CALIBRATION/VALIDATION REPORT - VERSION 9.0.0

WFRC / MAG

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1 Wasatch Front Travel Demand Model Documentation

The Wasatch Front Travel Demand Model (WF TDM) is a macro transportation model. It forecasts daily travel patterns based on household characteristics and where people live in relation to the location of their daily activites and transportation opportunities. Travel decisions are based on a series of models that are calibrated to travel behavior of Wasatch Front residents measured from household travel diary surveys. Trips are assigned to a set of highway or transit-system routes by time of day based on where and by what mode people are likely to travel and the best route available to them.

The travel demand models are able to evaluate transportation and traffic impacts resulting from:

» transportation improvements
» provision of new modes of travel and/or enhancement of existing alternative modes
» changes in land use activity
» changes in travel behavior or policies/economic circumstances affecting behavior

As such, travel demand output is used to forecast where future travel demand is likely to exceed capacity and to assess the merits of future transportation investments. Travel demand output is also used to analyze air quality and other ancillary impacts of the transportation system.

The current WF TDM covers Weber, Davis, Salt Lake, and Utah Counties and a portion of Box Eder County. The WF TDM is jointly owned by the Wasatch Front Regional Council (WFRC) and the Mountainland Association of Governments (MAG). To request a copy of the WF TDM, please contact the following persons:

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» Matt DeLora (MAG): mdelora@magutah.org

2 Life Cycle

The Life Cycle model determines the how much of the TAZ population and households from the processed socioeconomic input file will be in one of three life cycle categories:

- Life Cycle 1 – households with no children and no seniors
- Life Cycle 2 – households with children and no seniors
- Life Cycle 3 – households with seniors (may have children)

The Life Cycle model does its calculations in three phases:

- Determine the TAZ population that is in three age groups
- Determine each age group population that is in the three life cycle categories
- Determine the number of households in each life cycle category

2.1 Population by Age Group

The Life Cycle model first estimates how much of the TAZ population falls into one of three Age Group categories:

- Age Group 1 – 0 to 17 years old
- Age Group 2 – 18 to 64 years old
- Age Group 3 – 65+ years old

The initial share of the TAZ population in each Age Group is determined by multiplying the TAZ household population by the TAZ-level Age Group percentages in the `Lookup - BYTAZAgePct - AllCo.csv` file located in the `1_Inputs\\0_GlobalData\\1_HHDisag_AutoOwn` directory. These initial TAZ-level Age Group percentages were calculated from 2020 Census block and 2020 ACS block group data summarized at the TAZ level.

The Census data was also summarized at the medium district level. If the Census TAZ data had fewer than 50 people, the percentages from medium districts were used. The medium district distribution of 2020 Census Age Group percentages for the Wasatch Front can be seen in Figure 2.1. The share of population in each of the Age Groups varies significantly by geography. Urban areas tend to have the highest share of population 18-64 years old and the fewest children and seniors. Suburban and rural areas tend to have the highest share of children.

The initial TAZ-based population by Age Group is then factored to reflect the year being modeled. This is done using the county population by Age Group forecasts found in `ControlTotal_Age.csv` located in `1_Inputs\\2_SEData\\_ControlTotals` directory. The Age Group county-level percentages are calculated from county-level population projections from the Kem C. Gardner Policy Institute (GPI), 2020-2060 State and County Total Population by Sex and Single-Year of Age. The GPI projections show a trend in all counties in the Wasatch Front model space toward a more senior population and fewer children. Adult population in the age range of 18-64 also saw a slight increase in population share.

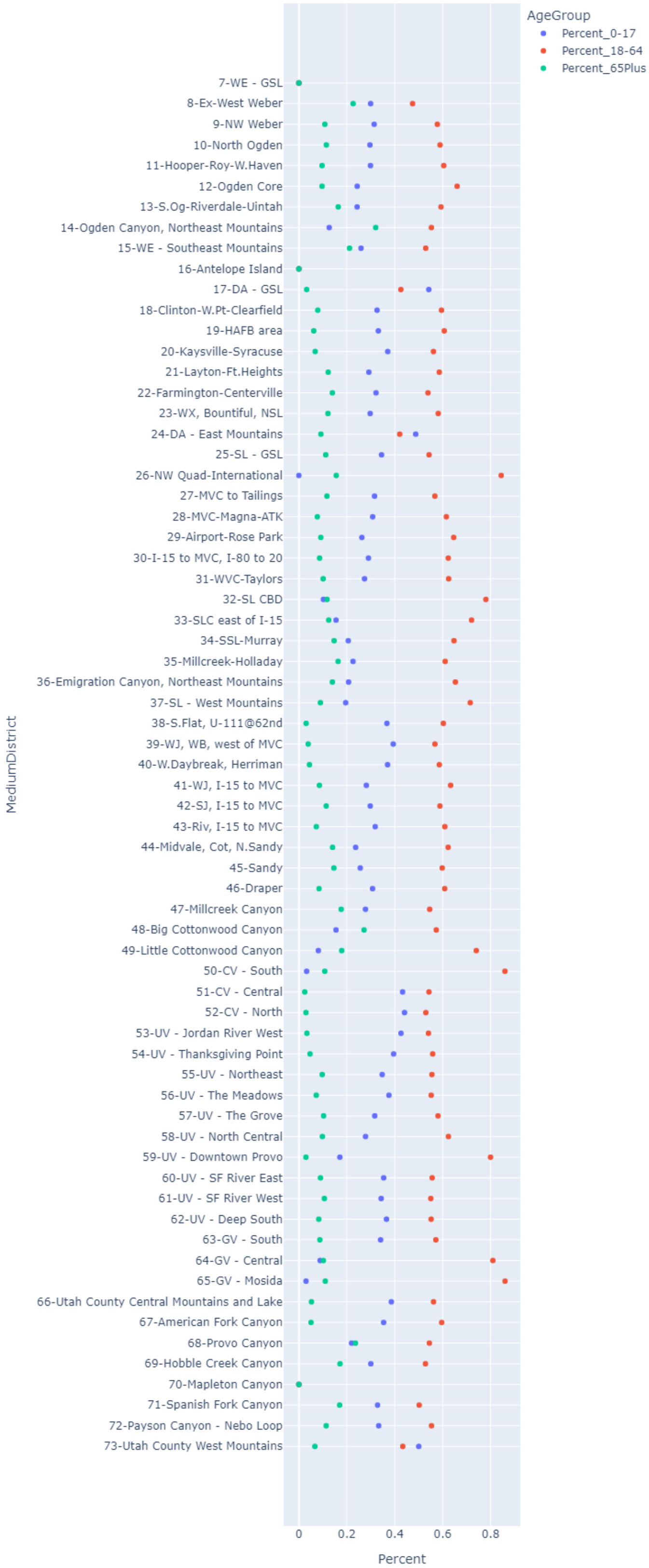

Figure 2.1: 2020 Census % Population by Age Group by Medium District.

