THE NEXT GENERATION TRIANGLE REGIONAL MODEL

Caliper

wsp

ITRE
Institute for Transportation Research and Education
NC STATE UNIVERSITY

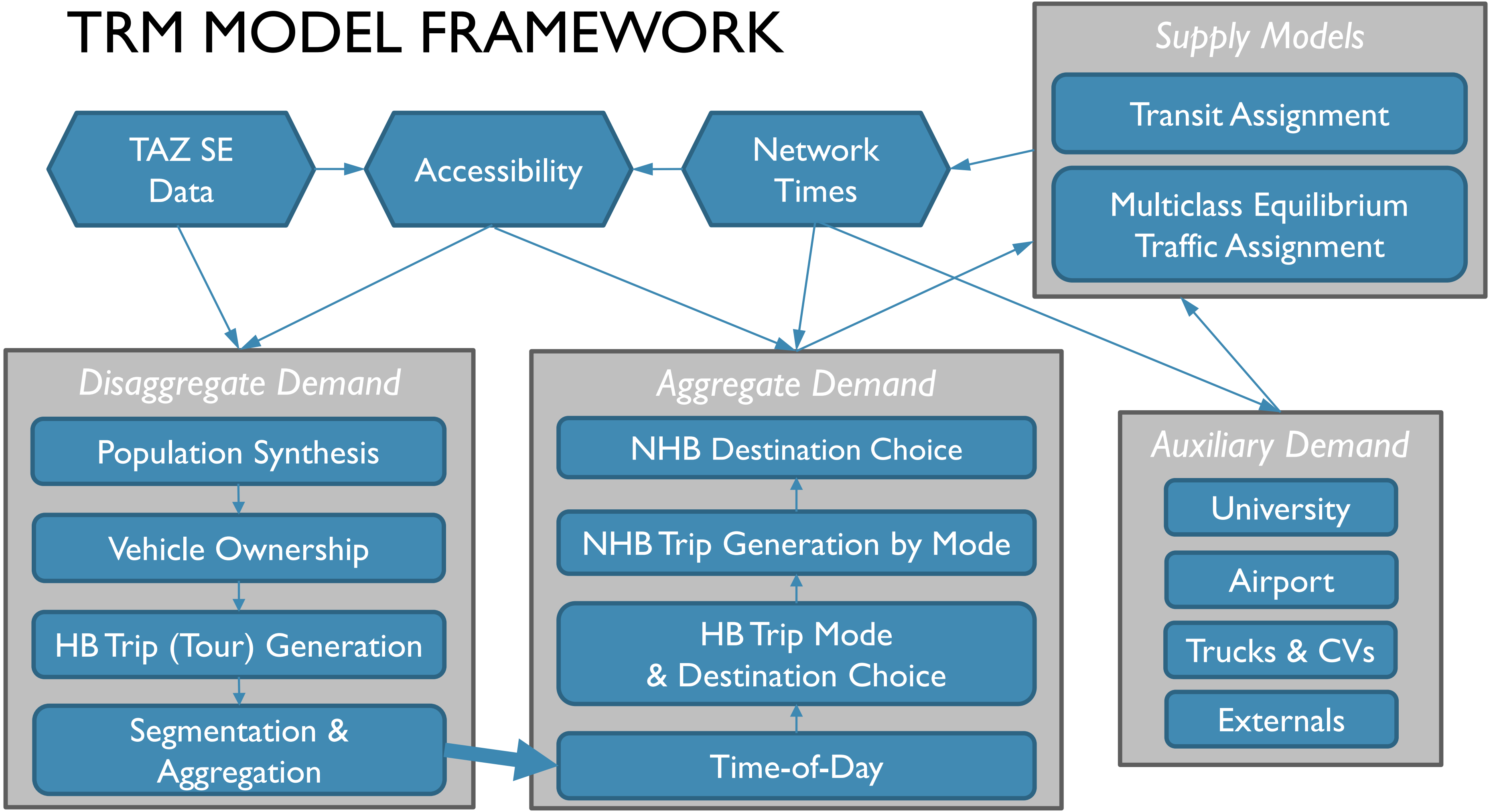
CAMPO
NC Capital Area Metropolitan Planning Organization

DCHC
Metropolitan Planning Organization
Planning Tomorrow's Transportation

GO Triangle

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

TRM MODEL FRAMEWORK



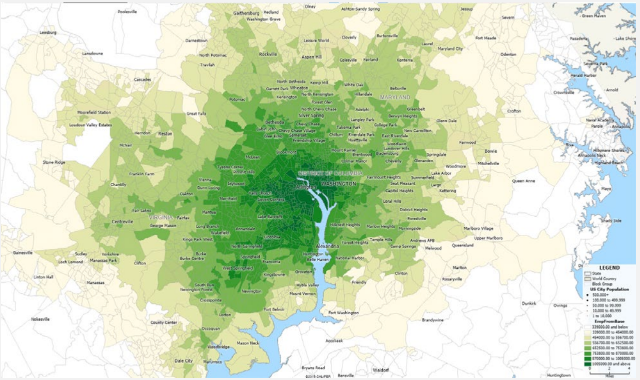
NETWORK DEVELOPMENT

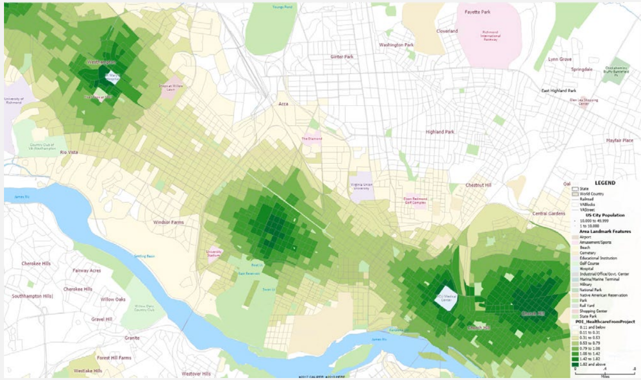
- Master network approach
- All-streets
  - Used TIGER and a custom conflation algorithm to add all streets to existing model network
  - All streets used for walk, bike, and transit walk access skimming

ACCESSIBILITY VARIABLES

- What is accessibility?
  - How easy it is to get somewhere else
  - Average (expected) cost of a trip from this zone

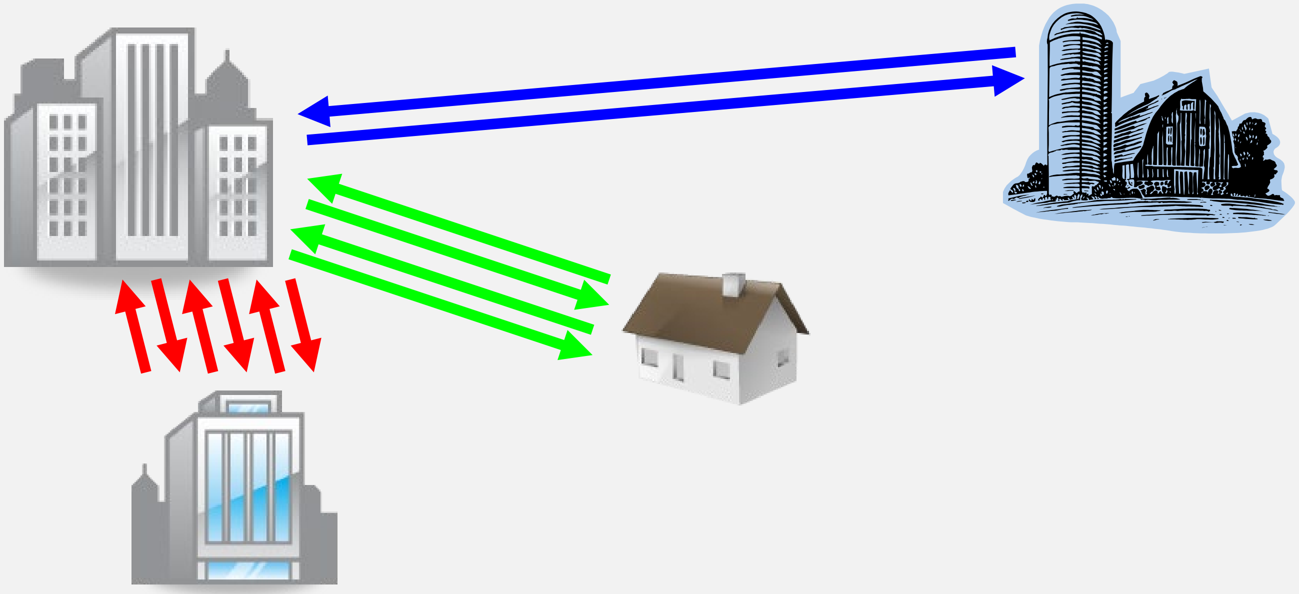
- What does Accessibility (the expected cost of a trip) affect?
  - Auto ownership
  - Frequency of trip-making
  - Destination chosen
    - Convenience for trip-chaining (cost of next trip)
    - Trip length differences by residential location





ACCESSIBILITY VARIABLES

- With accessibility in both generation and distribution:
  - ***Fewer***, but ***longer rural*** trips
  - ***More, shorter urban*** trips



LOGSUM ACCESSIBILITIES

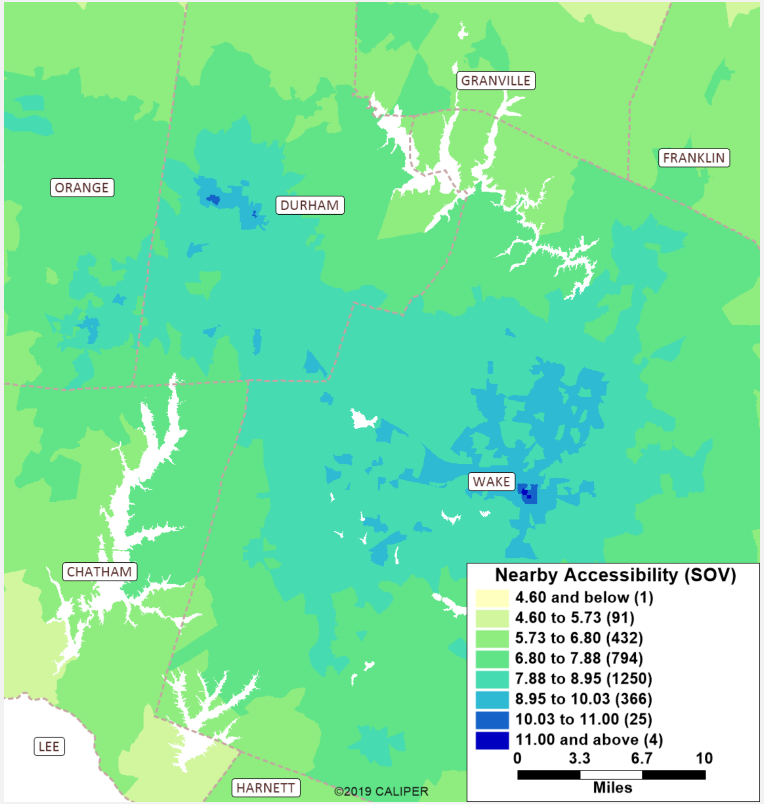
- Complex ABMs can have dozens of accessibility variables, customized for particular types of travelers and calculated as logsums of complex nested mode & destination choice models
- TRM will use just a few, standard formal accessibility variables calculated as logsums of gravity models

$$A_i = ln\left(\sum_j S_j t_{ijm}^{-\alpha} e^{-\beta t_{ijm}}\right)$$

- Where A_i is the accessibility of zone i, t_{ijm} is the travel time between zone i and another zone j by mode m and S_j are the number of attractions in zone j

