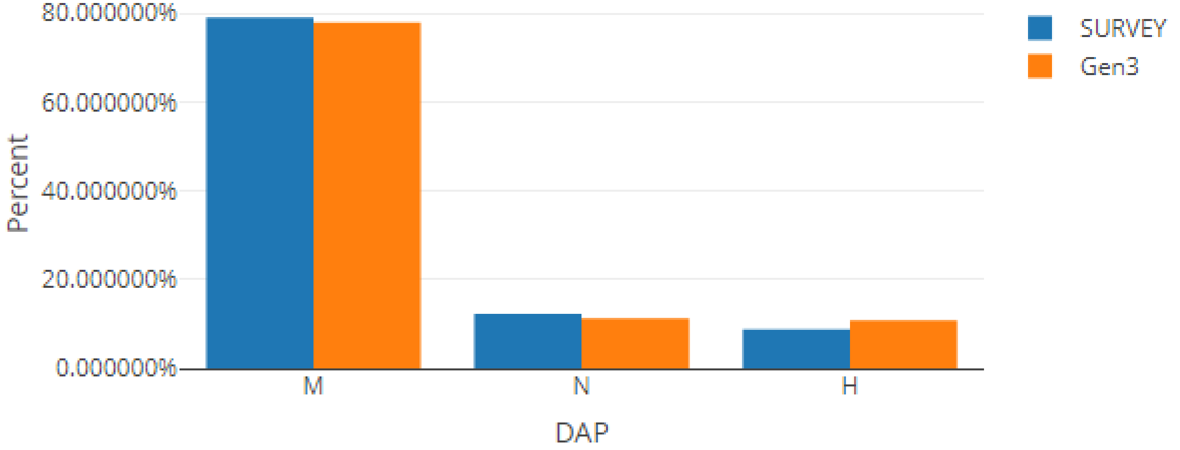
- Jurisdiction-level auto ownership constants added for three key jurisdictions – Alexandria, Arlington, and DC – where 0 and 1 household autos were significantly under-estimated by the model, likely due to non-included attributes or non-linear relationships in density or transit accessibility effects not considered by the model.
- Estimating observed levels of auto ownership in these three key jurisdictions is important to accurately model non-motorized travel and transit ridership

Coordinated daily activity model calibration

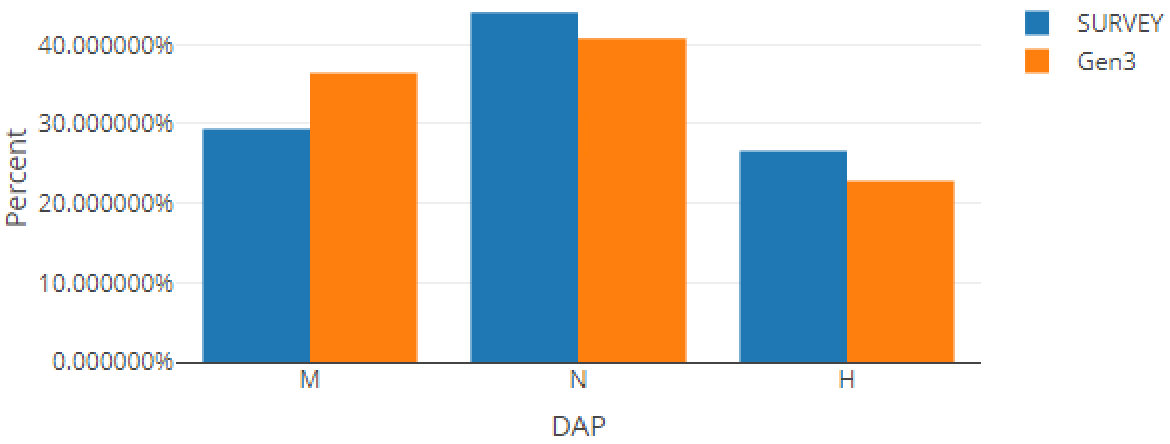
Mandatory (M): At least one work or school activity; Non-mandatory (N): At least one non-work/school activity; Home (H): Stayed home or out of region