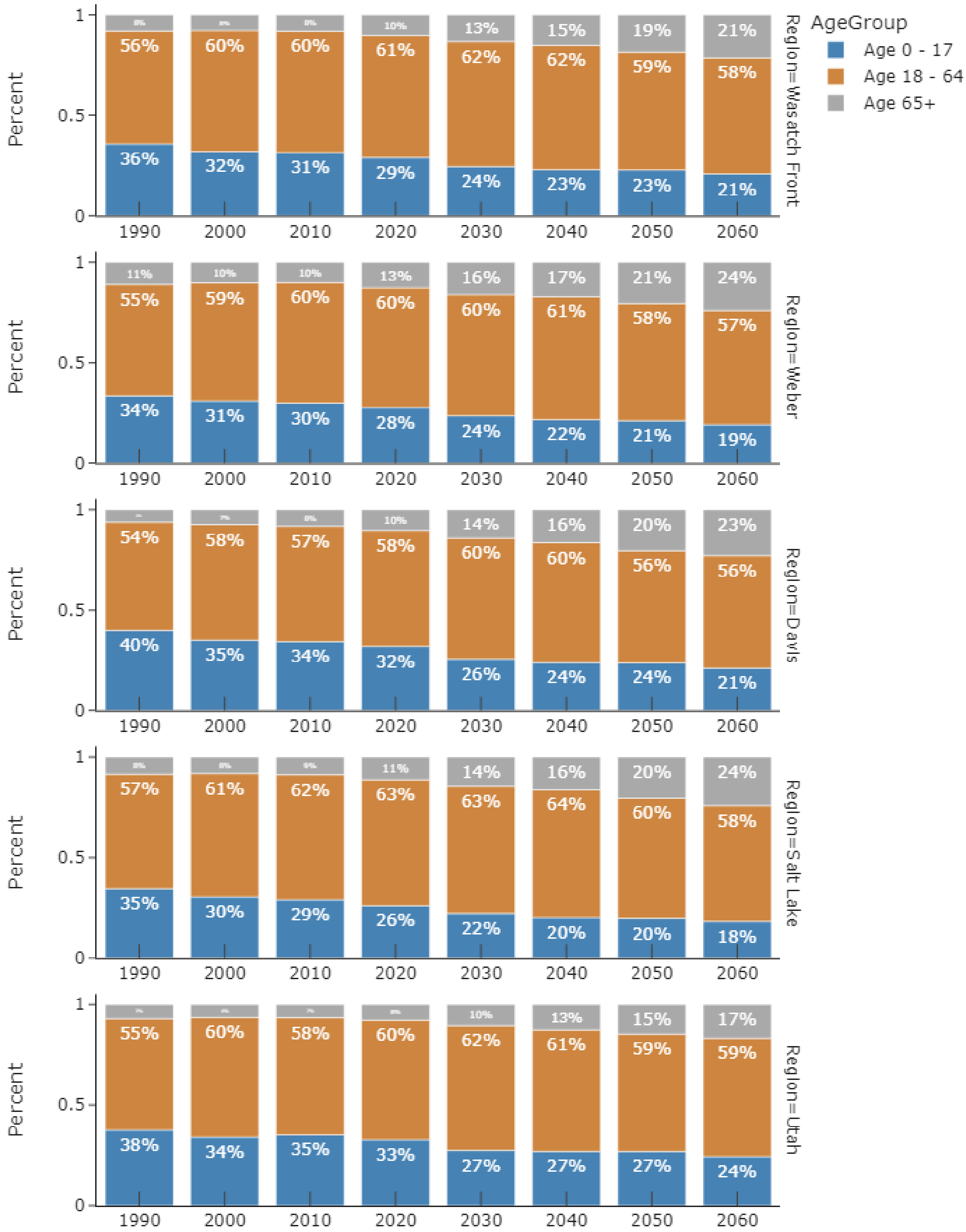

Figure 2.2: GPI County Population Projections by Age Group for Wasatch Front Counties.

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The 2020 model base year population by county and Age Group was compared to the 2020 GPI county-level population by Age Group, shown in Figure 2.3. The model's estimate of the population in each Age Group mirrors the GPI county-level projections.

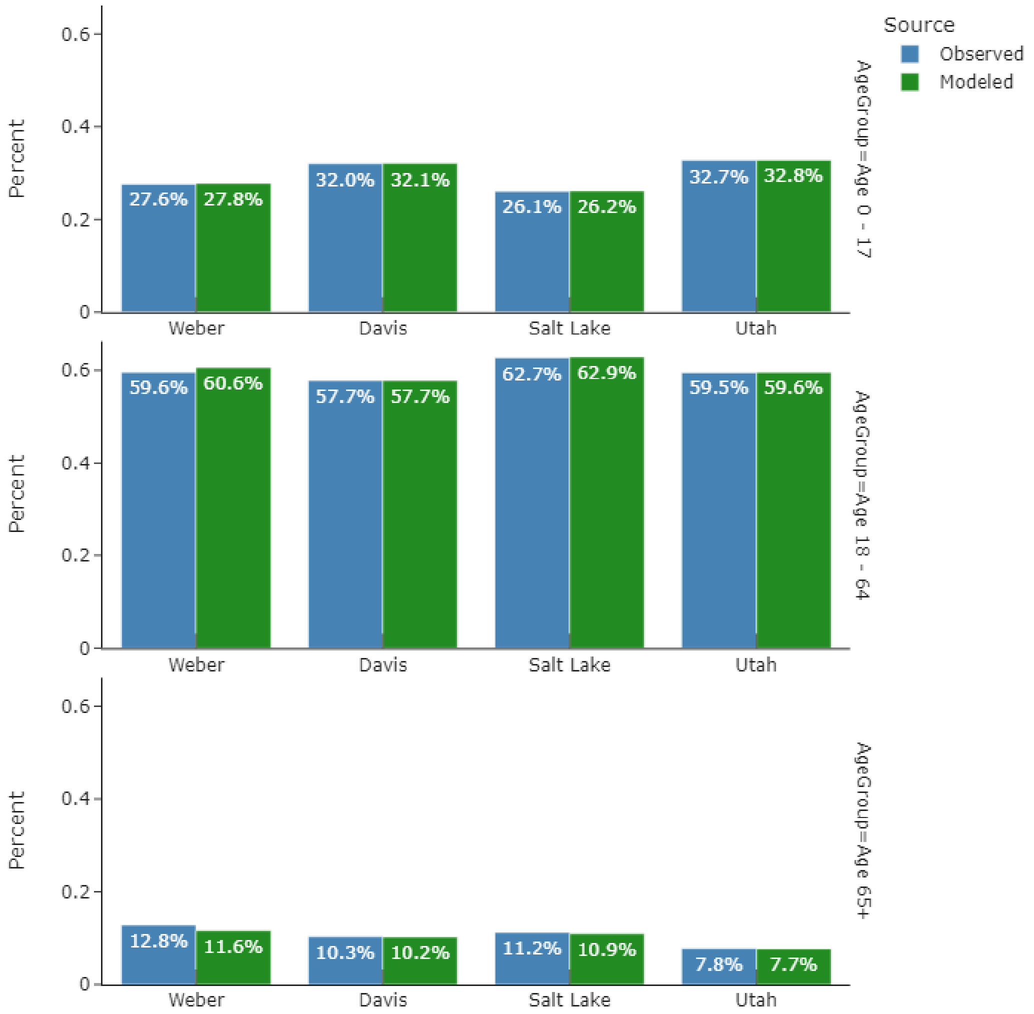

Figure 2.3: 2020 Model vs. 2020 GPI – % Population by Age Group and County.