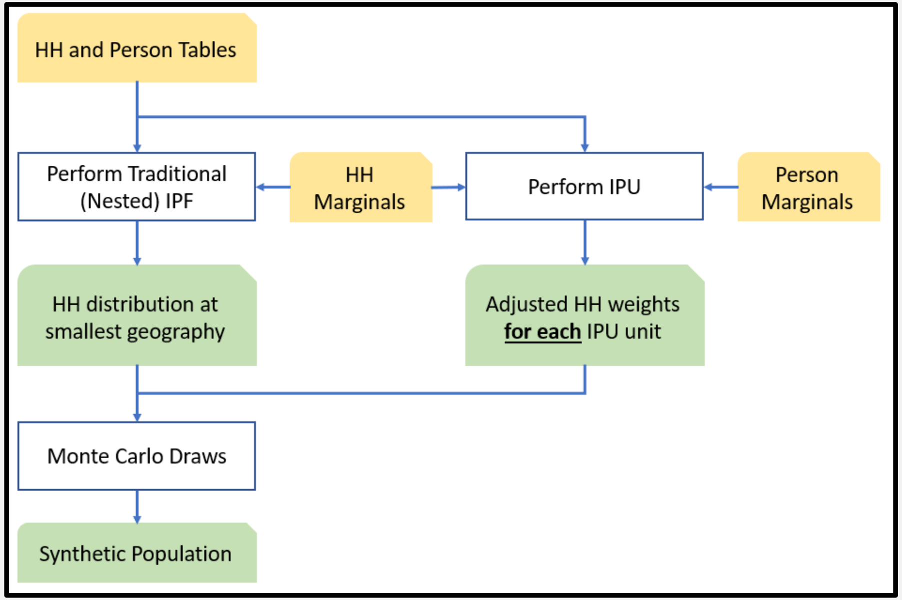
STANDARD ACCESSIBILITIES

- General Accessibility
  - S =1.9 x HH + 1.5 x K12enr + 5.7 x Uenr + 18.7 x RetailEmp + 5.6 x ServiceEmp + 3.0 x OtherEmp
  - Alpha = 0.93; Beta = 0.09
- Nearby Accessibility
  - S = 4.1 x RetailEmp + 1.2 x ServiceEmp + 0.5 x OtherEmp + 0.5 x HH
  - Alpha = 1.35; Beta = 0.10
- Employment Accessibility
  - S = Total Employment
  - Alpha = 0.30; Beta = 0.07

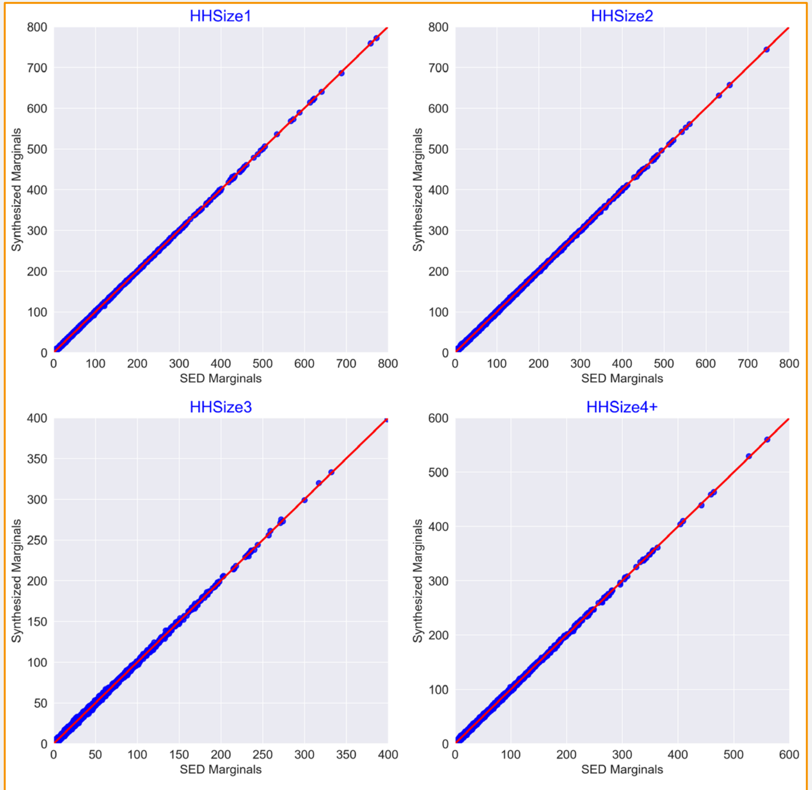


POPULATION SYNTHESIS

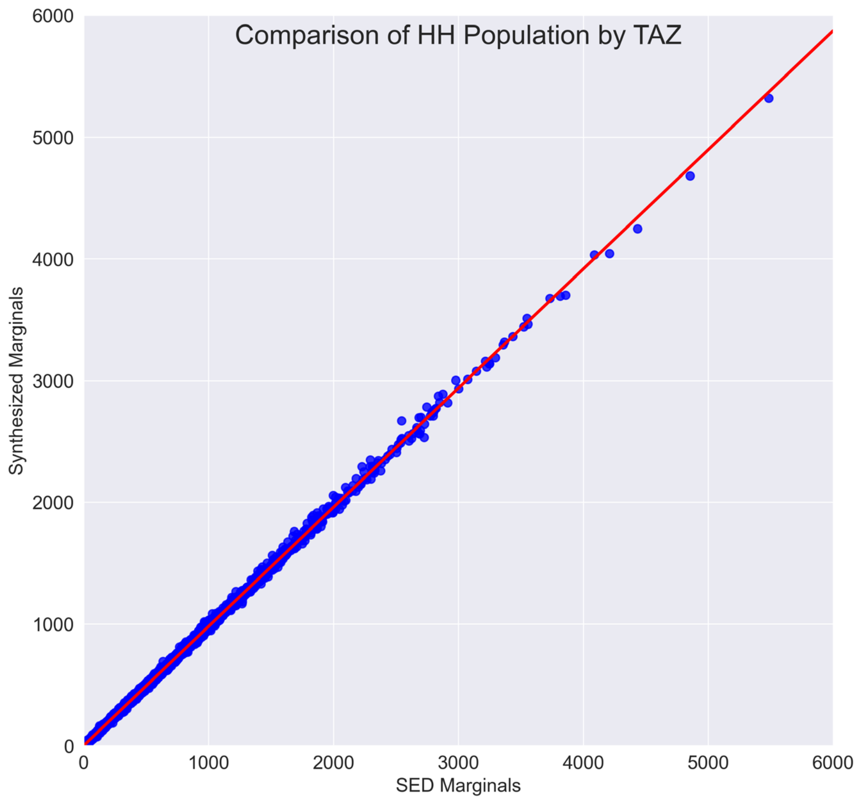
- Full synthesis
- Occurs during model run
- TransCAD 9's version of IPU
  - Household and Person level controls
  - Support for controls at multiple levels of geography
  - Extremely fast
    - TRM base year runs in ~ 2 minutes



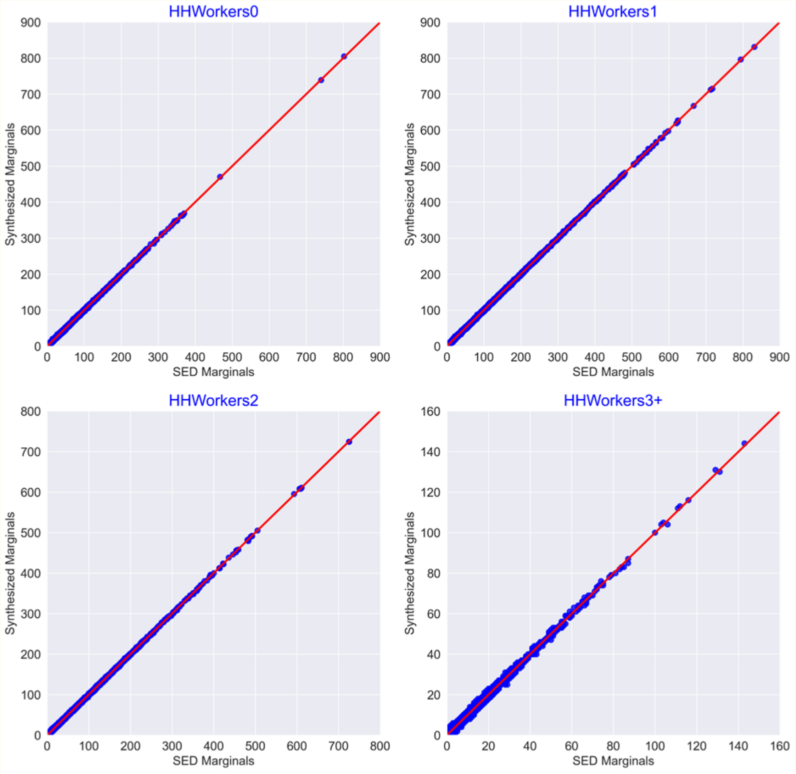
POPULATION SYNTHESIS – RESULTS, PERSONS



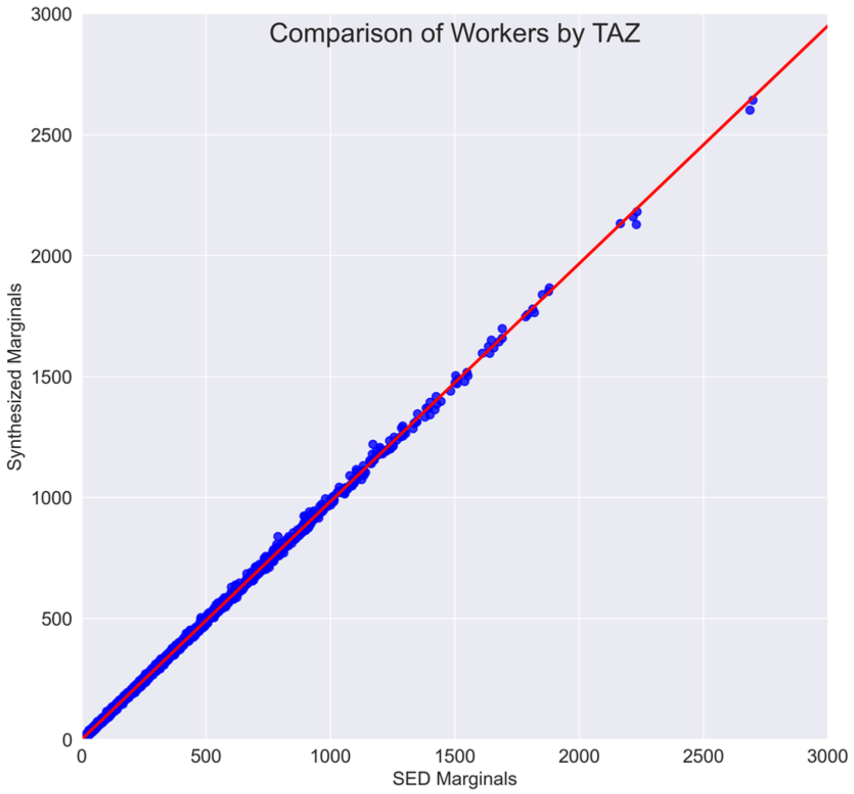
Synthesized vs SED Marginals by TAZ: HH by Size