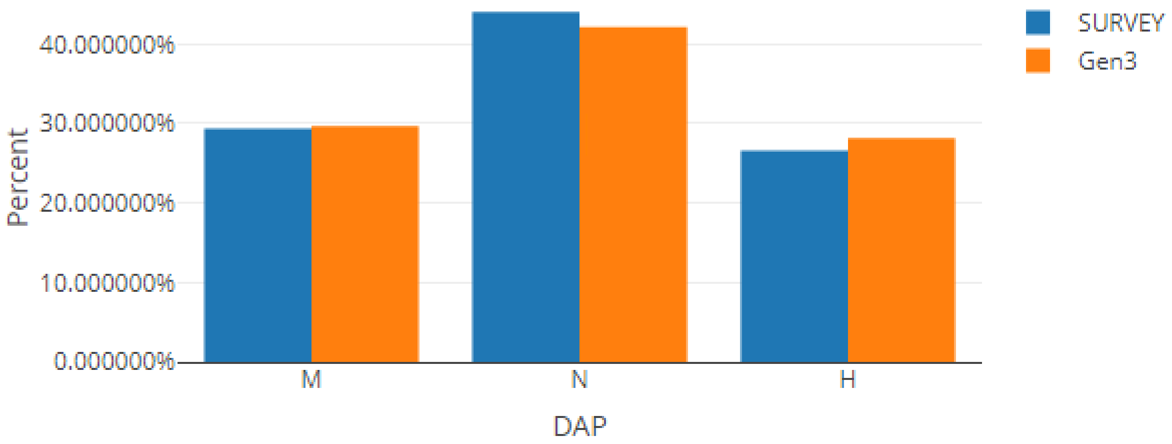
Full-Time Workers





Part-Time Workers



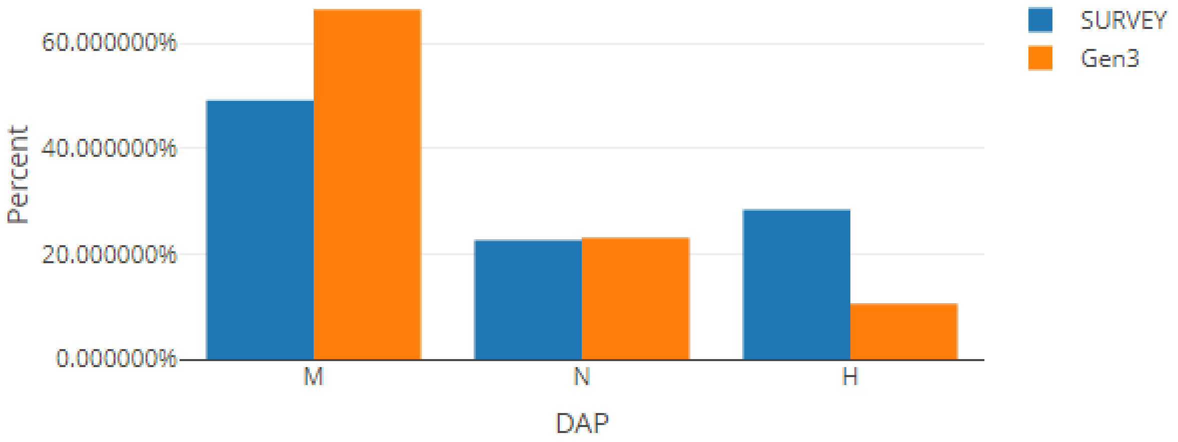


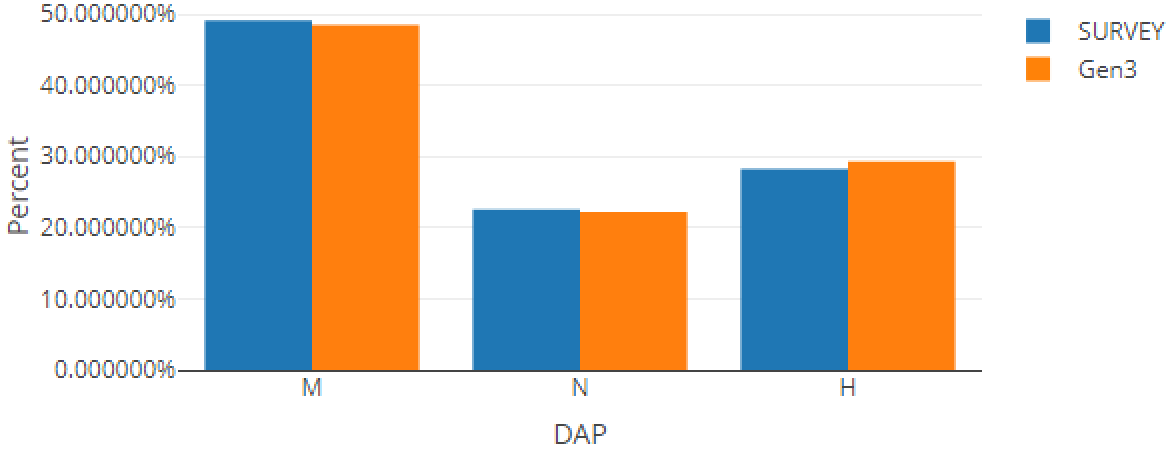
Before

After

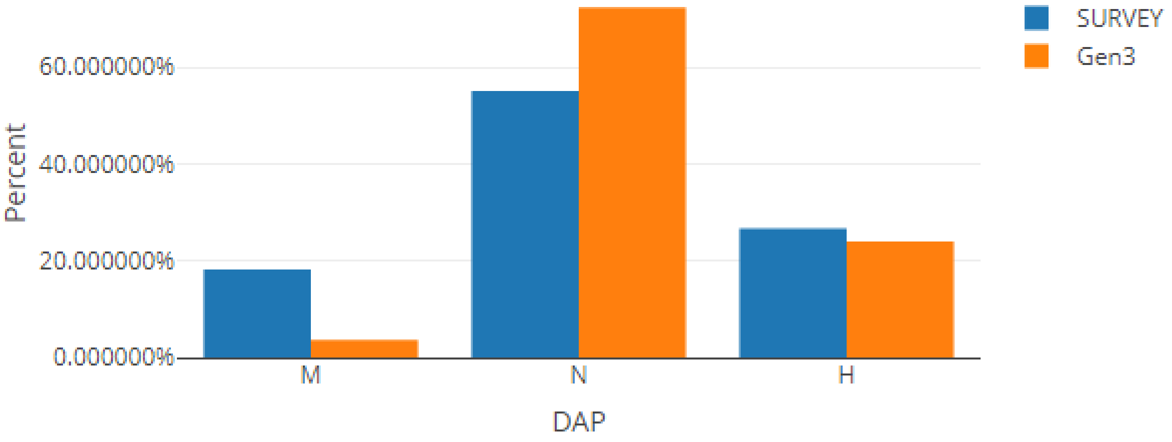
Coordinated daily activity model calibration