2.2 Population by Life Cycle

The Life Cycle model uses parameters estimated from the 2012 Household Survey to convert population in Age Groups to population in a Life Cycle category. Unique parameters were estimated for each county and are found in Table 2.1.

Table 2.1: Percent of Age Group Population in Life Cycle 2 by County

County	0-17 Population Age Group (LC2 Fac 0-17)	18-64 Population Age Group (LC2 Fac 18-64)
Box Elder	0.993	0.664
Weber	0.982	0.606
Davis	0.974	0.711
Salt Lake	0.961	0.525
Utah	0.981	0.659

Only factors for Life Cycle 2 were estimated. Life Cycle 1 has no children leaving the 0-17 population to be divided between Life Cycles 2 and 3. Life Cycle 3 has no adults age 18-64 leaving the 18-64 population to be divided between Life Cycles 1 and 2. All of 65+ population lies completely within Life Cycle 3. Table 2.2 contains the equations used to calculate Life Cycle population.

Table 2.2: Equations to Calculate Age Group Population in Each Life Cycle Category

Age Group	Life Cycle 1	Life Cycle 2	Life Cycle 3
0-17	0	LC2 Fac 0-17	1 – (LC2 Fac 0-17)
18-64	1 – (LC2 Fac 18-64)	LC2 Fac 18-64	0
65+	0	0	1

Almost all of the child-aged population is contained within Life Cycle 2, ranging between 96.1% in Salt Lake County and 99.3% in Box Elder County. The remaining child population is in Life Cycle 3. The majority of the adult-not-a-senior population is contained in Life Cycle category 2, ranging between 52.5% in Salt Lake County and 71.1% in Davis County, with the remainder falling into Life Cycle 1.

The shares of the modeled 2019 base year population by Life Cycle were compared to the 2012 Household Survey at the county level. The model's estimate of population by Life Cycle category seemed reasonable at this level of geography with all modeled comparison points falling within 4% of the observed data.

2.3 Households by Life Cycle

The Life Cycle model calculates households by Life Cycle using the average household size for each Life Cycle category. Unique average household sizes were estimated for each county and Life Cycle from the 2012 Household Survey.

Table 2.3: Average Household Size by Life Cycle and County

County	Household Size for Life Cycle 1	Household Size for Life Cycle 2	Household Size for Life Cycle 3
Box Elder	1.86	4.21	2.41
Weber	1.88	4.53	1.81
Davis	2.14	4.68	2.33

County	Household Size for Life Cycle 1	Household Size for Life Cycle 2	Household Size for Life Cycle 3
Salt Lake	1.86	4.44	1.81
Utah	2.11	4.75	2.21

The TAZ-level population by Life Cycle category are divided by the average household size factors to generate an estimate of the share of TAZ-level households in each Life Cycle category. The share of households in each Life Cycle category is then multiplied by the total households in the TAZ to get the adjusted number of households per Life Cycle category.

A final check is made to avoid unrealistic household sizes for zones with smaller populations. The number of households for a given Life Cycle category are capped at the minimum and maximum household sizes found in Table 2.4.

Table 2.4: Allowed Minimum and Maximum Average Household Size by Life Cycle

Life Cycle Category	Minimum Household Size	Maximum Household Size
1	1	4
2	2	8
3	1	4

The shares of the modeled 2019 base year households by Life Cycle were compared to the 2012 Household Survey at the county level. The model's estimate of households by Life Cycle category seemed reasonable at this level of geography with all modeled comparison points falling within 1.5% of the observed data.

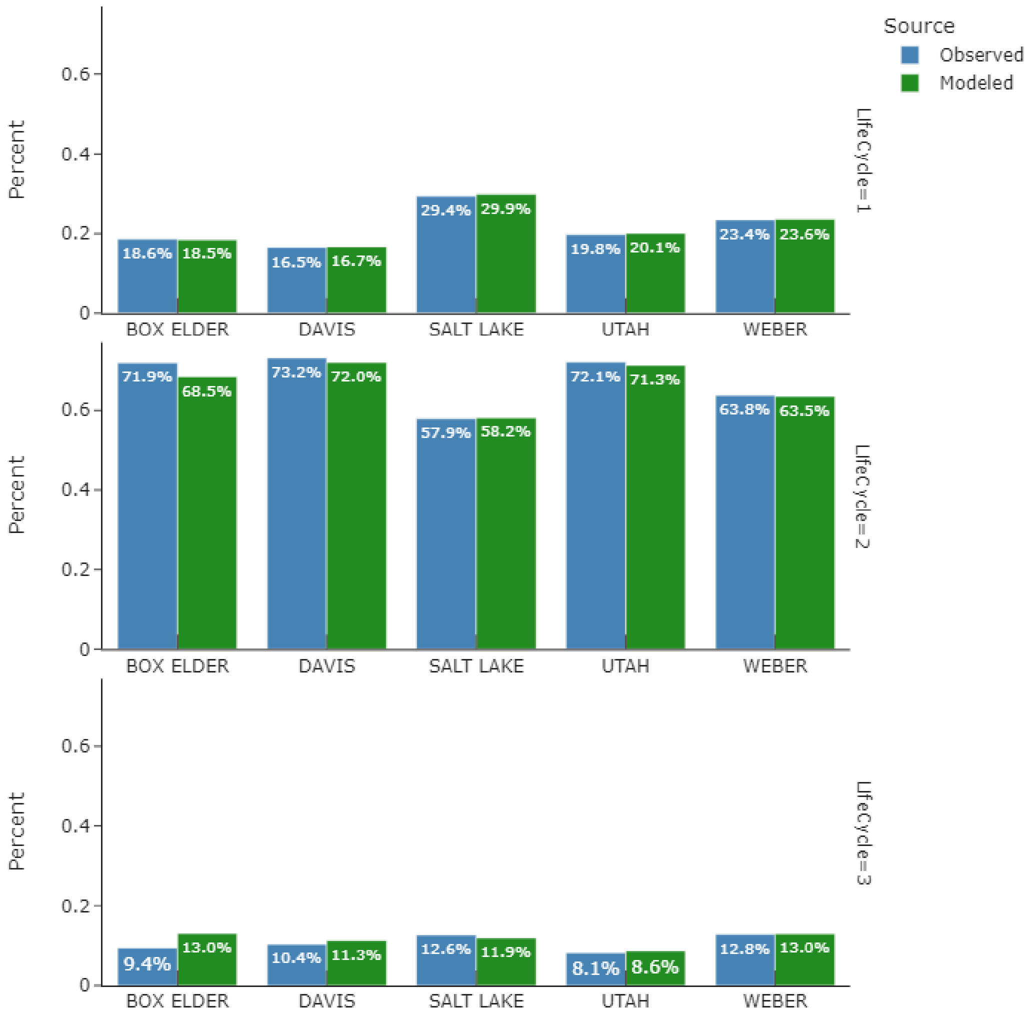

Figure 2.4: 2019 Model vs. 2012 Household Survey – % Population by Life Cycle and County.