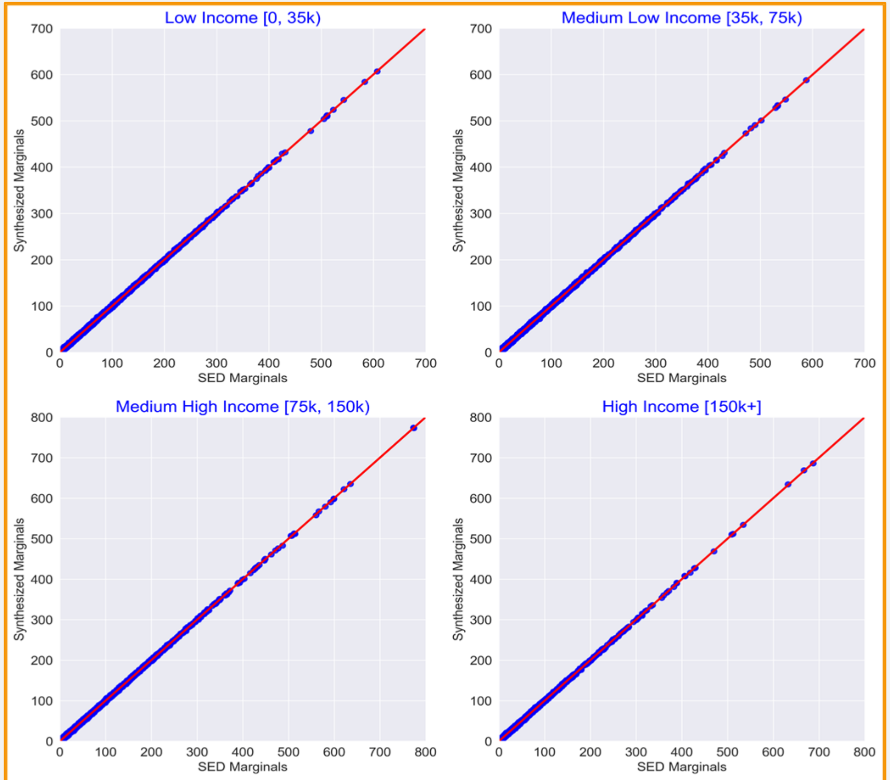
POPULATION SYNTHESIS – RESULTS, WORKERS



Synthesized vs SED Marginals by TAZ: HH by #Workers



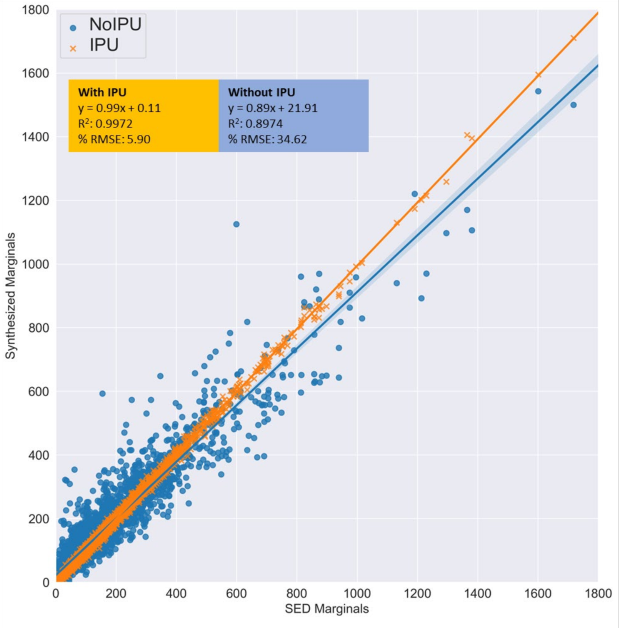
POPULATION SYNTHESIS – RESULTS, INCOME



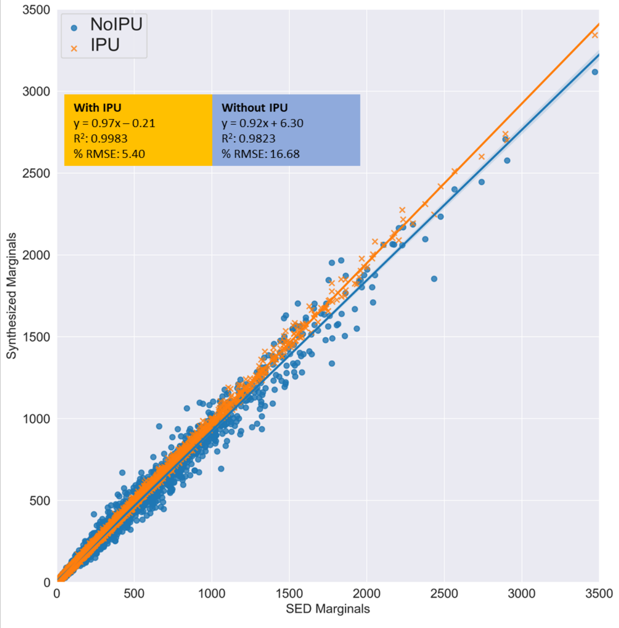
Synthesized vs SED Marginals by TAZ: HH by Income

POPULATION SYNTHESIS – RESULTS, AGE GROUPS

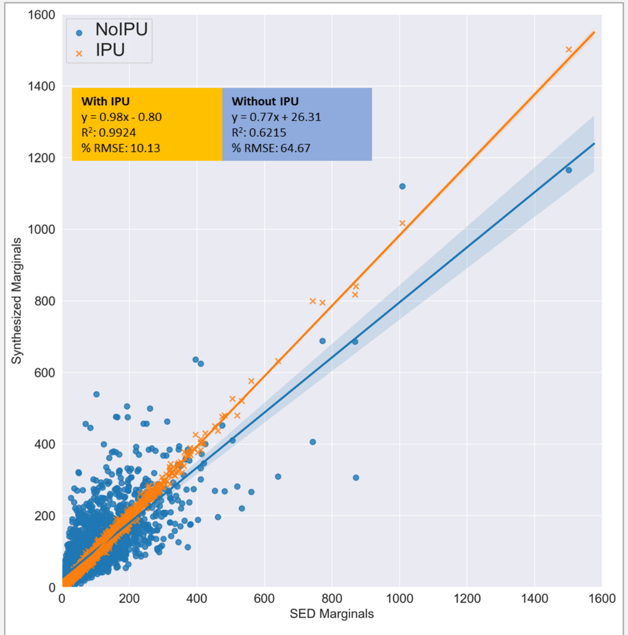
- Person level attributes show benefit of IPU over IPF



Synthesized vs SED Marginals by TAZ: Kids

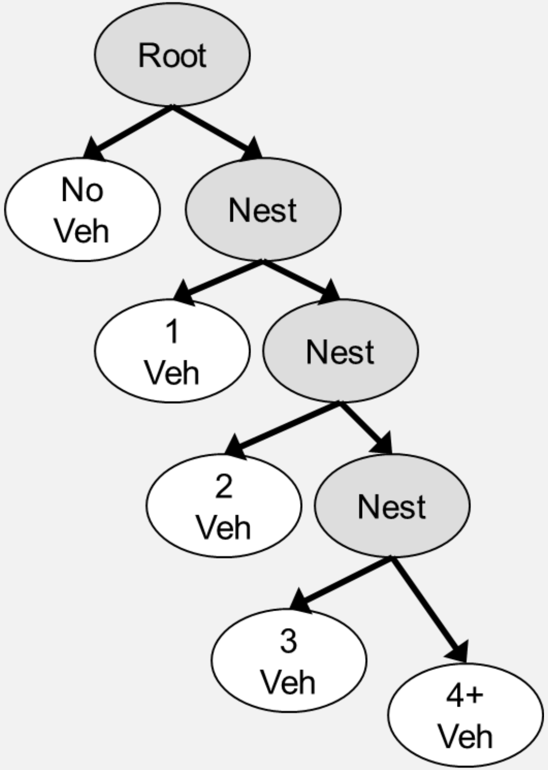


Synthesized vs SED Marginals by TAZ: Adults Under 65



Synthesized vs SED Marginals by TAZ: Seniors

VEHICLE OWNERSHIP



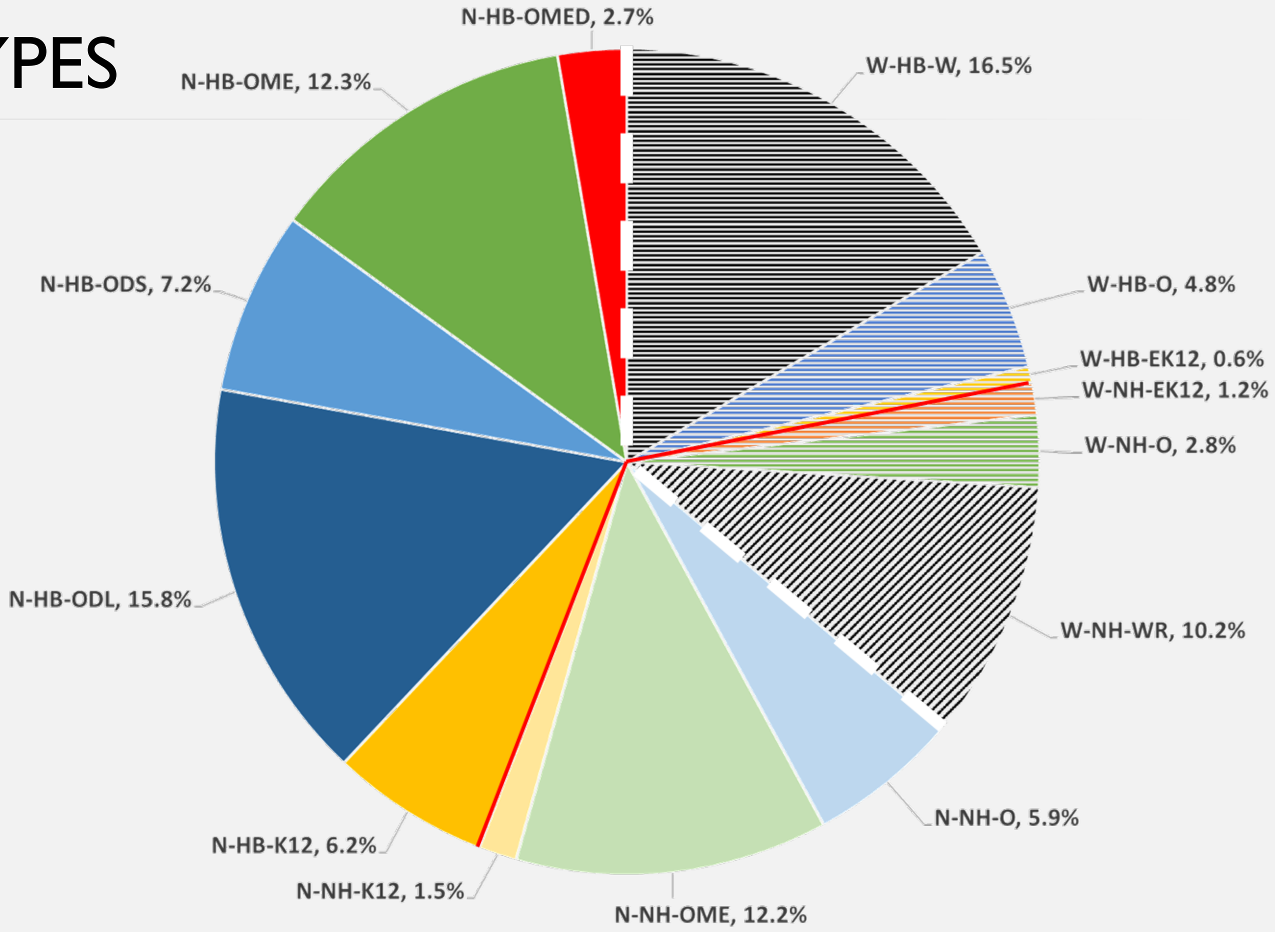
- Ordered nested logit
  - Households change # of vehicles one at a time
- Each household chooses how many vehicles to own / lease
  - No aggregation bias
  - Vehicle ownership levels respond to
    - Demographics (household size, income, number of workers, seniors, etc.)
    - Gas prices
    - Transit availability / accessibility
    - Urban design factors (walkability)

TRIP TYPES (14)