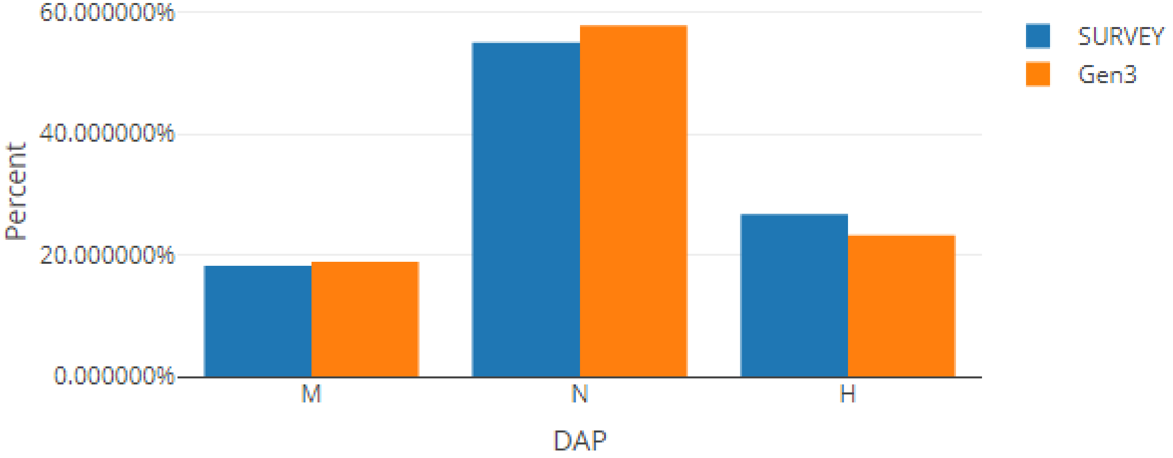
University Students





Preschool Child





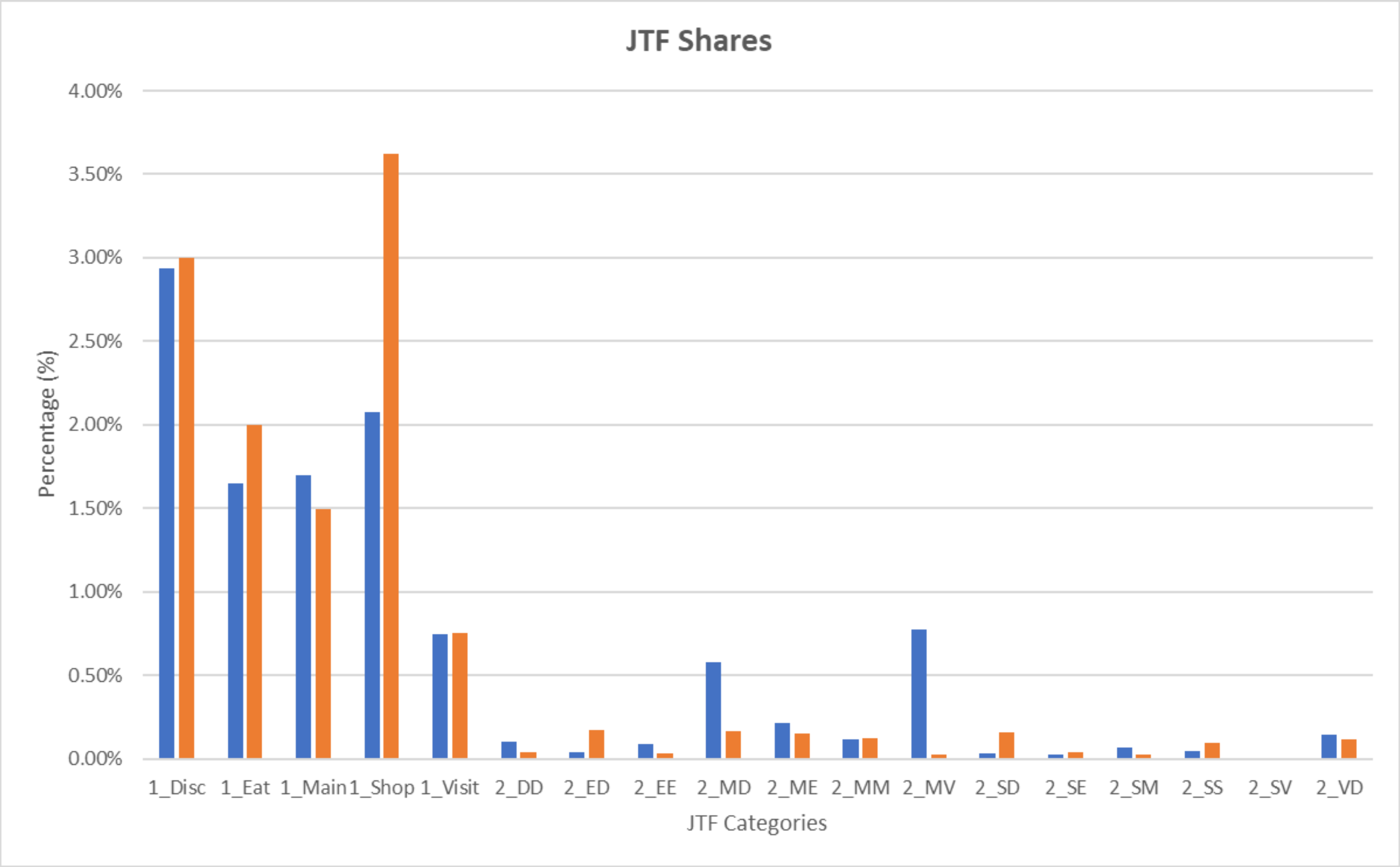
Before

After

Fully joint tour frequency calibration

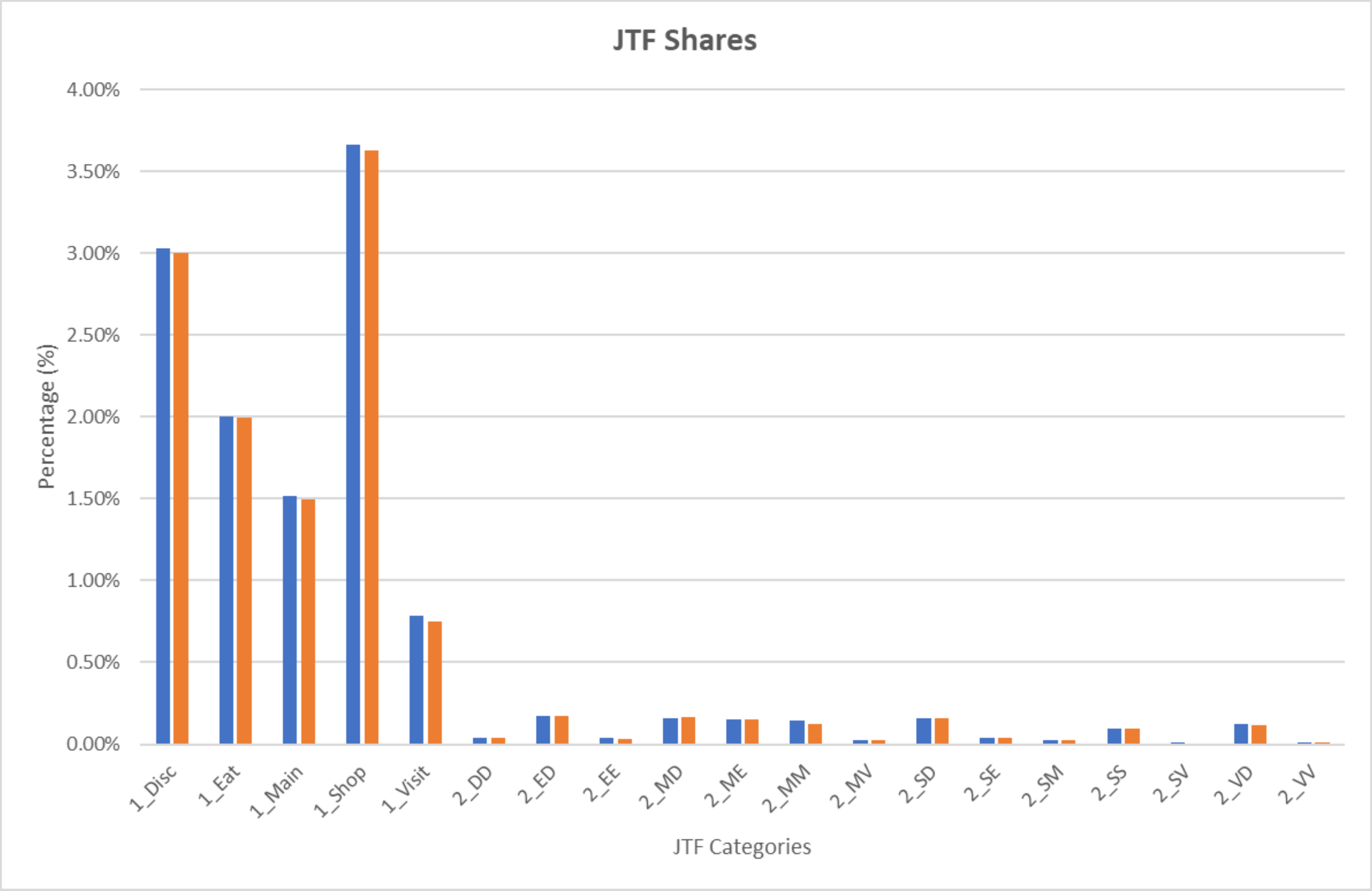
Fully joint tours: Two or more household members travel together on the entire tour

Note: 0 joint tours is an alternative in the model but is not shown in the chart



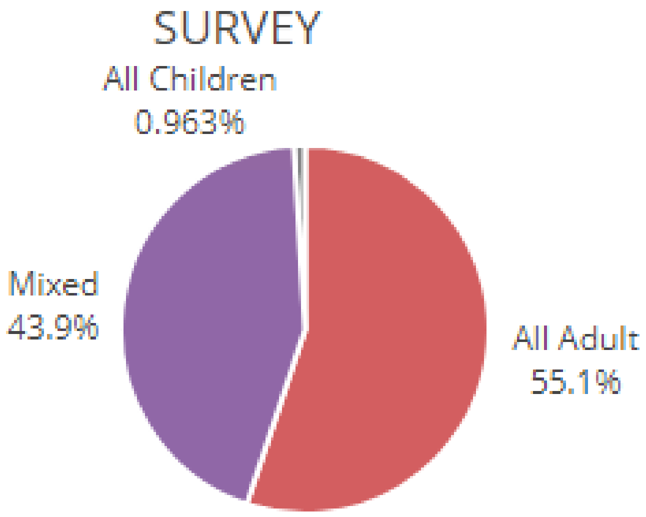
Before

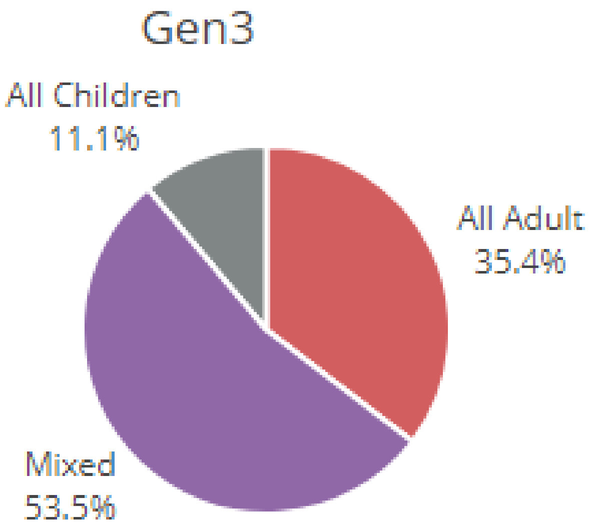
Fully joint tour frequency calibration



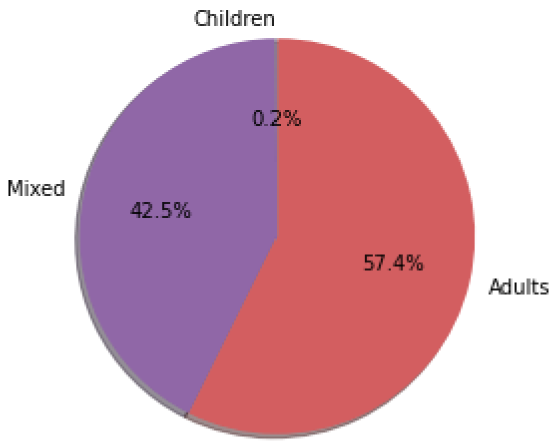
After

Fully joint tour participation calibration





Before



After

Calibration Next Steps

- Summarize non-mandatory tour destination choice at jurisdiction level. Calibrate jurisdiction constants if necessary.
- Full model run. Summarize assignment results and evaluate screenlines, transit boardings.
- Calibrate time of day choice if necessary.
- Calibrate mode choice models. Focus on operator level boardings. Iterate with assignment.

Gen3 Model Development Project Update

New ActivitySim Mandatory Location Choice Constraint Mechanism

Purpose and need

Shadow pricing is slow

Most activity-based models use a process called ‘shadow pricing’ to ensure that total workers who choose to work in a zone is proportional to the total input employment in the zone

The models do this by running the work location choice model, comparing total workers to total input employment, and calculating a ‘shadow price’, or zonal adjustment factor, to use in the next iteration.

The process is repeated until the model ‘converges’.