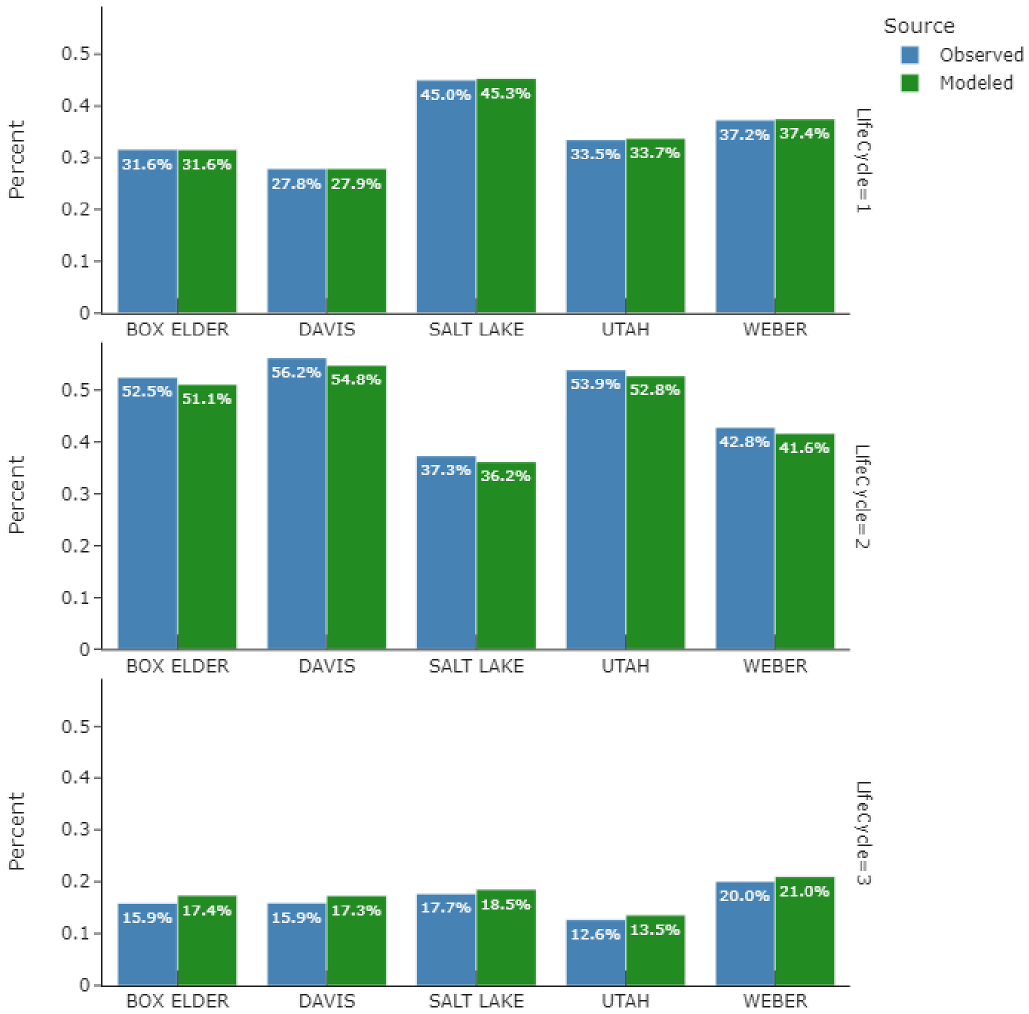

Figure 2.5: 2019 Model vs. 2012 Household Survey – % Households by Life Cycle and County.

3Household Disaggregation

The Household Disaggregation model classifies a TAZ's households by:

- Household Size
- Income
- Number of Workers

Household Disaggregation is done in three steps with each step adding another level of disaggregation: estimating the distribution of households by size group, further disaggregation by income group and income level, and further disaggregation by number of workers per household. This results in 96 groupings when using the four income groups or 48 groupings when using low/high income levels.

For disaggregation to household size groups, the following lookup files contain the distribution of households across the six household size groups according the average household size for the three life cycle categories: `Lookup - HH Size_LC1.csv`, `Lookup - HH Size_LC2.csv`, and `Lookup - HH Size_LC3.csv`. The distributions in these files are grouped by county. There is also a third lookup file that contains a regional distribution used for comparison purposes: `Lookup - HH Size.csv`. When computing income ratios, the regional median household income of $74,946 (2019 dollars) is used from the latest ACS.

Further disaggregation by income groups is done in multiple steps. First a target TAZ distribution by income is calculated using a county distribution found in `Lookup - Income.csv`. Then a Fratar/Furness balancing method is used to get the matrix distribution across income groups and household sizes. The matrix is initialized with the values found in Table 3.1, which is hard-coded into the `2_HHDisaggregation.s` script with the source being the 2012 Household Survey. The balancing method is run through until convergence is reached at (0.0001) or a max of 15 iterations.

Table 3.1: Initialization Seed Values for Household Size and income Group

Household Size	Income Group 1 Seed	Income Group 2 Seed	Income Group 3 Seed	Income Gruop 4 Seed
1	0.591	0.167	0.21	0.032
2	0.286	0.155	0.351	0.208
3	0.253	0.18	0.351	0.216
4	0.211	0.151	0.395	0.243
5	0.154	0.157	0.46	0.229
6	0.118	0.122	0.479	0.281

Final disaggregation by worker is a simple distribution which is found in the `Lookup - Worker.csv` file. This file contains a distribution across the worker groups by each of the 24 combinations of the six household size groups and the four income groups. Households are then aggregated back to the two income levels (low/high).

3.1 Household Size

The Household Disaggregation model estimates how many households are in six Household Size categories:

- 1 person households
- 2 person households
- 3 person households
- 4 person households
- 5 person households
- 6 or more person households

The model uses the TAZ's average household size to look up the share of households in each of the six Household Size categories. This is done independently for each of the three Life Cycle categories estimated in the previous model step.

???Is there newer data than the 2018 spreadsheet???

2010 Census Block Group data was used to determine the initial relationship between average household size and the number of households in each size category. To increase sample size, all Block Groups in Utah were included. Draft curves were estimated from the data's polynomial trendline as shown in Figure 3.1.

The results from the equations derived from the Census data were adjusted to remove negative values and to smooth and scale the resulting curves. The sum of the individual curves at any given average household size is 1. Figure 3.2 shows the smoothed curves for household size share by average household size.

The 2012 Household Survey was used to estimate the share of households in each Household Size category by Life Cycle. The entire statewide database was used and aggregated to medium districts in order to obtain sufficient number of survey records in a group yet preserve a sufficient number of observations to estimate lookup curves by Life Cycle. The estimated Life Cycle curves were then used to weight the Household Size lookup curves derived from the Census data (termed "All Data" in Figure 3.3) to obtain Household Size lookup curves by Life Cycle.