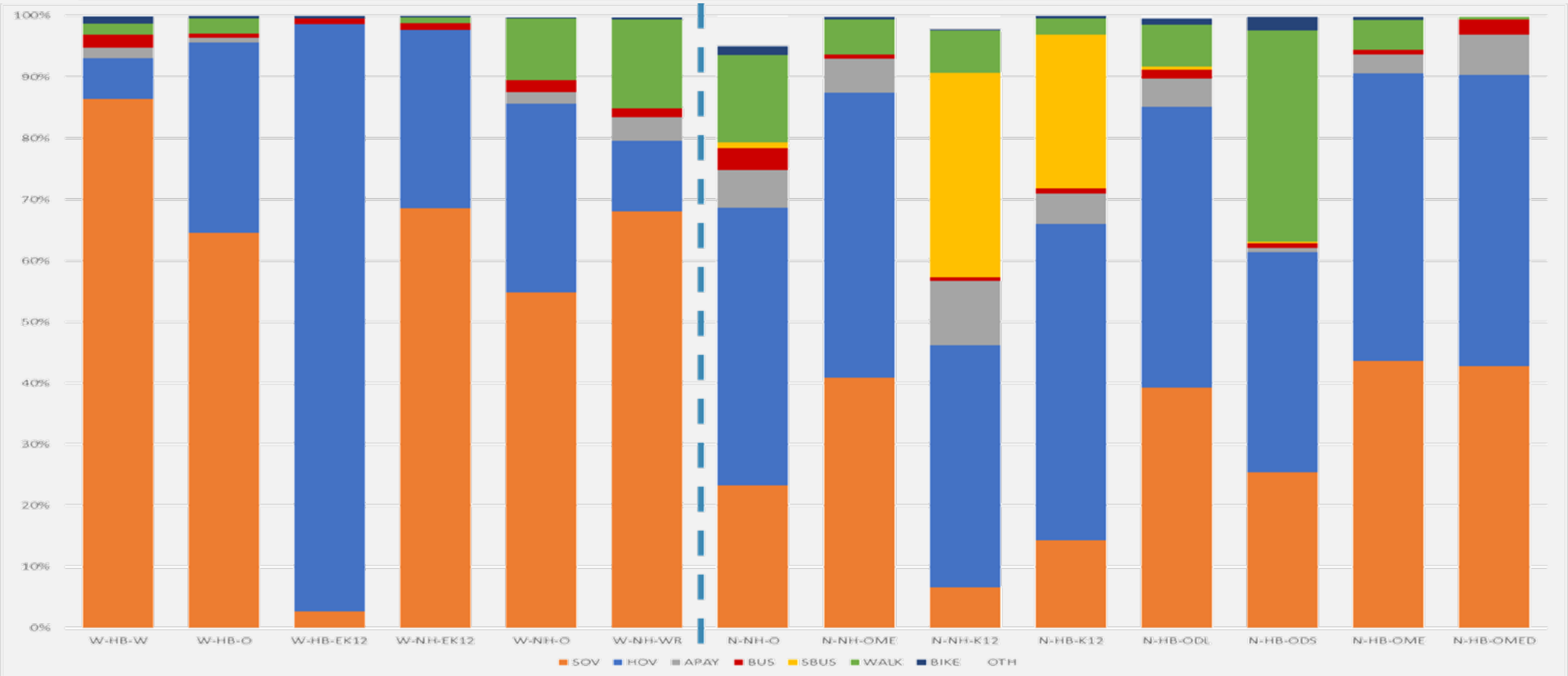
- Work Tours
  - Home-Based
    - Work
    - Other
    - Escort to School
  - Non-Home-Based
    - Escort to School
    - Other
    - Work Related
- Non-Work Tours
  - Home-Based
    - School
    - Other – Discretionary Long
    - Other – Discretionary Short
    - Other – Maintenance / Eat
    - Other – Medical
  - Non-Home-Based
    - School
    - Other – Maintenance / Eat / Medical
    - Other – Discretionary

PMT BY TRIP TYPES

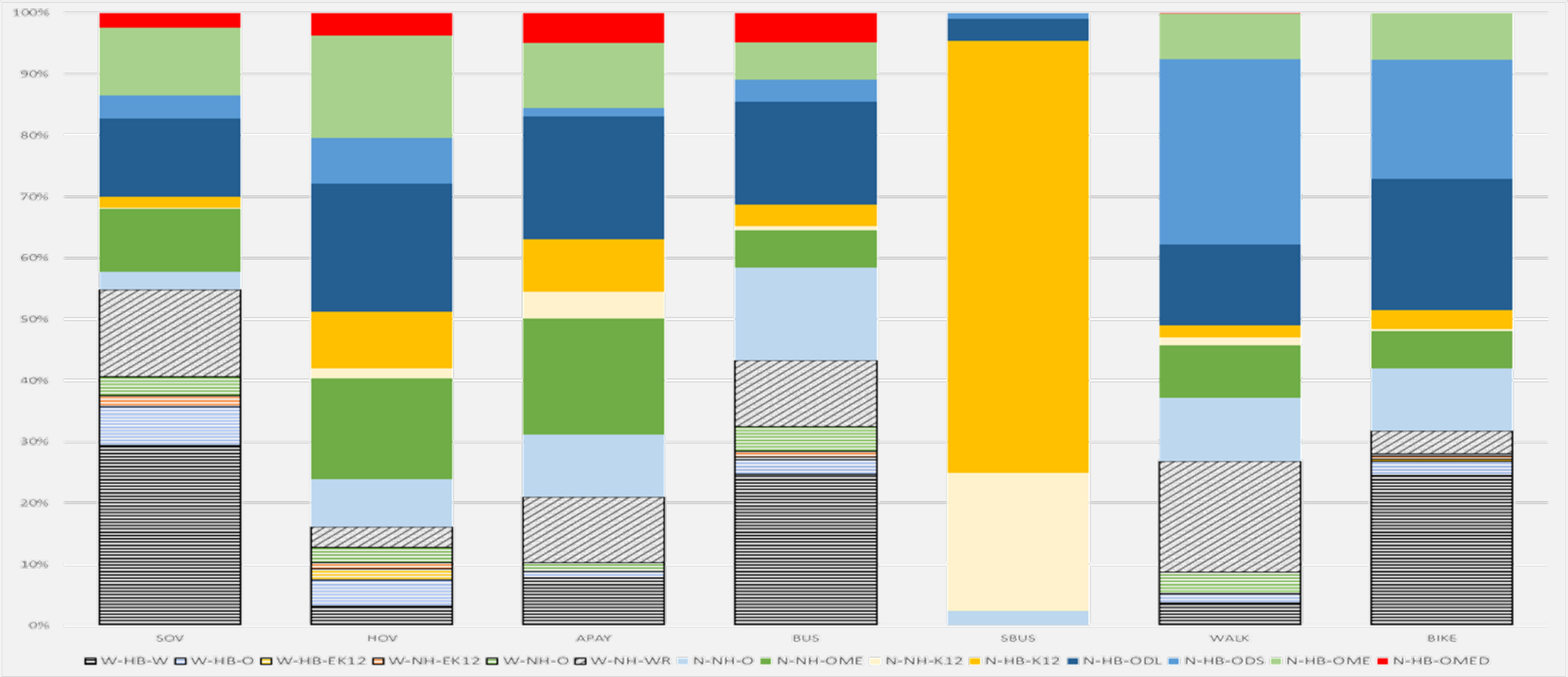
- PMT
  - Work Tours
    - 36.2%
  - Nonwork Tours
    - 63.8%
  - Home-based
    - 66.1%
  - Non-Home-based
    - 33.9%
  - School
    - 9.6%



MODE SHARE DIFFERENCES BY TRIP TYPES



MODE COMPOSITION BY TRIP TYPES



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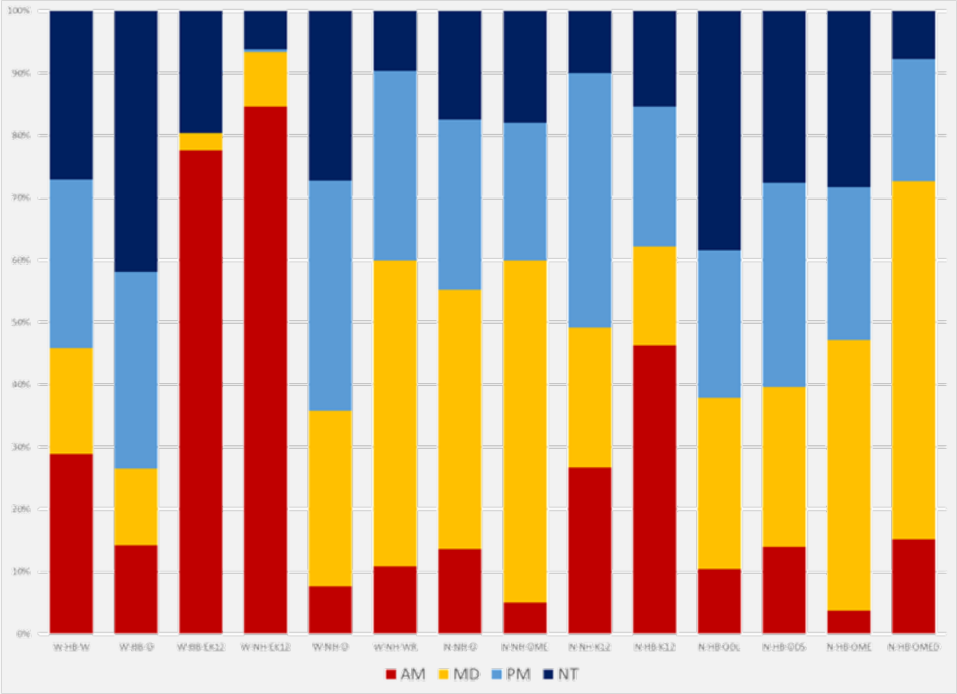
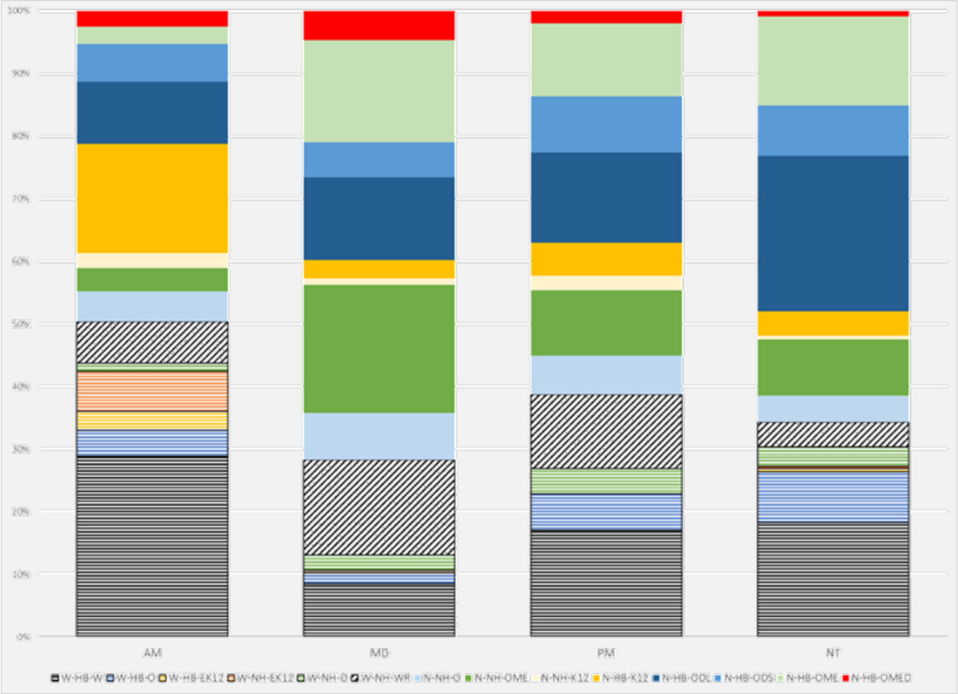
TRIP TYPES AND TIME OF DAY