This is a slow process.

Purpose and need

Shadow pricing is not guaranteed to converge

Because of the way that the prices are calculated (by segment), there’s no guarantee that total workers will equal total input employment after any number of iterations.

The procedure does not consider in-commuting or out-commuting, which can be problematic for regions with big neighbors (like MWCOG).

Purpose and need

Managing shadow prices is a pain

There are no definitive rules for when this process should be run, and when it can be turned off to save runtime.

If shadow pricing is turned off, some other version of shadow prices is typically used as an input. But its not clear which prices should be used or how good they are.

Shadow prices also don’t work very well with small sample sizes.

Revised constraint mechanism

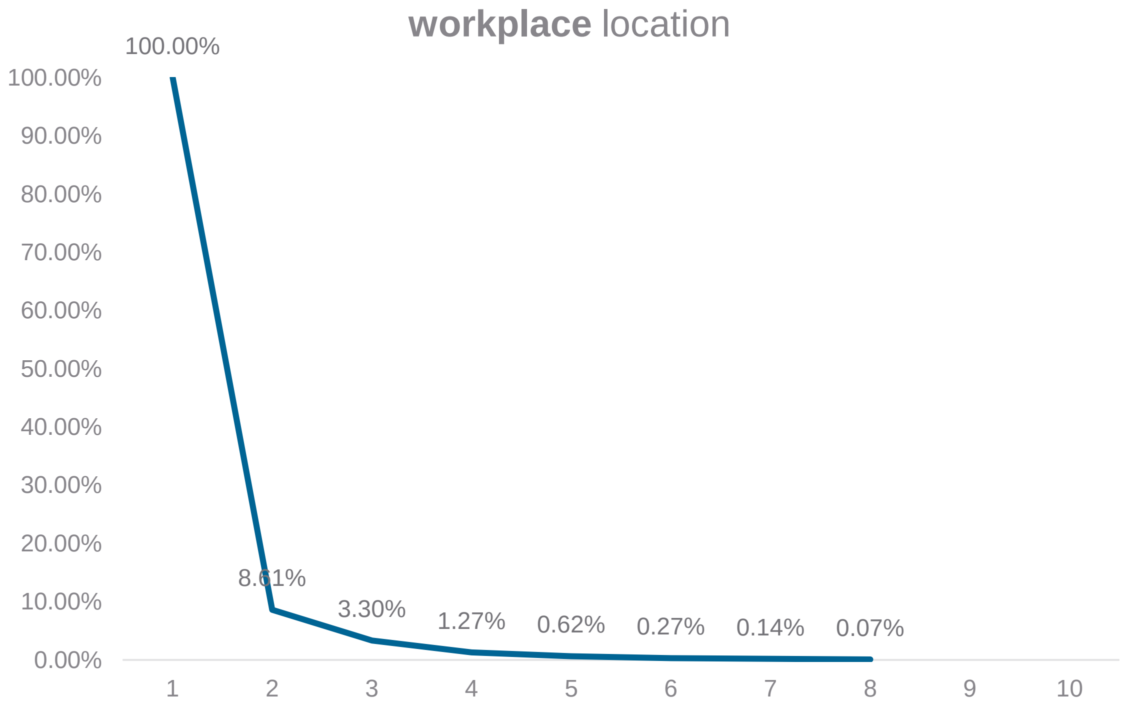
We created a new simulation-based constraint mechanism in ActivitySim that greatly speeds up runtime and accuracy

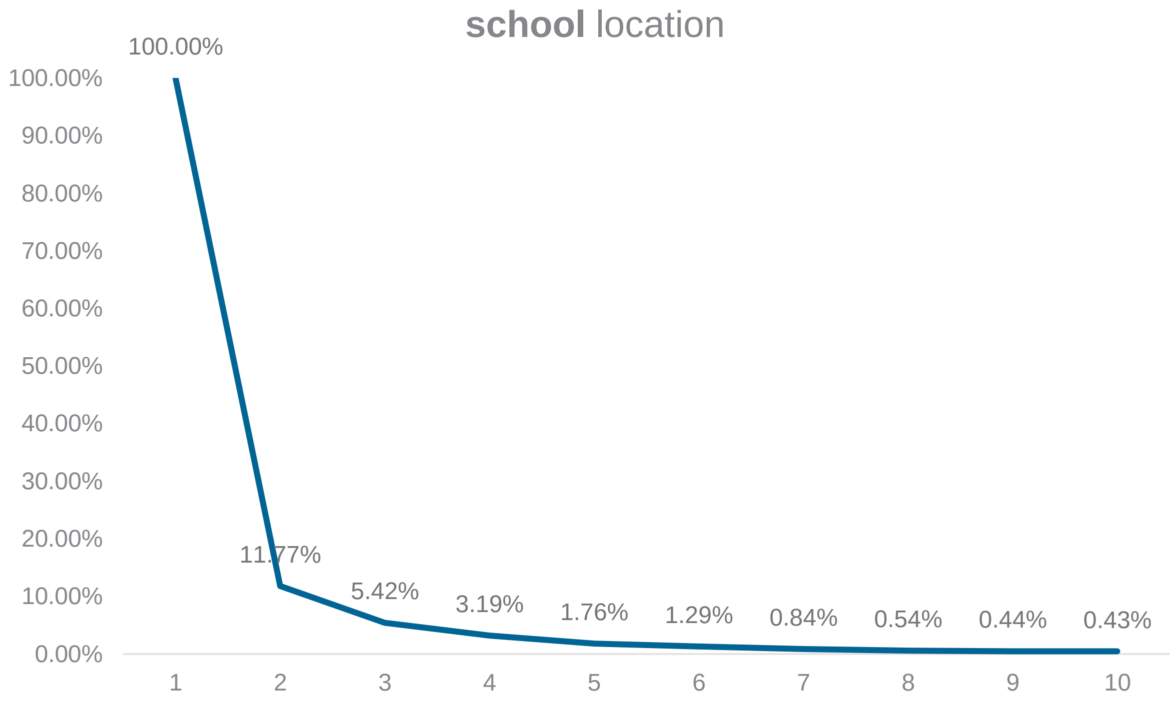
Runs all workers through location choice

For each zone, compare estimated workers to total input employment. If zone is over-estimated, randomly select workers (equal to the number over the total jobs) and re-run them in the next iteration after removing all over-estimated zones.

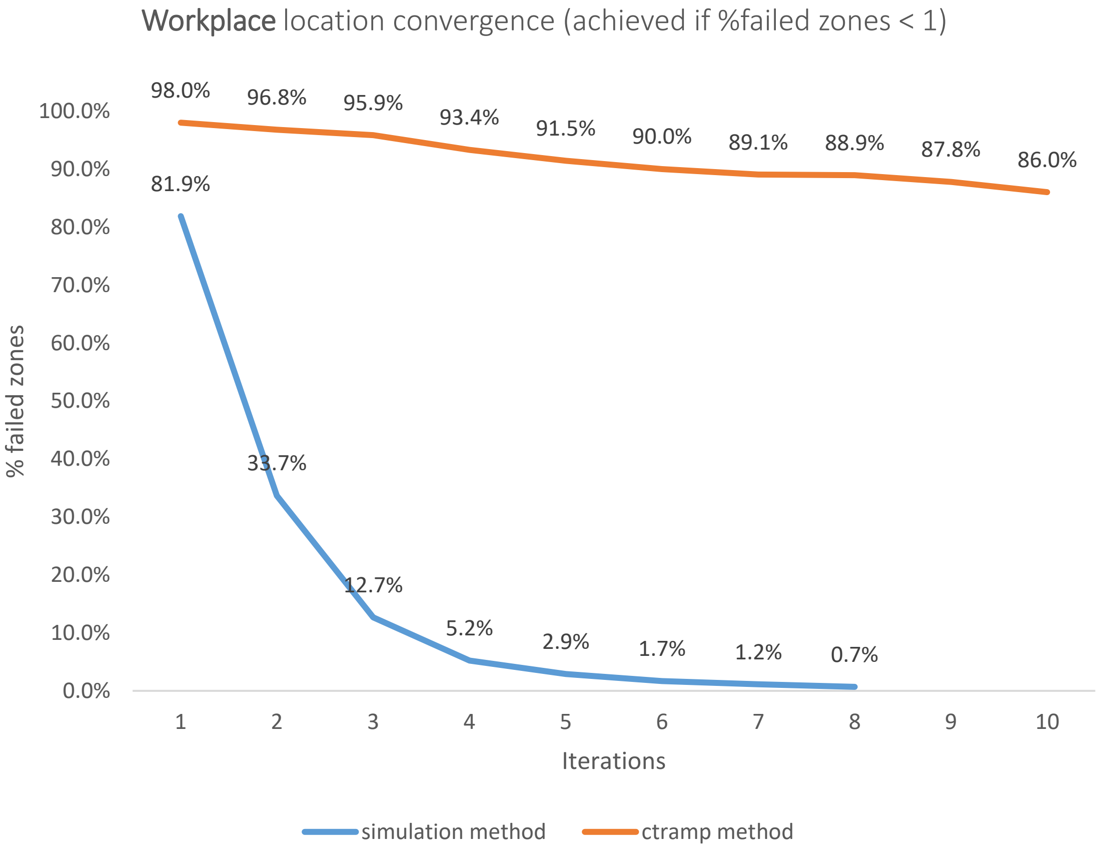
The new procedure is much faster than shadow pricing and is guaranteed to converge. And no more shadow prices to manage.