The Household Size lookup curves were then calibrated to county-level household size data from the 2010 Census as shown in Figure 3.4, Figure 3.5, and Figure 3.6. The county-level adjustments were done to tailor to the lookup curves to account for local variations.

The shares of the modeled 2015 base year households by Household Size category were validated to 2010 Census and 2016 ACS data at the county level. The model's estimate of households by each of the six Household Size category matches within about 2% of the observed data for all counties.

???Update to use 2019 Model???»

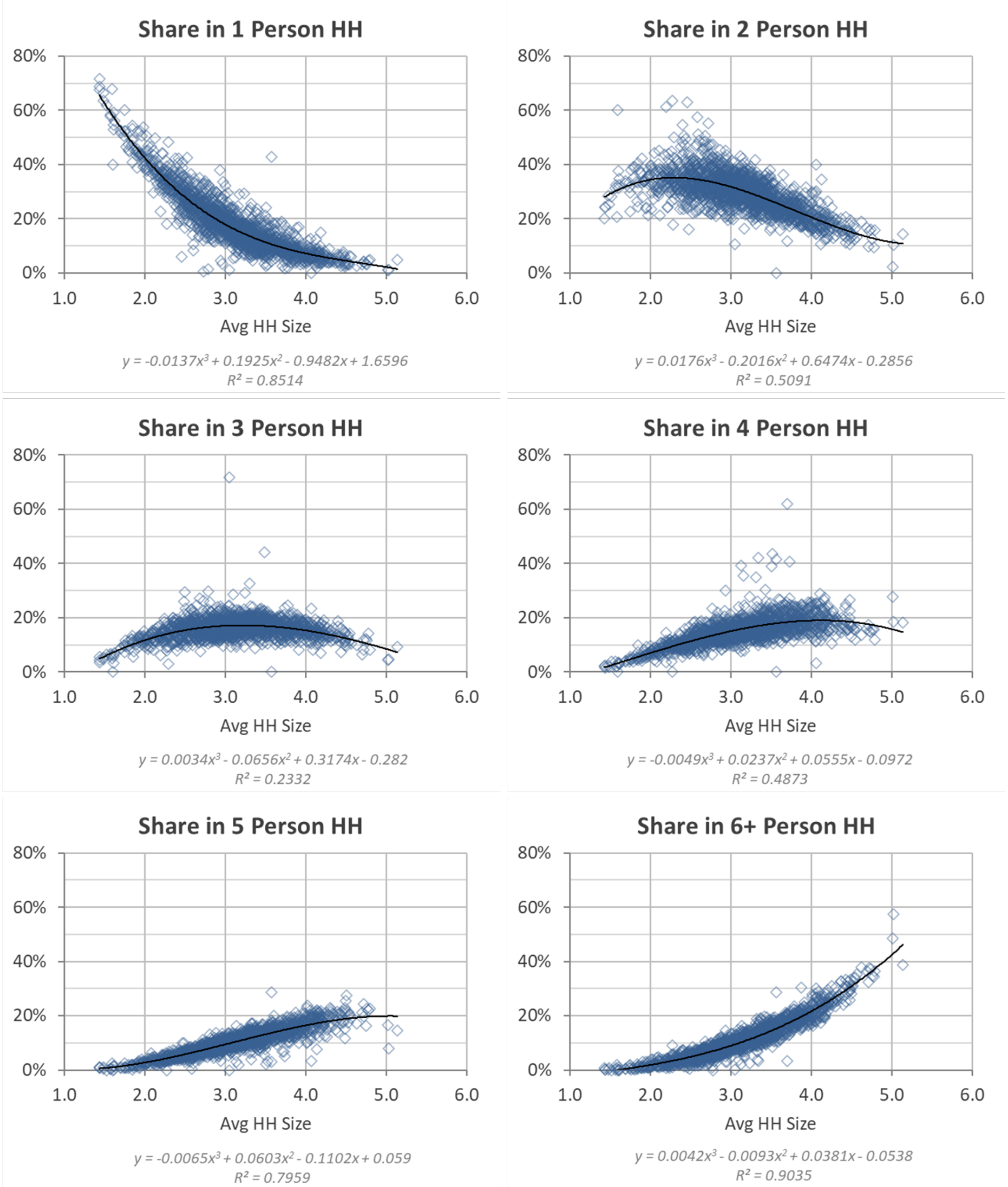

Figure 3.1: 2010 Census Block Group Data - Household Size Share by Average Household Size.

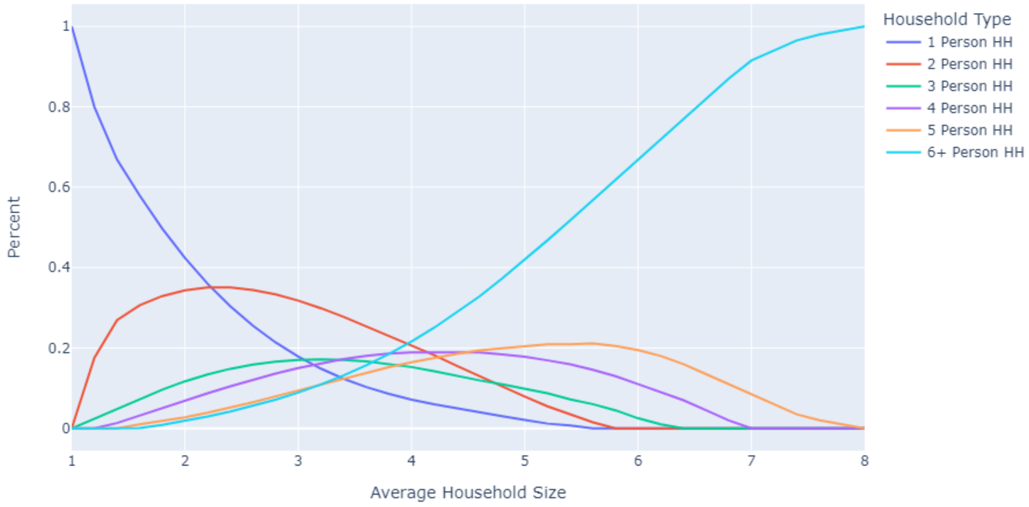

Figure 3.2: Household Size Share by Average Household Size – All Data.