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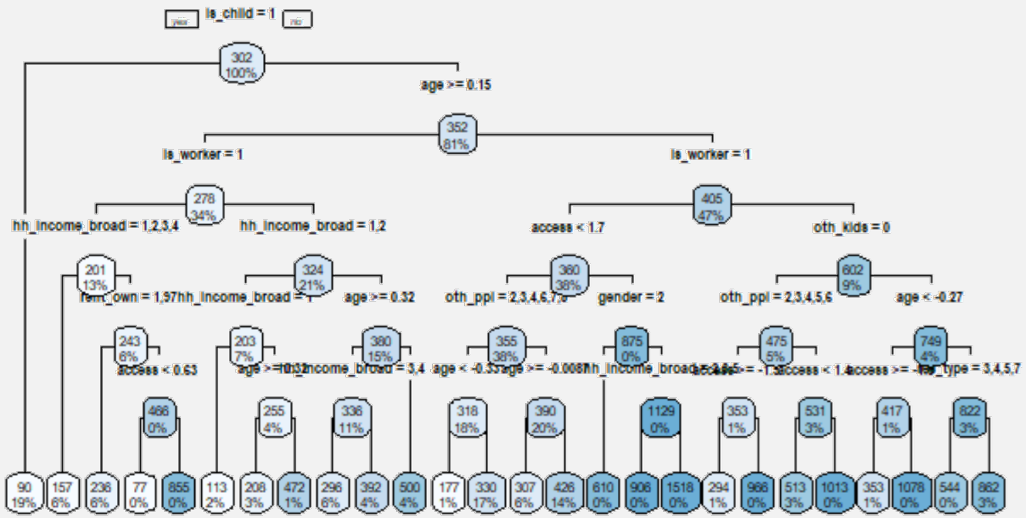
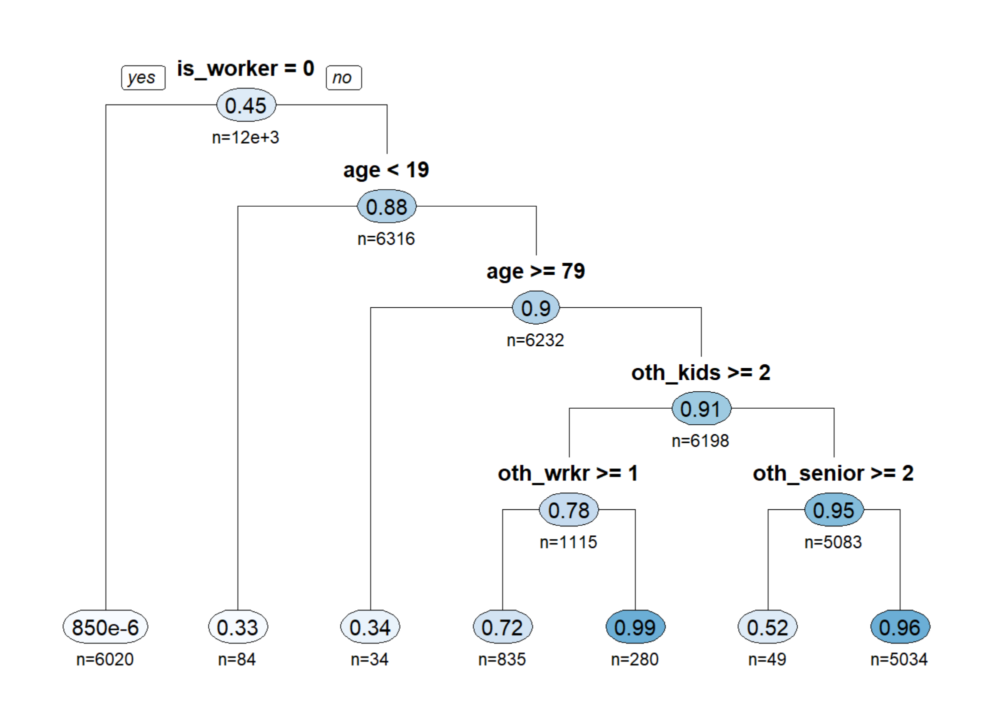
HB TRIP PRODUCTION MODELS

- HB trip generation is equivalent to tour generation
  - just divide by 2
- Disaggregate models
  - Benefits
    - Sensitivity to more factors
    - Full survey support
      - no empty cells
  - Statistical form
    - Tested and rejected due to poor fit
      - Generalized linear models (GLM)
      - Ordered logit
    - Settled on rationalized decision trees
      - ANOVA based, rates by category similar to cross-class, but eliminates empty cells and uses more variables



RESIDENT PRODUCTION

- Tested:
  - GLM (up to and including zero-inflated negative binomial)
  - Logit
  - Machine Learning (the winner)
    - Rationalized Decision Trees



- https://caliper-corporation.github.io/TRMG2/resident_production.html

RESIDENT PRODUCTION

trip_type	rule	category	rate	stdev	samples
N_HB_K12_All	age < 5	12	0.2	0.75	729
N_HB_K12_All	age >= 19 and age < 57 and oth_kids >= 1 and is_worker = 0	10	0.58	1.31	484
N_HB_K12_All	age >= 19 and oth_kids < 1	3	0	0.08	7167
N_HB_K12_All	age >= 19 and oth_kids >= 1 and is_worker = 1 and gender = 1	6	0.16	0.62	1114
N_HB_K12_All	age >= 19 and oth_kids >= 1 and is_worker = 1 and gender = 2	7	0.28	0.84	1033
N_HB_K12_All	age >= 5 and age < 19 and per_inc < 16563 and oth_wrkr < 2	15	0.94	0.95	277
N_HB_K12_All	age >= 5 and age < 19 and per_inc < 16563 and oth_wrkr >= 2	16	1.27	1	159
N_HB_K12_All	age >= 5 and age < 6 and per_inc >= 16563	18	0.78	0.94	113
N_HB_K12_All	age >= 57 and oth_kids >= 1 and is_worker = 0	9	0.05	0.49	87
N_HB_K12_All	age >= 6 and age < 19 and per_inc >= 16563	19	1.34	0.92	1173

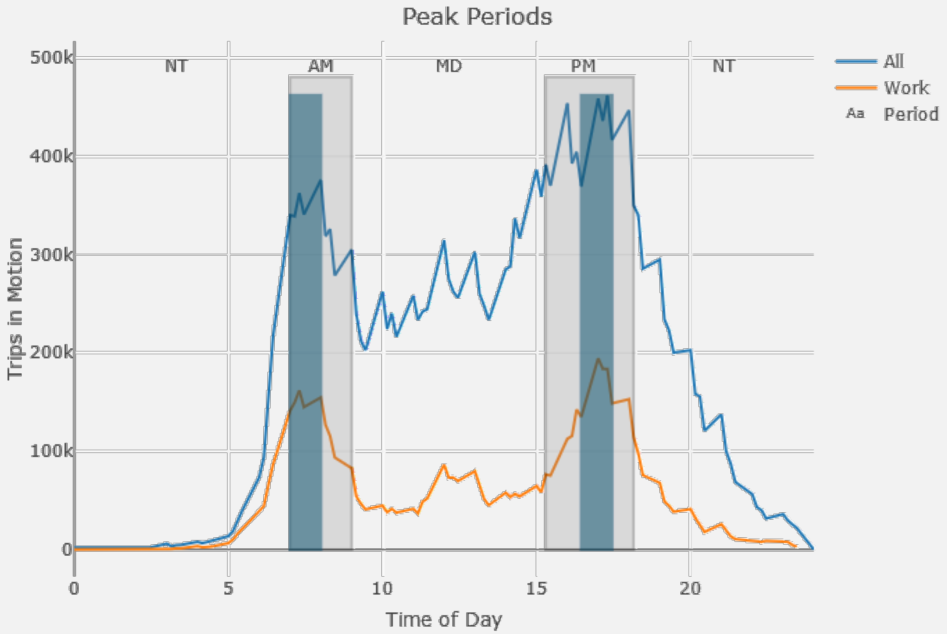
SEGMENTATION & AGGREGATION

- Disaggregate trips summed to aggregate market segments
- Market segments may be traditional, pre-defined fixed
  - Example:
    - No vehicles,
    - Vehicle Insufficient Low Income
    - Vehicle Insufficient High Income
    - Vehicle Sufficient Low Income
    - Vehicle Sufficient High Income
- Or dynamic, implied latent classes (e.g., transit captives) based on the survey data and synthetic population

TIME OF DAY

- Time of day after generation
  - separate feedback of impedances by period for destination & mode choices

- 4 periods
  - AM Morning Peak
  - MD Midday Off-peak
  - PM Evening Peak
  - NT Night Off-peak



- Peak hour assignment as post-process

CHOICE MODELS – IN PROGRESS

- Data exploration of choice sets, captivity, segmentation
- Destination choice
  - Standard: impedance, interaction of impedance and residential accessibility, psychological barriers, destination accessibilities, constants, (no sampling)
  - Research: hierarchical, intervening opportunities, parameterized constraint, etc.
- Mode choice
  - Captivity
  - Auto intercept
  - Separate new transit modes
  - MaaS nest? (data allowing)

NON-MOTORIZED CHOICE

- Will remain a separate choice
  - Disaggregate choice, access to all synthetic population attributes
  - Allow for future option to build out a full non-motorized model
  - Simplify estimation of a potentially new mode choice model
  - Uses walk accessibility logsums
    - Gravity models estimated by trip type based on walk skims
    - Leverages the all-streets network

Work HB (W/O - no EK12)

Parameter	Estimate	Std. Error	t Test
IsSenior	-0.622	0.321	-1.94
HHwKids	-0.634	0.138	-4.61
VehPerAdult	-1.446	0.166	-8.69
WalkAccessibility	1.023	0.088	11.60
Const(NonMotorized)	-2.165	0.181	-11.96
Asymptotic rho squared	0.8165		
Adjusted rho squared	0.8157		

Nonwork HB-K12

Parameter	Estimate	Std. Error	t Test
VehPerAdult	-0.762	0.316	-2.41
WalkAccessibility	0.636	0.317	2.01
Const(NonMotorized)	-2.795	0.343	-8.15
Asymptotic rho squared	0.8048		
Adjusted rho squared	0.8034		

MIXED USE INDEX

- Measure mixed use with Gini-Simpson Diversity Index (D)

$$D_i = 1 - \sum_g \left(\frac{|g_i|}{\sum_{g'} |g'_i|} \right)^2$$

  - Where i indexes the zones
  - g is each group of attraction types
    - g = {Home, Work, Other}
    - Using standard attraction coefficients from NCHRP 365, 716, etc.
  - $|g_i|$ is the number of attractions of type g in zone i
  - $\sum_{g'} |g'_i|$ is the total attractions in zone I
- Totally homogenous = 0; totally diverse = 1
- Sort of like an intrazonal accessibility

WALKABILITY INDEX

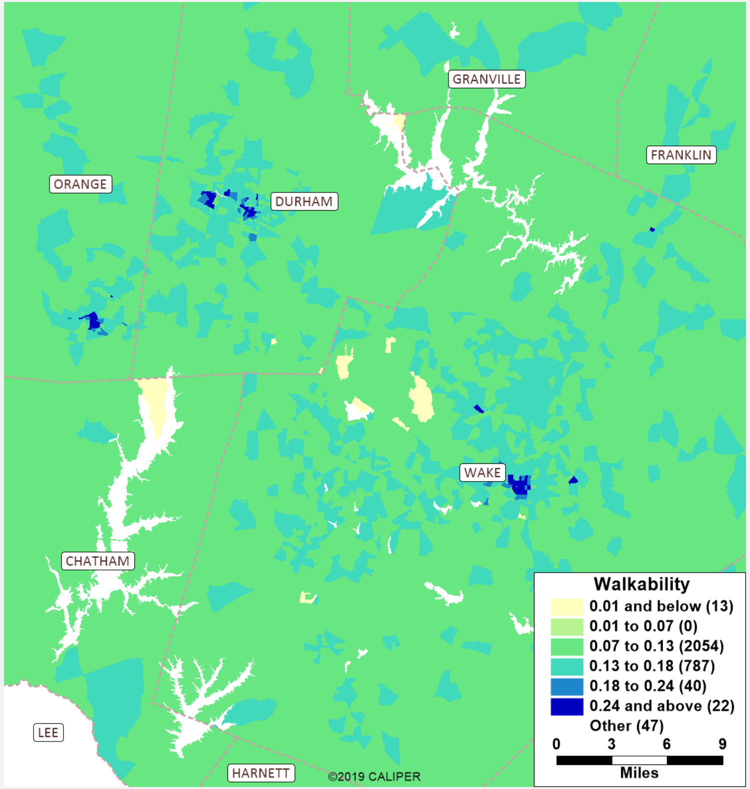
- Modeled as binary logit model of TAZ level mode shares (walk vs. non-walk)

$$W_i = \frac{e^{V_i}}{1 + e^{V_i}} = \frac{1}{1 + e^{-V_i}}$$

  - Where W_i is the walkability of zone i as a function of
  - V_i as the deterministic 'utility' of walking in zone i