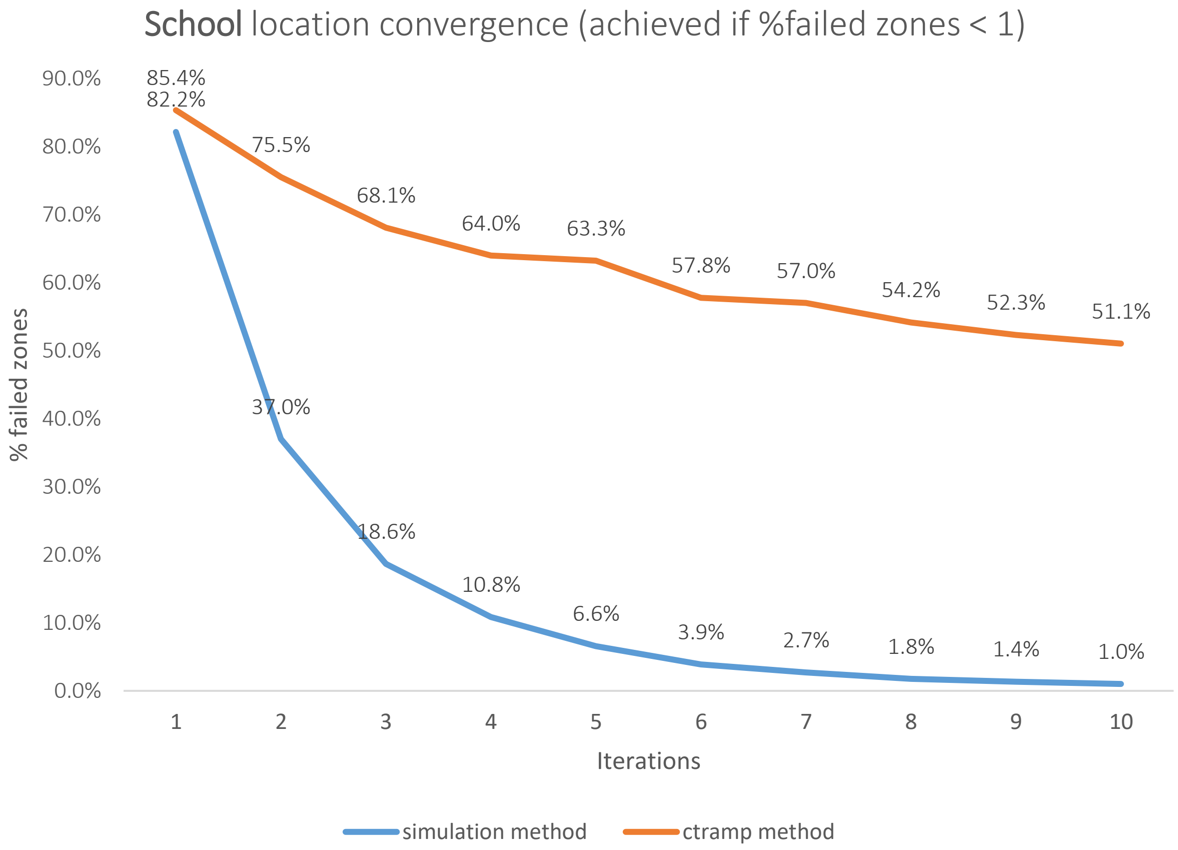
Tests | MTC full model: persons-to-simulate set size change per iter