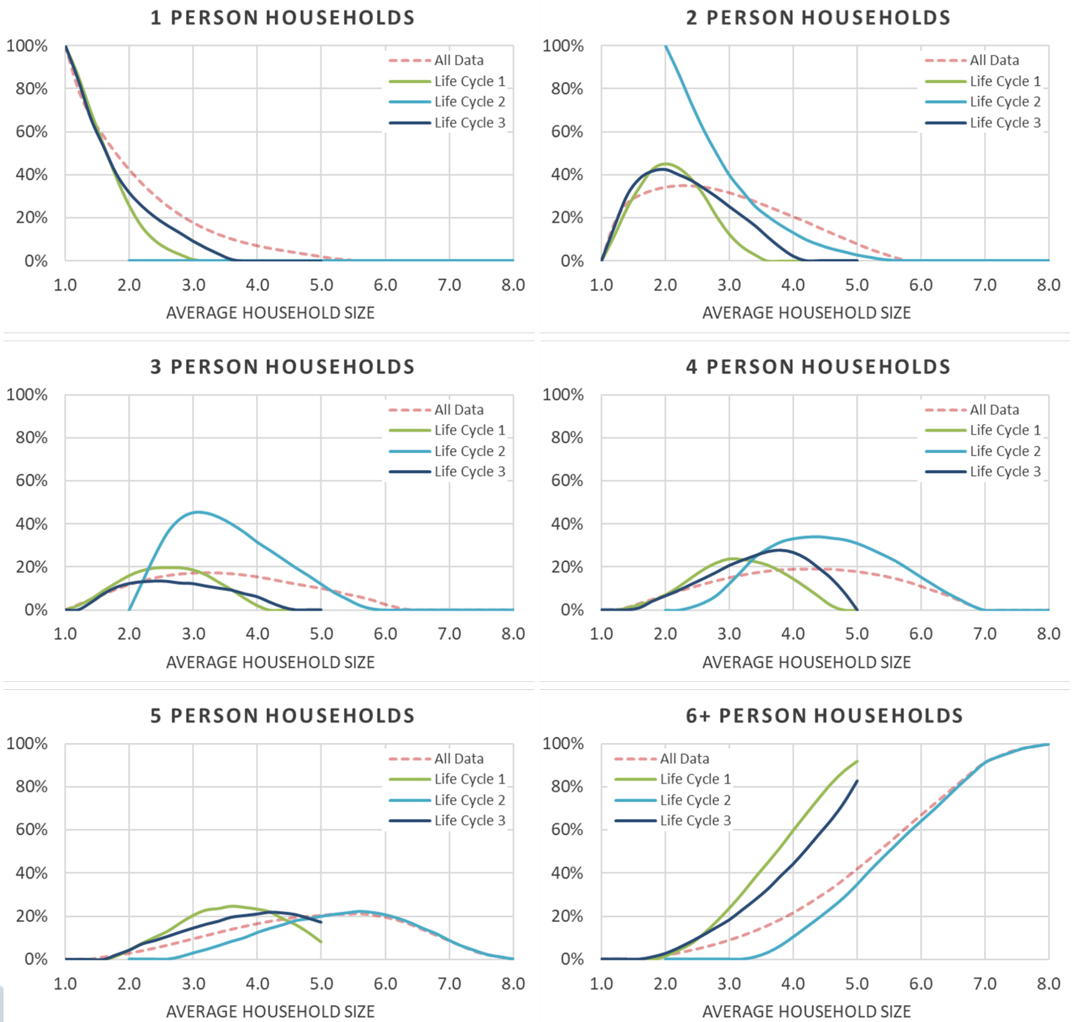

Figure 3.3: Comparison of Life Cycle and All Data Household Size Lookup Curves.

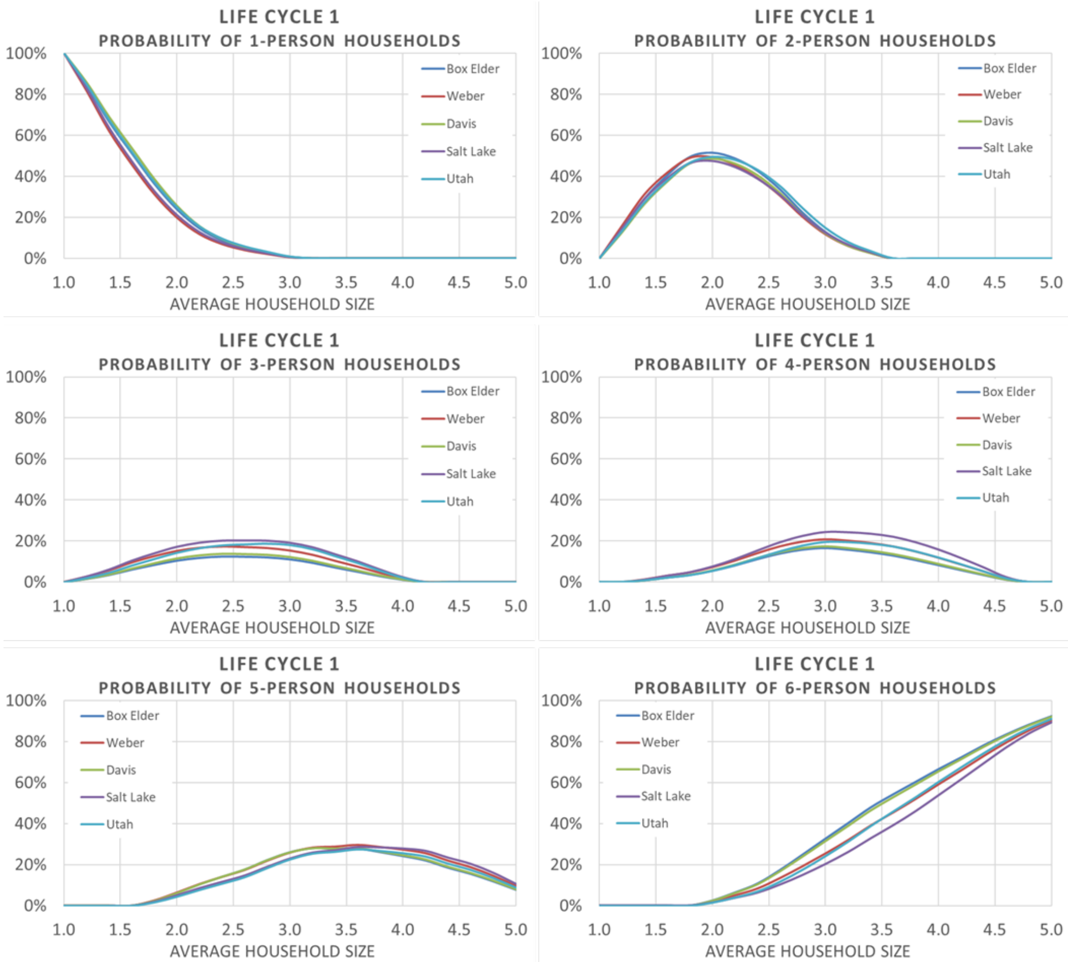

Figure 3.4: Comparison of Household Size Lookup Curves by County – Life Cycle 1.