- Allows walkability parameters to be estimated from survey
- Also makes walkability range from 0 to 1 for easy assertion of alternative future scenarios

WALKABILITY INDEX

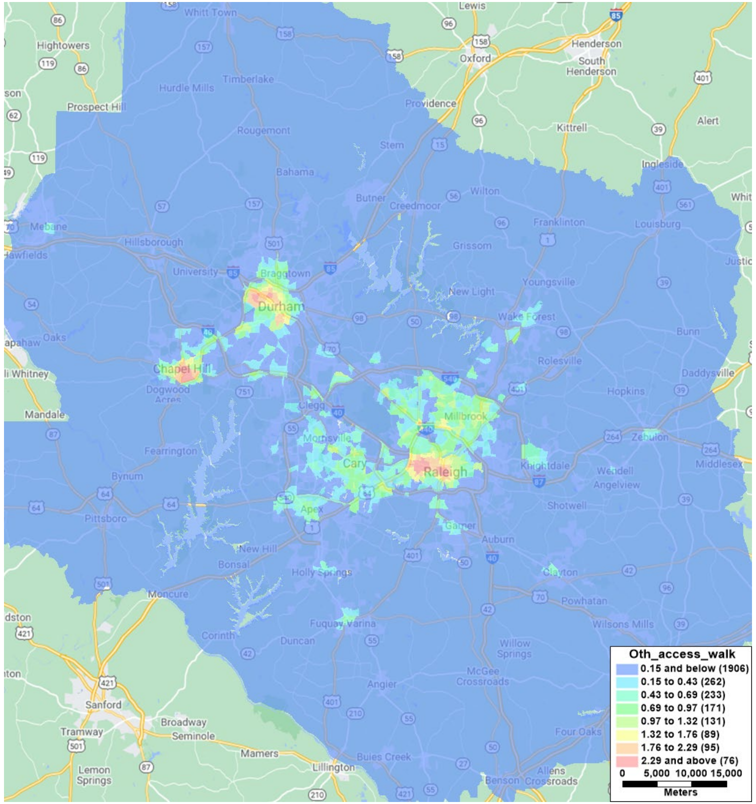


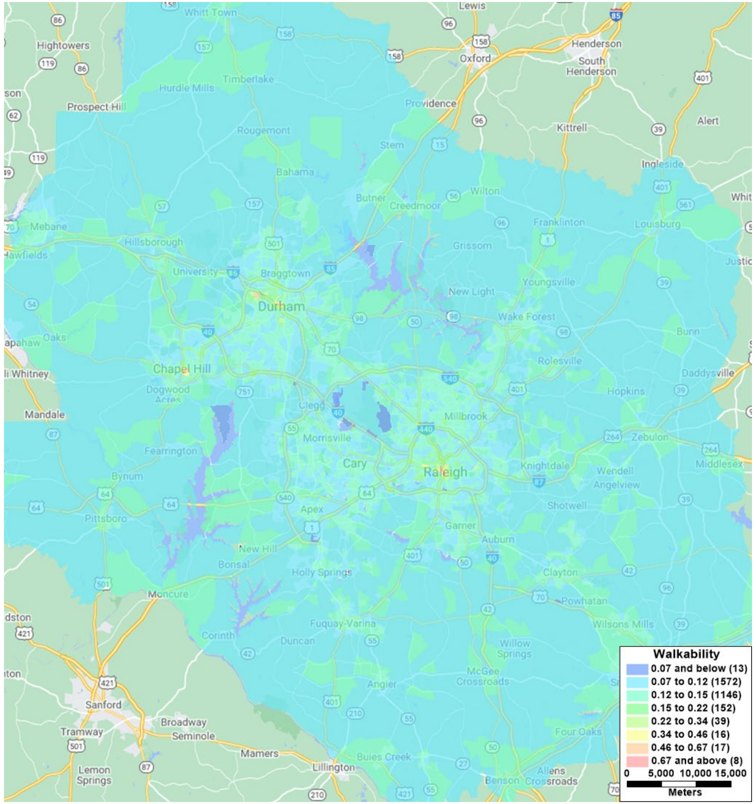
- Utility of walking in a zone is typically a function of *z-score transforms* of some explanatory variables

$$z(x) = \frac{x - mean(x)}{std.dev.(x)}$$

- Variables tested:
  - *Intersection approach density*
  - *Attraction density* (standard coefficients, buffered)
    - = 1.9 x HH + 1.5 x K12enr + 5.7 x Uenr + 18.7 x RetailEmp + 5.6 x ServiceEmp + 3.0 x OtherEmp
    - Dining included with retail
  - Mixed Use Index
  - *Industrial employment density* – was not significant

WALK ACCESSIBILITY VS. WALKABILITY





NON-MOTORIZED CHOICE

Nonwork HB-ODL

Parameter	Estimate	Std. Error	t Test
VehPerAdult	-1.116	0.128	-8.72
WalkAccessibility	0.431	0.088	4.91
IsChild	-0.456	0.119	-3.84
IsWorker	-0.279	0.094	-2.98
IncomePerCapita	0.000	0.000	2.70
Walkability	3.851	1.628	2.37
Const(NonMotorized)	-1.782	0.222	-8.04
Asymptotic rho squared	0.5888		
Adjusted rho squared	0.5874		

Nonwork HB-OME

Parameter	Estimate	Std. Error	t Test
VehPerAdult	-1.888	0.143	-13.22
WalkAccessibility	0.666	0.106	6.31
IsWorker	0.297	0.103	2.87
IncomePerCapita	0.000	0.000	4.52
Walkability	6.382	2.118	3.01
Const(NonMotorized)	-2.578	0.266	-9.70
Asymptotic rho squared	0.7190		
Adjusted rho squared	0.7179		

Nonwork HB-ODS

Parameter	Estimate	Std. Error	t Test
IsSenior	-0.361	0.083	-4.37
IsWorker	-0.189	0.060	-3.14
Walkability	0.277	1.718	0.16
HHwKids	-0.578	0.069	-8.44
NoAutos	0.888	0.213	4.16
IncomePerCapita	0.000	0.000	8.42
WalkAccess	0.018	0.073	0.25
Const(NonMotorized)	-0.198	0.210	-0.94
Asymptotic rho squared	0.0432		
Adjusted rho squared	0.0411		

Nonwork HB-OMED

Parameter	Estimate	Std. Error	t Test
NoAutos	2.165	1.135	1.91
IsSenior	-157479.4	310.0	-508.03
Const(NonMotorized)	-5.296	0.683	-7.76
Asymptotic rho squared	0.9661		
Adjusted rho squared	0.9607		

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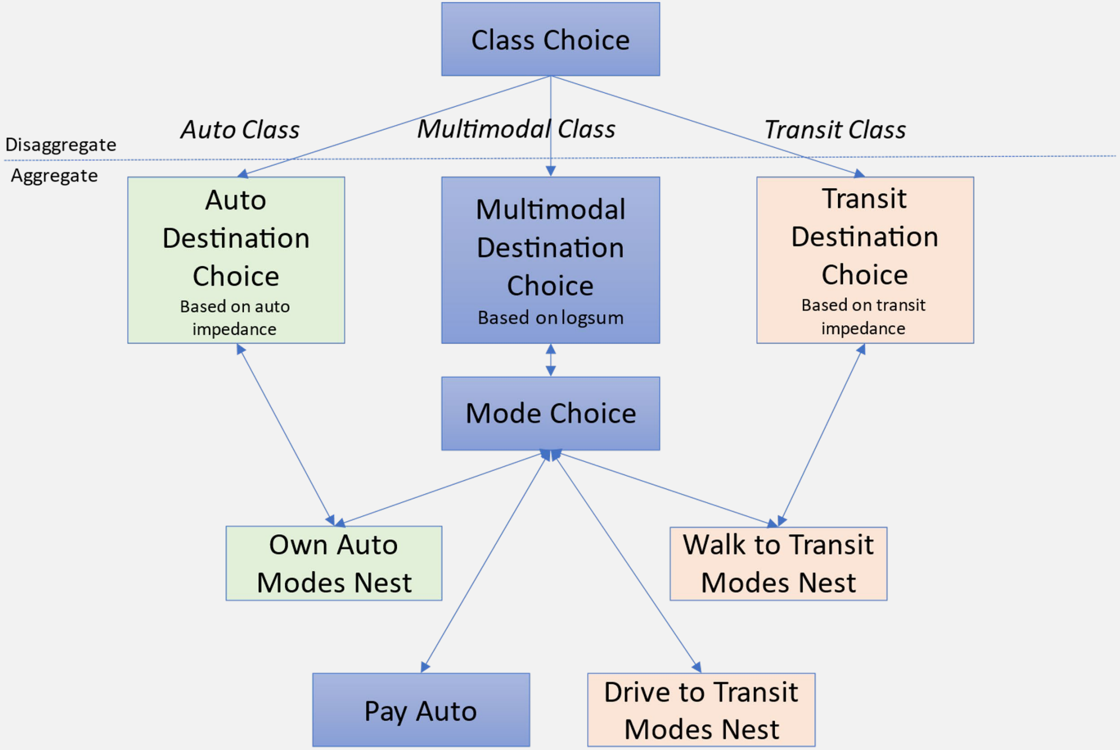
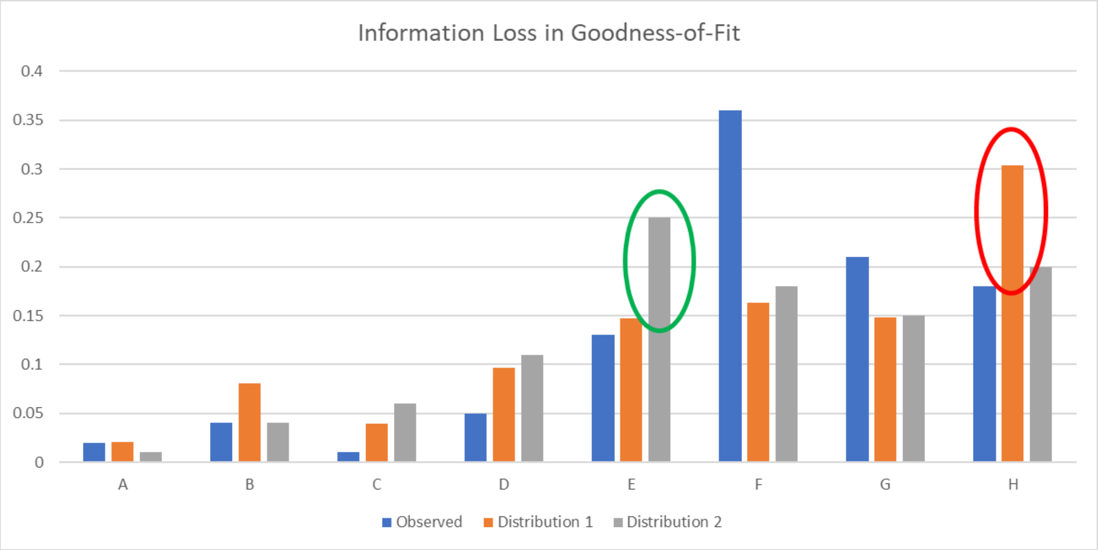
MODE & DESTINATION CHOICE

- Latent class approach
  - Three classes
    - Auto captives
    - Fee choosers
    - Transit captives
  - Disaggregate choice
    - Disability? Drivers license?
  - Partial segmentation
    - e.g., long + short discretionary
- Traditional, simple destination & mode choice for minor trip types