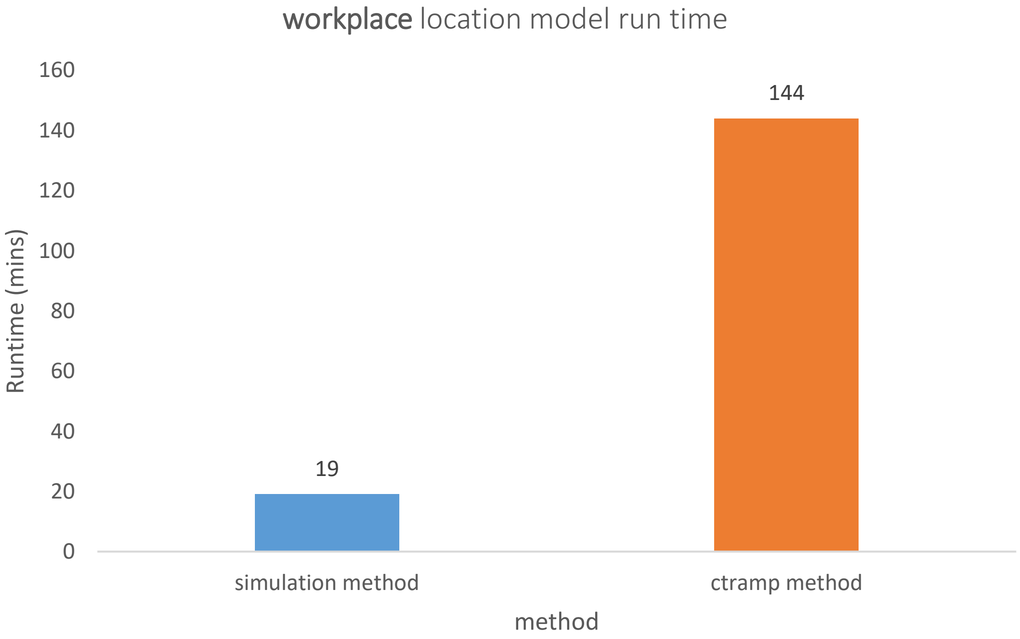
MTC full model: convergence

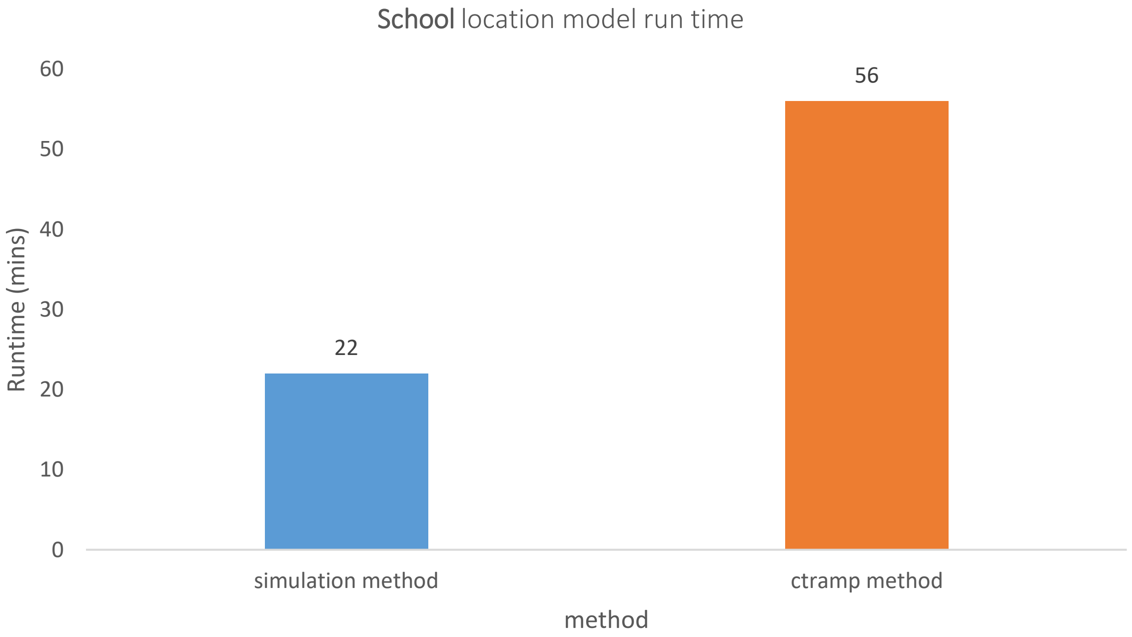




MTC full model: Run time

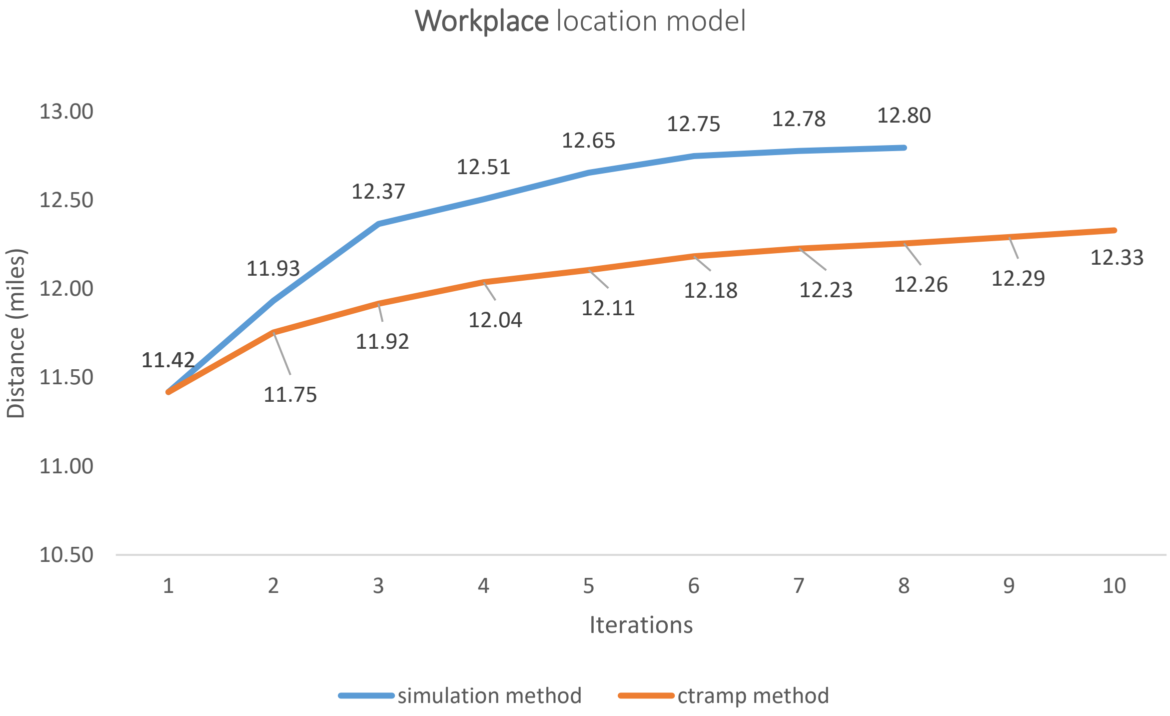
10 iteration run

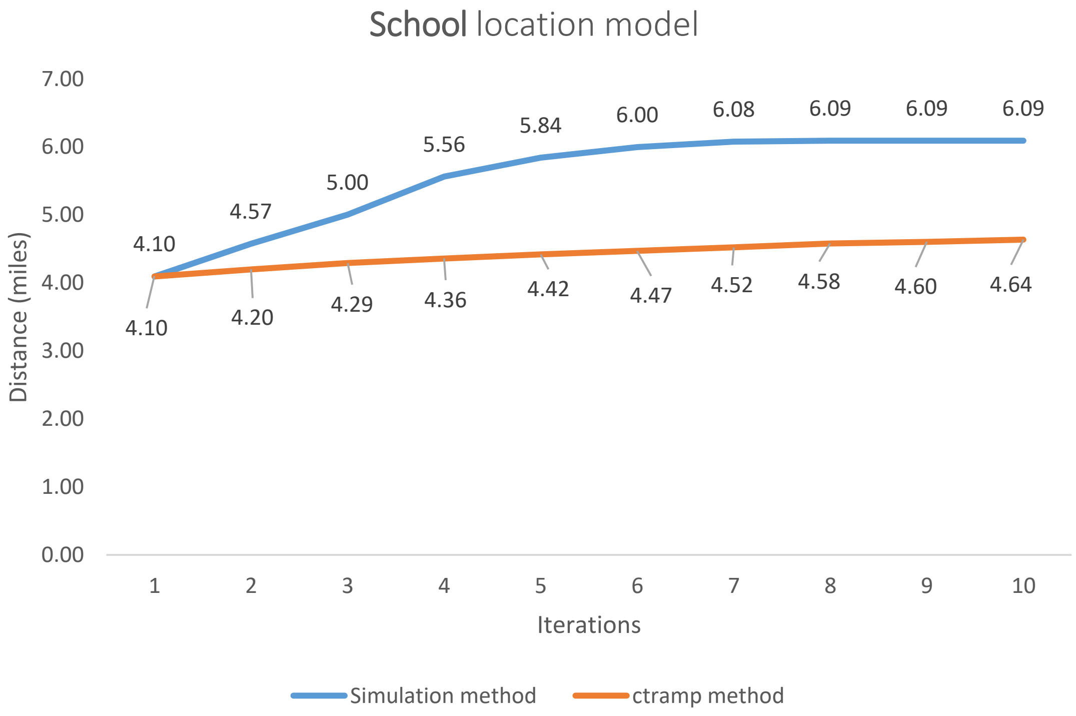




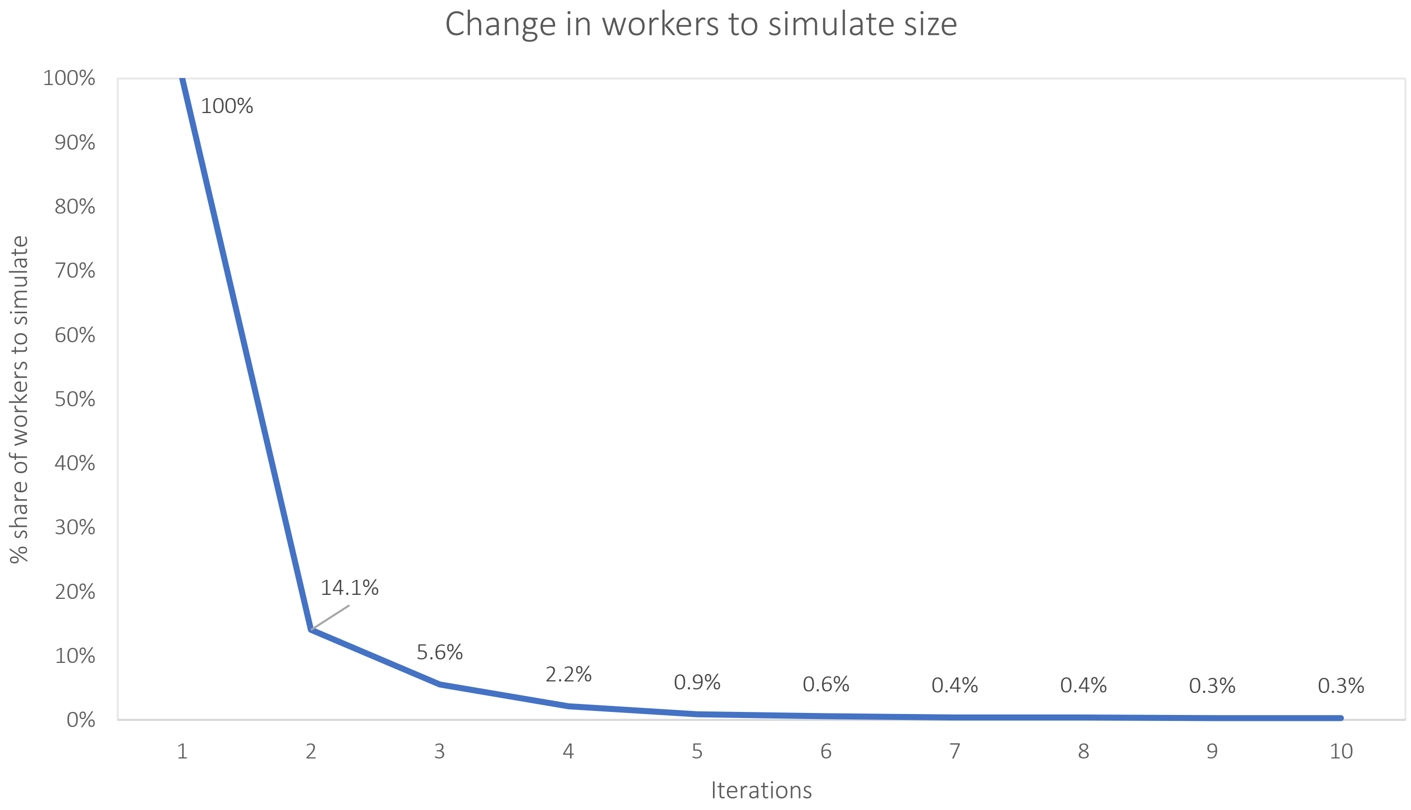
20 intel cores
Chunk_size: 0 (as much ram as needed)