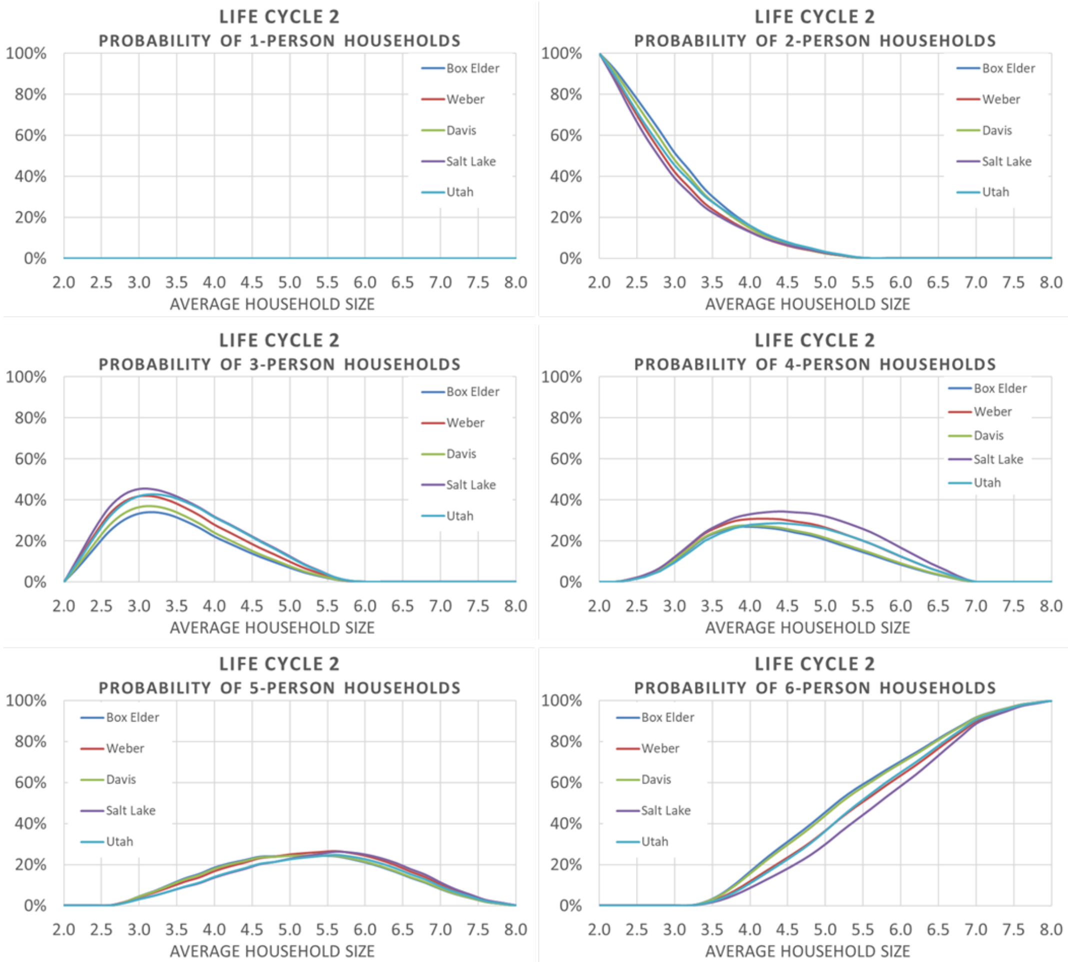

Figure 3.5: Comparison of Household Size Lookup Curves by County – Life Cycle 2.

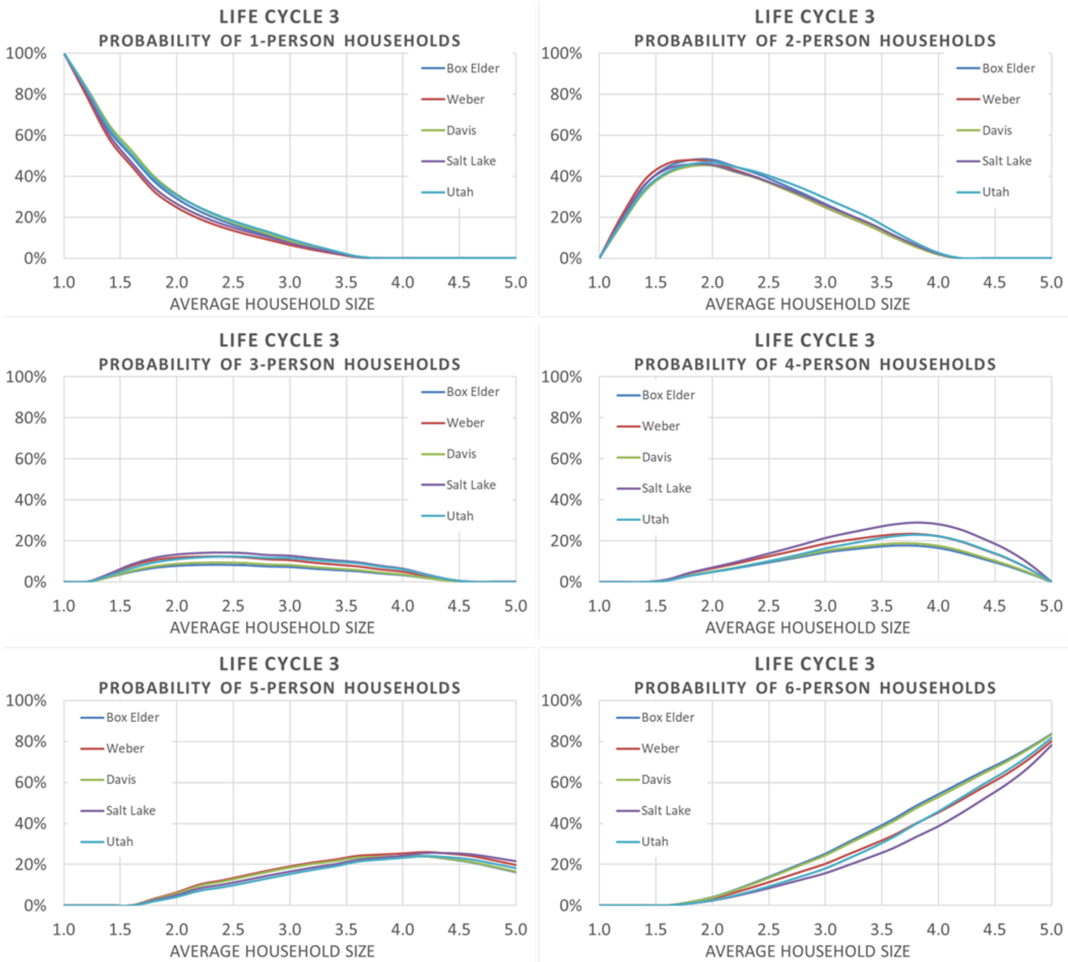

Figure 3.6: Comparison of Household Size Lookup Curves by County – Life Cycle 3.