DESTINATION CHOICE

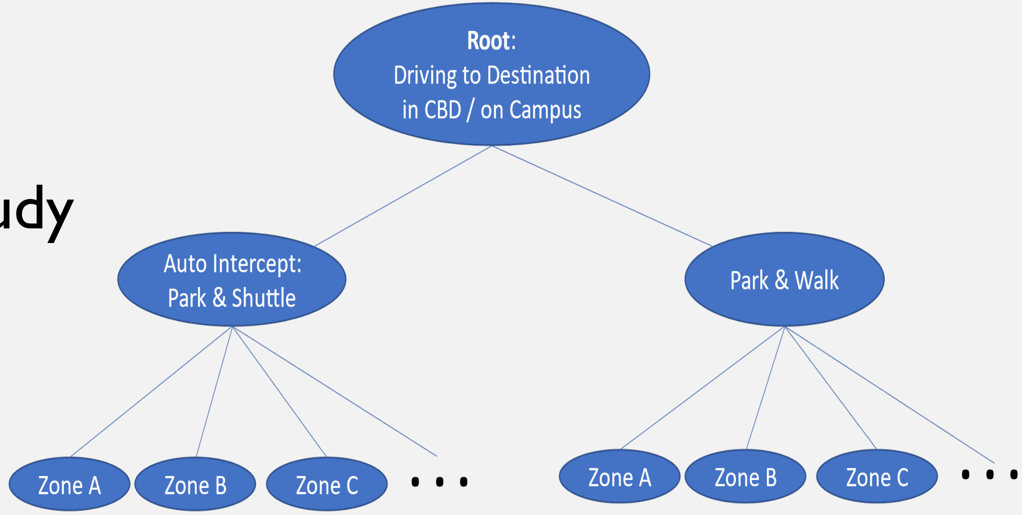
- Using minimum Wasserstein distance loss function
  - Powerful in computer vision; building on hierarchical destination choice
  - Gives credit for getting close



Log Likelihood	-1.85	-1.85
Wasserstein Distance	1.63	**1.20**

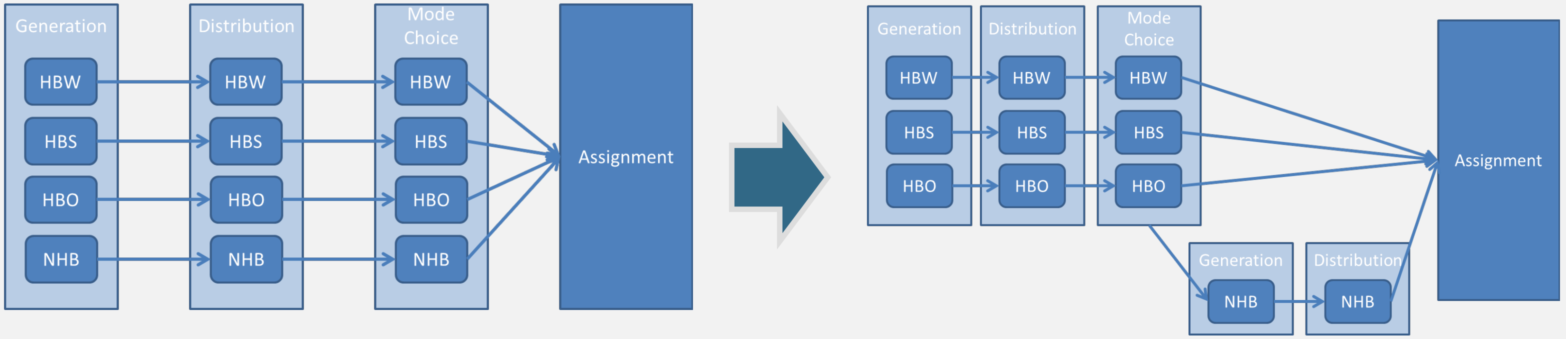
PARKING CHOICES

- Only for downtown & major campus areas
- Nested Mode & Destination Choice Model
  - Lowest level mode choice
    - park & shuttle (auto intercept)
    - park & walk
  - Parking zone choice
- Based on the 2016 study



NON-HOME-BASED TRIP MODELS (TMIP METHOD)

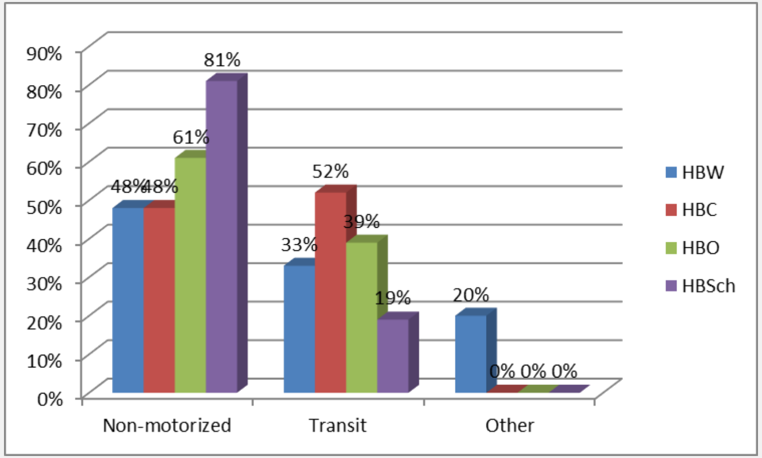
- After and conditional on HB trip models
  - NHB trips generated separately by mode based on HB trip destinations by mode (~Markov transition probabilities)

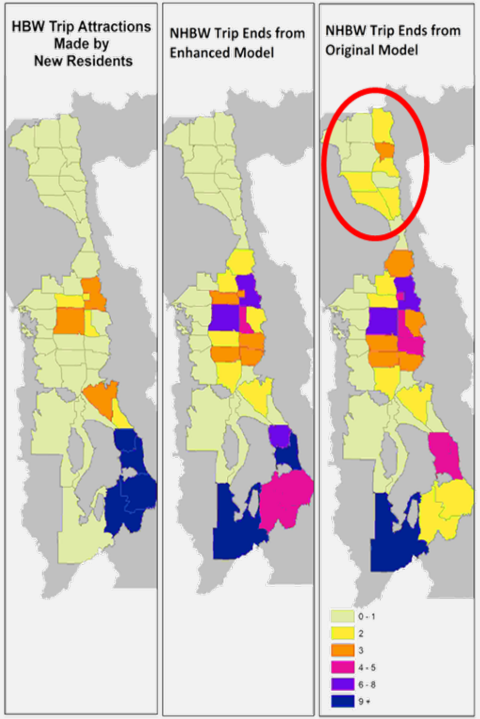


NON-HOME-BASED TRIP MODELS (TMIP STUDY)

- Creates consistency of modes and destinations within tours

Mode Shares of NHB Trips Generated by Transit HB Trips





- Segmentation of NHB trips (reporting)
  - A few residential segments (by home counties)

NHB TRIP GENERATION BY MODE

- Initially, we model NHB trips purely as a function of HB trips

$$\hat{Y}_{t,m} = \sum_{t,m} \beta_{t,m} X_{t,m}$$

- Where
  - Y is the number of NHB trips of a particular type and mode
  - $\beta_{t,m}$ are the coefficients which multiply
  - X are the number of HB trips by type, *t*, and mode, *m*
- Modeling NHB trip ends that are not attached to HB trips in other areas added complexity but little benefit

NHB TRIP GENERATION BY MODE

- TRM Example: N_NH_O_All_sov

term	estimated_as	estimate	std.error	statistic	p.value
N_HB_OD_Long_hov	N_HB_OD_All_hov	0.0209	0.0037	5.6162	0
N_HB_OD_Short_hov	N_HB_OD_All_hov	0.0209	0.0037	5.6162	0
N_HB_OD_Long_sov	N_HB_OD_All_sov	0.1034	0.0041	25.021	0
N_HB_OD_Short_sov	N_HB_OD_All_sov	0.1034	0.0041	25.021	0
N_HB_OME_All_hov	N_HB_OME_All_hov	0.0026	0.0034	0.7798	0.4355
N_HB_OMED_All_hov	N_HB_OME_All_hov	0.0026	0.0034	0.7798	0.4355
N_HB_OME_All_sov	N_HB_OME_All_sov	0.0292	0.0044	6.6661	0
N_HB_OMED_All_sov	N_HB_OME_All_sov	0.0292	0.0044	6.6661	0

  - All HB trip types (on Nonwork tours) by auto modes generate NHB SOV trips
  - No HB trips by non-auto modes generate NHB SOV trips
    - You have to have taken a car with you make a NHB trip by SOV.

NHB TRIP GENERATION BY MODE

- TRM Example: N_NH_OME_All_walk
  - NHB walk trips can be made by many more modes – because they don't require having a vehicle with you
  - Note how likely auto-pay HB trips are to generate NHB walk trips

term	estimated_as	estimate	std.error	statistic	p.value
N_HB_K12_All_t	N_HB_K12_All_t	0.0813	0.0472	1.7235	0.0848
N_HB_OD_Long_auto_pay	N_HB_O_All_auto_pay	0.5896	0.0225	26.237	0
N_HB_OD_Short_auto_pay	N_HB_O_All_auto_pay	0.5896	0.0225	26.237	0
N_HB_OME_All_auto_pay	N_HB_O_All_auto_pay	0.5896	0.0225	26.237	0
N_HB_OMED_All_auto_pay	N_HB_O_All_auto_pay	0.5896	0.0225	26.237	0
N_HB_OD_Long_hov	N_HB_OD_All_hov	0.0062	0.0028	2.238	0.0252
N_HB_OD_Short_hov	N_HB_OD_All_hov	0.0062	0.0028	2.238	0.0252
N_HB_OD_Long_t	N_HB_OD_All_t	0.0681	0.0218	3.1296	0.0018
N_HB_OD_Short_t	N_HB_OD_All_t	0.0681	0.0218	3.1296	0.0018
N_HB_OD_Long_walk	N_HB_OD_Long_walk	0.0398	0.0082	4.831	0
N_HB_OD_Short_sov	N_HB_OD_Short_sov	0.0129	0.0055	2.3628	0.0181
N_HB_OD_Short_walk	N_HB_OD_Short_walk	0.0131	0.004	3.261	0.0011
N_HB_OME_All_bike	N_HB_OME_All_bike	0.1197	0.0477	2.5095	0.0121
N_HB_OME_All_hov	N_HB_OME_All_hov	0.0075	0.0026	2.8264	0.0047
N_HB_OME_All_sov	N_HB_OME_All_sov	0.0251	0.0034	7.3015	0
N_HB_OME_All_t	N_HB_OME_All_t	0.0695	0.0276	2.5216	0.0117
N_HB_OME_All_walk	N_HB_OME_All_walk	0.1767	0.0089	19.884	0
N_HB_OMED_All_walk	N_HB_OME_All_walk	0.1767	0.0089	19.884	0
N_HB_OMED_All_hov	N_HB_OMED_All_hov	0.0168	0.0091	1.8509	0.0642

BOOSTING NHB GENERATION MODELS

- But not all HB trips (even of the same type and mode) are equally likely to generate NHB trips
- HB trips to high accessibility locations, with many other attractive destinations nearby are more likely to be connected to a NHB trip (to one of these other nearby destinations)
- So, we can boost our original model with this additional information (accessibility) to produce an even better model
- *But, this doesn't always work for work tours, both because NHB trips on subtours break the relationship and because convenience has little effect on work relatd trips*

BOOSTING NHB GENERATION MODELS

- So, we model NHB trips as function of HB trips and accessibility

$$Y = \alpha A^{\gamma} \sum_{t,m} \beta_{t,m} X_{t,m}$$

- Where
  - A is a measure of accessibility to nearby destinations
  - α and γ are parameters

- This way, the accessibility term (αA^{γ}) scales the productivity of the HB trips