MTC full model: average half-tour length change

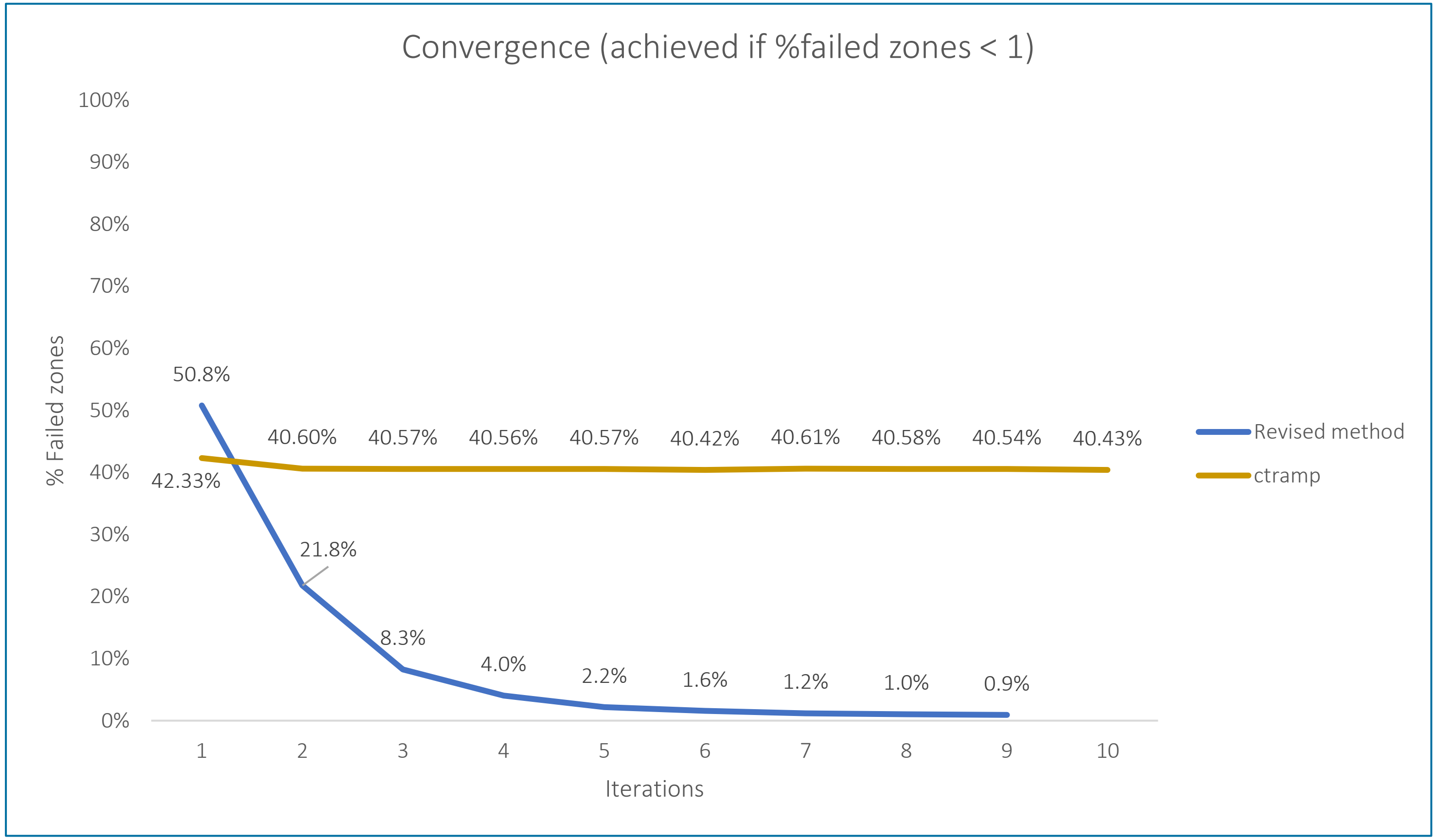

Workplace location model


School location model

SEMCOG 2-zone: persons-to-simulate set size change per iter



SEMCOG 2-zone: Percent of MAZs not reaching convergence

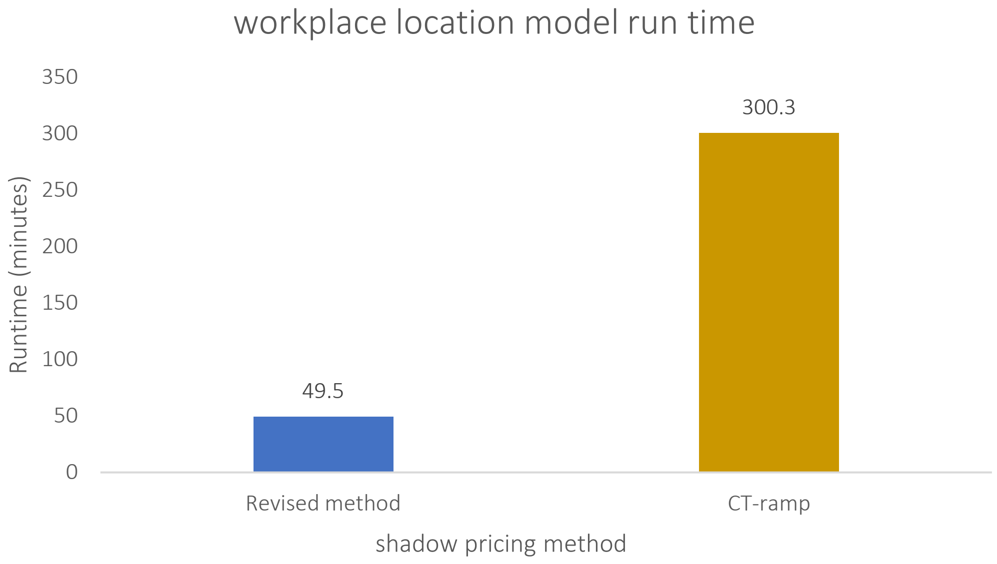


- Note: convergence for CT-RAMP is based on proportion of workers in MAZ compared to proportion of size term in MAZ

- There are four size term segments (by income group) so if any of the four fail to reach convergence, MAZ is flagged as failing for CT-RAMP

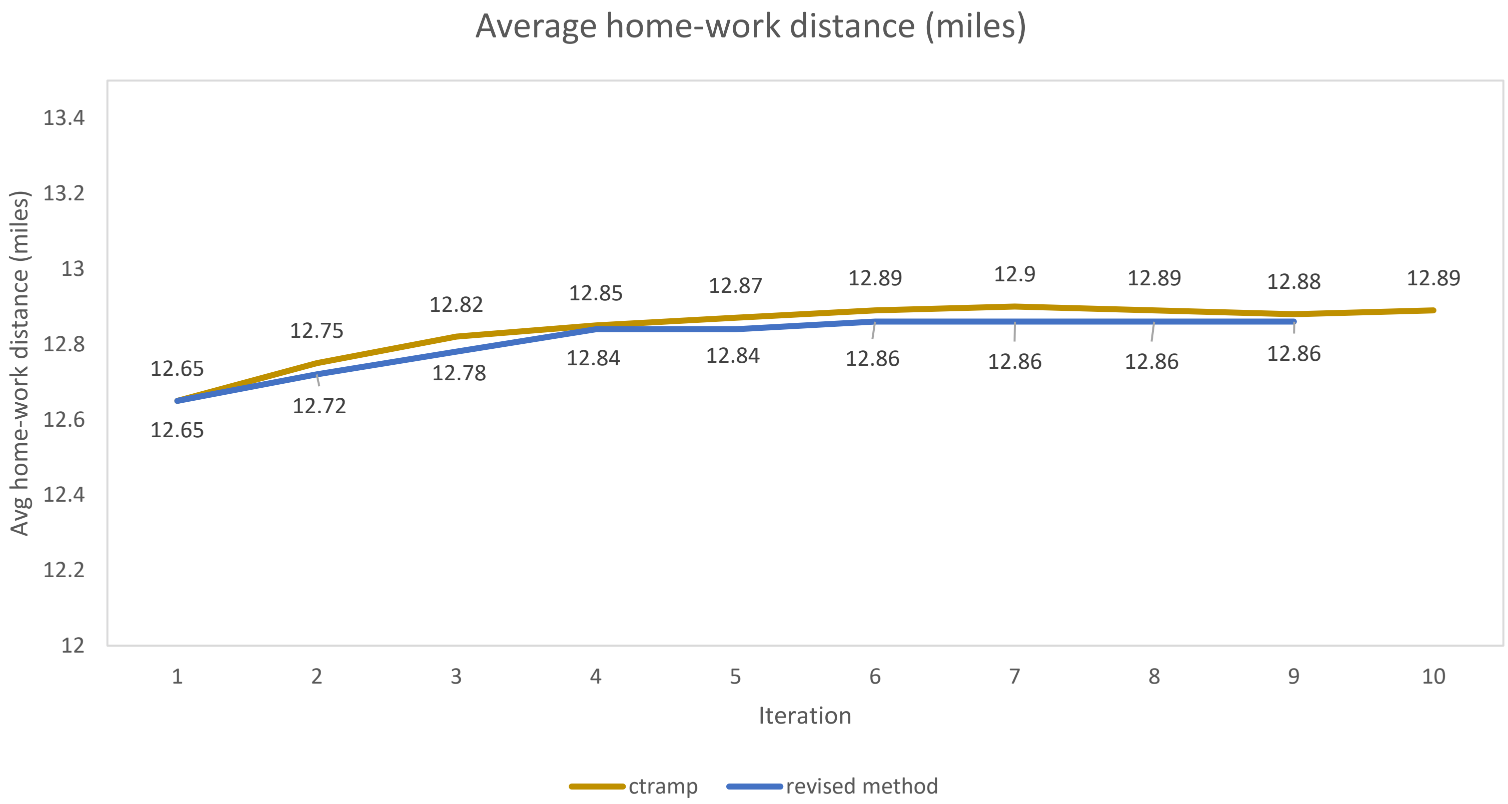
SEMCOG 2-zone: Run time

10 iteration run (revised method runs for 9 iterations as it converges)



16 intel cores
150 GB of RAM

SEMCOG 2-zone: average half-tour length change



Contacts

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Shadow pricing

- In destination choice, the shadow price is a constant that is added to each destination alternative in order to 'doubly constrain' the model.
- A doubly constrained work location choice model is one in which the output of the model matches both origin constraints (workers) and destination constraints (employment)
- Compensates for market competition

$$P_{i,j} = \frac{e^{U_{i,j}}}{\sum_{i,j} e^{U_{i,j}}}$$

Origin constraint: $\sum_{j} P_{i,j} * Workers_i = Workers_i$ (given, because $\sum_j P_{i,j} = 1.0$)

Destination constraint: $\sum_{i} P_{i,j} * Workers_i = Employment_j$ (requires shadow price)

Calculation of shadow prices

- Shadow prices are calculated in one of two ways
  - Additional alternative-specific constant for each destination zone
  - Multiplier on size term

$$P_{i,j} = \frac{e^{U_{i,j}}}{\sum_{i,j} e^{U_{i,j}}}$$

Sample Utility Equation:

$U_j = \beta_{logsum} * \text{logsum}_{ij} + \beta_{dist} * \text{dist}_{ij}$	(quality variables)
$+ \ln(\text{retail\_emp}_j + \theta_{service\_emp} * \text{service\_emp}_j)$	(quantity variable - size)
$+ C_j$	(shadow price)

where:

$C_j = \ln\left[\frac{Employment_j}{Workers_j}\right]$	(requires iteration)

Calculation of shadow prices

- Shadow prices are calculated in one of two ways
  - Additional alternative-specific constant for each destination zone
  - Multiplier on size term

$$P_{i,j} = \frac{e^{U_{i,j}}}{\sum_{i,j} e^{U_{i,j}}}$$

Sample Utility Equation:

$U_j = \beta_{logsum} * logsum_{ij} + \beta_{dist} * dist_{ij}$ (quality variables)

$+ \ln(retail\_emp_j + \theta_{service\_emp} * service\_emp_j)$ (quantity variable - size)

$* C_j$ (shadow price)

where:

$C_j = \frac{Employment_j}{Workers_j}$ (requires iteration)

Calculation of shadow prices

- Total workers typically not equal to total employment
  - In and out-commuting
  - Workers who work more than one job
  - Differences in sources of data
    - Worker totals from 5-year ACS
    - Employment totals often count all jobs in a given year
- Therefore, scaling is used:

$$C_j = \frac{Employment_{\mathrm{j}} / \sum Employment_{\mathrm{j}}}{Workers_{\mathrm{j}} / \sum Workers_{\mathrm{j}}}$$

Shadow pricing in ActivitySim

- In ActivitySim, work location choice size terms are segmented by income group of the worker

Employment Type	**Income Group**			
	Low	Medium	High	Very high
Industrial	1.0000	0.2828	0.3528	0.1523
Retail	2.3131	0.5745	0.2593	0.1345
Other	2.2566	1.3069	0.8100	0.8100
Office	1.0000	1.0000	1.0000	1.0000

- The shadow prices are segmented by income group, and size terms are used instead of employment as targets:

$$C_{j,income} = \frac{Size_{j,\ income} / \sum Size_{j\ income}}{Workers_{j,income} / \sum Workers_{j,income}}$$

- Because prices converge to size term rather than employment, there is no guarantee of matching total jobs by zone.

Shadow pricing in ActivitySim

- There are two methods for calculating prices

`SHADOW_PRICE_METHOD: ctramp`

$$C_{j,income}(iter + 1) = C_{j,income}(iter) * \text{DAMPING\_FACTOR}$$

$$where{:}\ 0 < DAMPING\_FACTOR < 1$$

`SHADOW_PRICE_METHOD: daysim`

if $modeled > desired$:

$$target = min(modeled, desired * (1 + \text{DAYSIM\_PERCENT\_TOLERANCE}),$$
$$desired + \text{DAYSIM\_ABSOLUTE\_TOLERANCE})$$

if $modeled < desired$:

$$target = max(modeled, desired * (1 - \text{DAYSIM\_PERCENT\_TOLERANCE}),$$
$$\text{desired - DAYSIM\_ABSOLUTE\_TOLERANCE})$$

$$C_{j,income}(iter + 1) = C_{j,income}(iter) + \log(\max(\text{target}, 0.01) / \max(\text{modeled}, 0.01))$$

- Every workers is re-simulated in every iteration, even workers who work in zones where modeled = desired!