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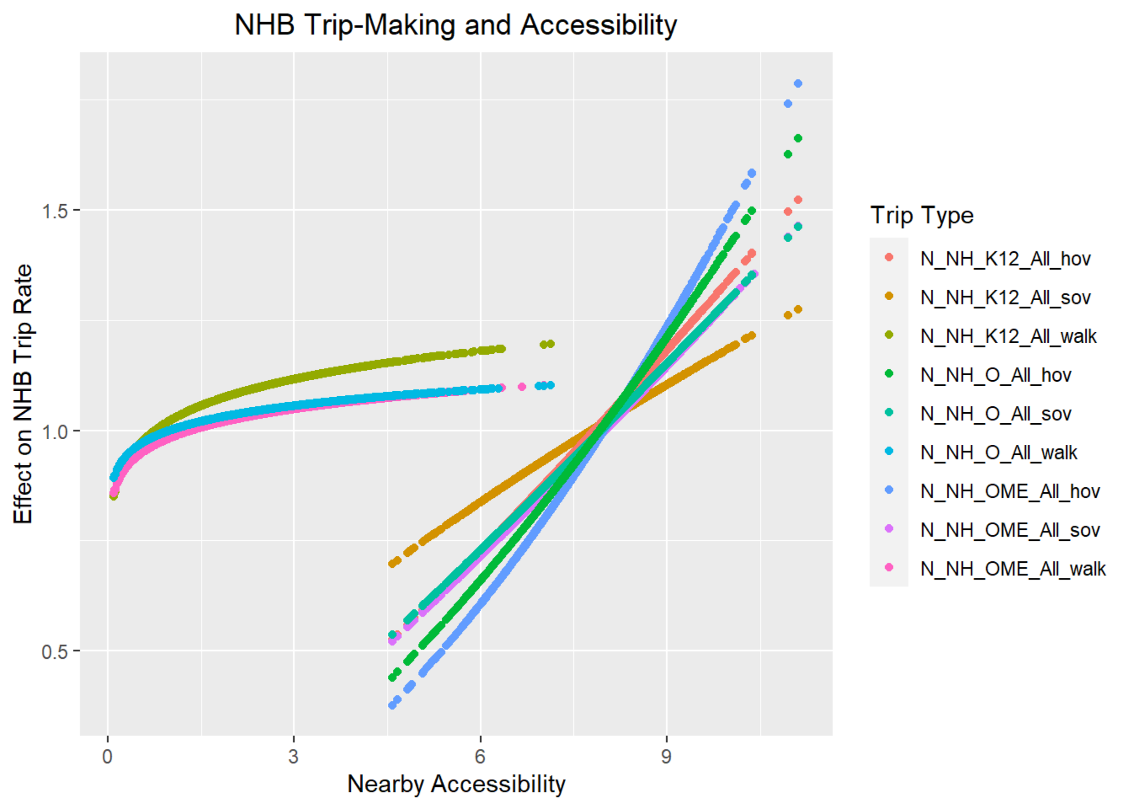
BOOSTING NHB GENERATION MODELS

- The NHB trip rate is decreased (~50%) in rural areas
- And the NHB trip rate marginally increases (up to ~+50%) in more accessible areas
- NHB by walk approaches 0 in non-walkable areas



SPECIAL MARKETS

- Universities
  - Stratifying students by (major) university
  - University trip purposes
    - Home-Based-Campus (UHC)
    - Home-Based-Other (UHO)
    - Campus-Based-Other (UCO)
    - On-Campus (UC1)
    - Inter-Campus (UCC)
    - University student Other-Other (UOO)
  - Simple component models (rates, gravity)
  - Logit mode choice models
- Simple models for airport trips
  - Driven by Streetlight / rMerge data

CVS AND TRUCKS

- Long-haul (external) trucks
  - From NCSTM
  - Based on ATRI
  - Long haul truck congested route choice as preload to general equilibrium
- Short-haul (internal) trucks & CVs
  - Simple trip-based (e.g., QRFM-style) model
  - But with linkage to Long-haul trucks

EXTERNAL MODELS

- Model boundary adjustments
  - New external station counts
- OD patterns from NCSTM/rMerge & Streetlight
- NHBNR (visitor) trips
  - Based on Streetlight / rMerge
  - CTPP & LEHD for in-commuters

ASSIGNMENT / VALIDATION / TESTS

- Highway Assignment
  - N-conjugate FW (MMA)
  - VDF TBD
  - Relative gap: 10^-5 or tighter
- Feedback
  - Independent by TOD
- Tolling
  - Determined by assignment
- Transit Assignment
  - Caliper's Pathfinder algorithm
- Validation
  - Upper-level models
  - Regional and link-level validation of highway assignment (next slide)
  - Boardings / Alightings by route and transit company
- Sensitivity testing
  - Measuring model response to specific, localized changes

ASSIGNMENT / VALIDATION / TESTS

1. 75% of freeway link within +/- 20% of traffic counts.
2. 50% of freeway link within +/- 10% of traffic counts.
3. 75% of links with 10,000 vehicles per day within +/- 30% of traffic counts.
4. 50% of links with 10,000 vehicles per day within +/- 15% of traffic counts.

Facility Type, Area Type, Counties	Target % Difference	
	Preferable	Acceptable (FHWA)
Interstate & Freeway	5%	7%
Major Arterials	8%	10%
Minor Arterials	10%	15%
Collectors & Locals	15%	25%
Each County	10%	15%
Urban, Suburban & Rural Area Types	10%	10%
Total	5%	10%

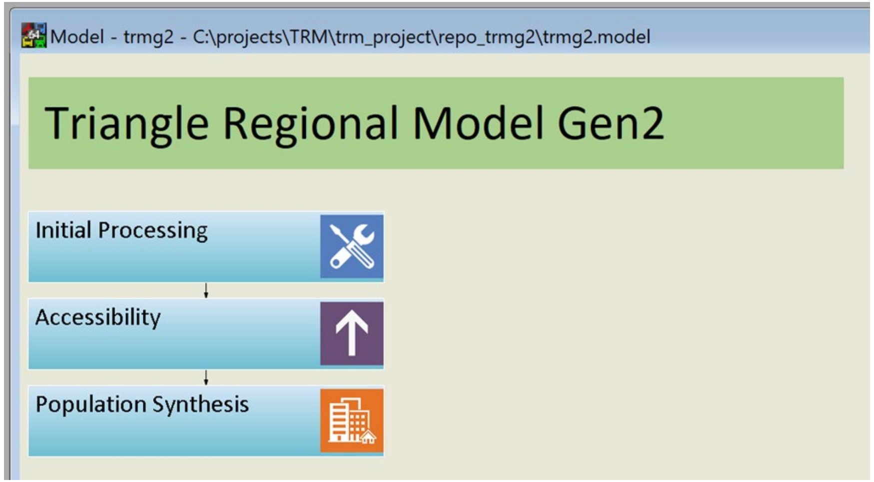
Facility Type	Target % RMSE
Interstate & Freeway	20%
Principal Arterials	35%
Minor Arterials	50%
Collectors	90%
Total	30 – 40%

Overall $r^2 \geq 0.90$

Volume Range	Desirable Percent Deviation	Desirable Percent RMSE
Less than 5,000	50%	100%
5,000 – 9,999	25%	45%
10,000 – 14,999	20%	35%
15,000 – 19,999	20%	30%
20,000 – 29,999	20%	27%
30,000 – 49,999	15%	25%
50,000 – 59,999	10%	20%
Greater than 60,000	10%	19%
Area wide (daily)	10%	40%

SCRIPTING / GITHUB / GUI

- TransCAD 9 platform
  - Flowchart front end
  - Final delivery will include all improvements over next 2 years



- 100% GISDK core model
  - Option for supplemental tools in R (e.g. validation already delivered)

- Model in GitHub repository

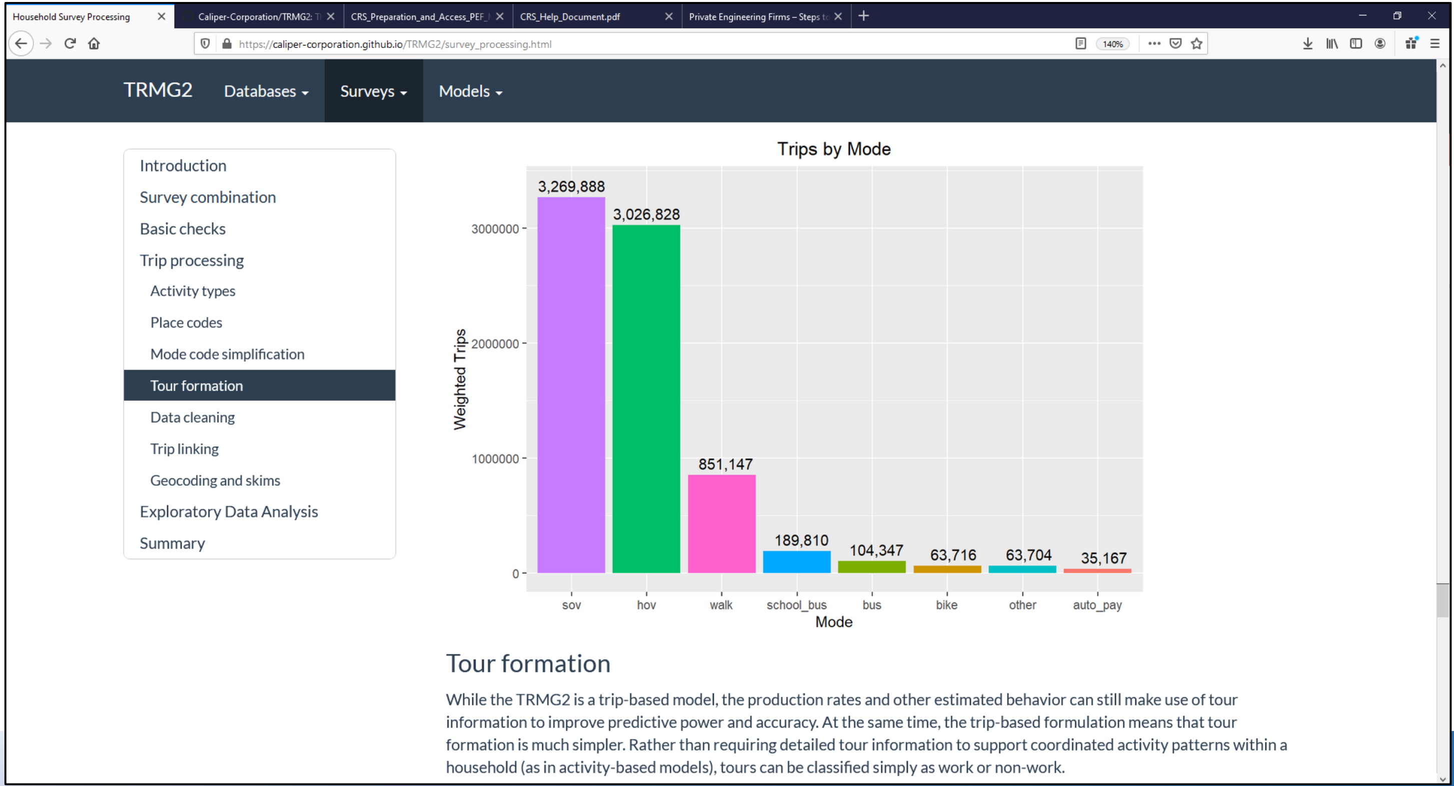
TASK 14 – POST PROCESSING TOOLS

- Automated reports and mapping
  - Volume/Capacity map
  - VMT / VHT by area type and facility type
  - Transit ridership by mode and time of day
  - Percent of households by type within ½ mile of transit stop
  - Regional mode shares
  - Data tables for input to MOVES

- Additional reporting tools as budget and schedule allow
  - VMT per person summarized to various geographies (including NHB)
  - Mode share summaries by region or TAZ
  - Accessibility measures (e.g. number of jobs within 30 minutes of each TAZ)

DOCUMENTATION

- Online documentation (GitHub pages)



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