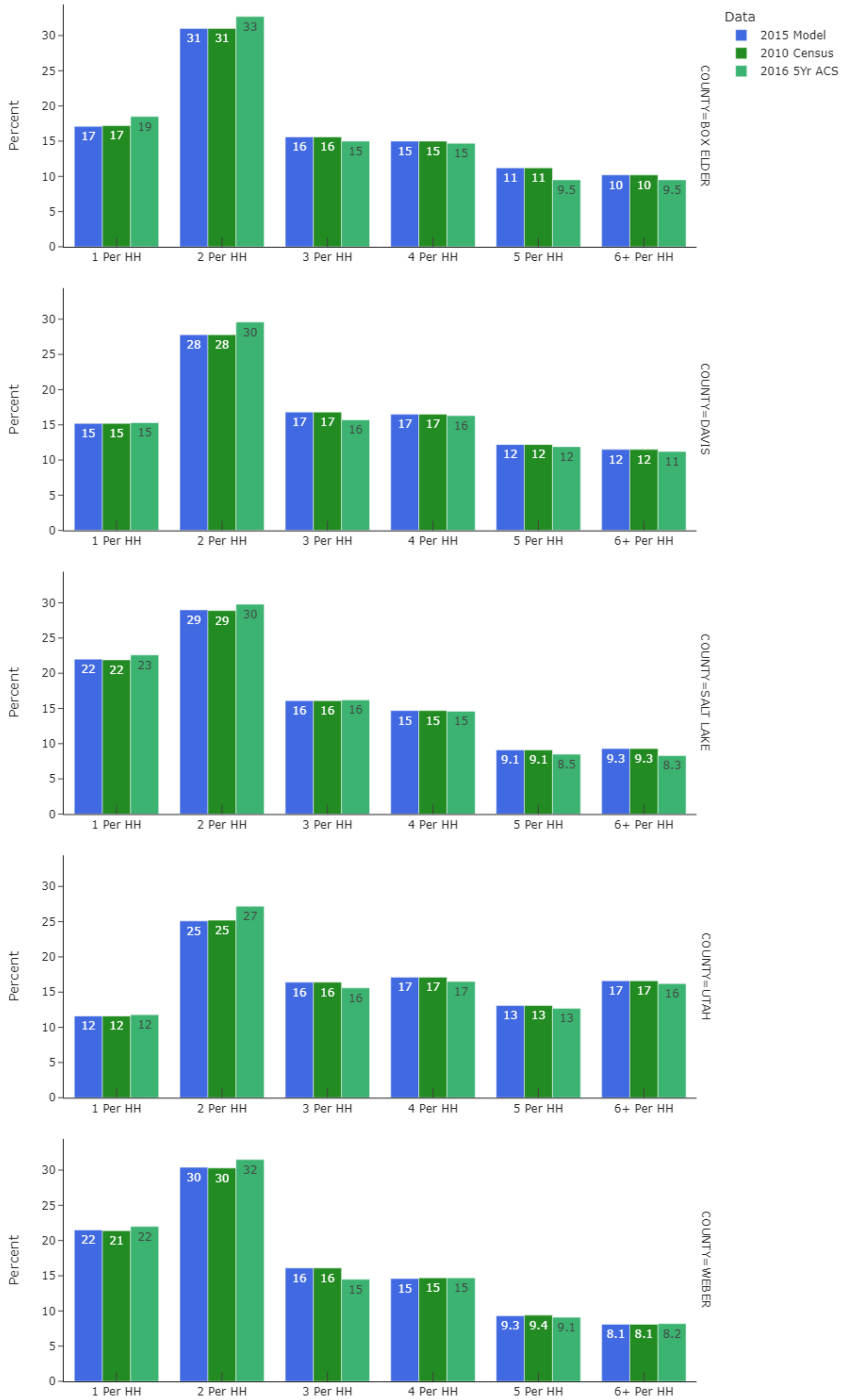

Figure 3.7: 2015 Model vs. 2010 Census & 2016 ACS – % Households by Household Size.

3.2 Income

???UPDATE – maybe from validation in this location: A:\1 - TDM\2 - Estimate Param\1 - HHDisag_AutoOwn???

- Income Gruops (Income Levels) in 2016 dollars:
    - 1: $0 to 35,000 (Low)
    - 2: $35,000 to 60,000 (High)
    - 3: $60,000 to 100,000 (High)
    - 4: $100,000 and above (High)

3.3 Worker

- Worker Groups: 0, 1, 2, 3+ workers per household

???UPDATE – maybe from validation in this location: A:\1 - TDM\2 - Estimate Param\1 - HHDisag_AutoOwn???

4Auto Ownership

The Auto Ownership model begins with the disaggregated households by TAZ and calculates how many vehicles each group owns. Households by vehicle ownership is grouped by 0, 1, 2, and 3+ vehicles. Auto ownership is based on utility functions for each combination of household size group, worker group, and income level (low/high). The utilities for each TAZ are then converted into probabilities. When the probabilities are multiplied by the associated number of households, then an auto ownership distribution by TAZ is created.

The utility functions for auto ownership contain a series of binary and linear variables. The binary variables are loop toggles that are set to 1 or 0 for household size groups, worker groups, and income levels. There are also two linear variables that are taken from TAZ attributes: population density of five nearest zones and employment within 30 minutes by transit. The coefficients for the utility function are shown in Table 4.1.

The code loops through the three groups to create utilities for each combination of binary variables for each TAZ. As can be seen in the table, for household size groups 5 and 6+, 3+ workers in a household, and high income, there are zero utility coefficients, which mean for combinations with these variables there is no utility. Additionally, the 3-vehicle utility is always set to 0 for every combination.

Table 4.1: Coefficients for Vehicle Ownership Utility Functions

Variable	0-Vehicle Utility Function Coefficients	1-Vehicle Utility Function Coefficients	2-Vehicle	3-Vehicle
Constant	-5.103	-1.97	0.15	0
Household Size of 1	3.288	2.953	0.581	0
Household Size of 2	0.277	0.503	0.42	0
Household Size of 3	-0.277	0.334	-0.445	0
Household Size of 4	0.039	-0.952	-0.809	0
Household Size of 5	0	0	0	0
Household Size of 6+	0	0	0	0
0 Worker in Household	0.998	0.514	0	0
1 Workers in Household	0	0.552	0.081	0
2 Workers in Household	0	0	0.07	0
3+ Workers in Household	0	0	0	0
Low Income (Group 1)	2.733	1.557	0.538	0
High Income (Group 2-4)	0	0	0	0
Population Density of 5 nearest Zones	0.05159	0.07346	0.02366	0
Employment within 30 minutes by transit	1.99e-05	8.342e-06	0	0

Using the utility values, probabilities for the vehicle ownership groups are calculated for each TAZ for each combination. The probability is the ratio of the exponential utility of each vehicle ownership group divided by the sum of the exponential utility of all three vehicle ownership groups for each combination. The vehicle ownership probabilities are multiplied by their associated household numbers as calculated in the household disaggregation script to get the number of households in each vehicle ownership group. Additionally, several aggregations are made to calculate total number of vehicles in different groupings. When calculating the number of vehicles in a 3+-vehicle group, the value of 3.5 number of vehicles per 3+ households is used.

???Which validation charts should I add???

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5 Trip Generation

A trip is defined as the movement of a person between two locations for a given purpose. Each trip has two trip ends. Each trip end is associated within a TAZ. Trips are comprised of a both a production zone and an attraction zone. The production zone is where the trip was produced, typically a household for a home-based trip or a place of employment for a non-home-based trip. The attraction zone is the location that is attracting a trip, typically a place of employment or commercial activity. Productions and attractions are travel direction agnostic, meaning that a to-work trip and from-work trip would show as two productions in the home location TAZ and as two attractions in the work location TAZ.

The Trip Generation script calculates productions and attractions at the TAZ level. The trip ends are not paired in this step but remain distinctly separated, which is then used as input into the Trip Distribution model that pairs trip ends together. The script calculates productions and attractions per zone using trip generation rates and adjustments. All values produced by this script represent person trips, not vehicle trips. The trip generation rates are calculated from the household travel survey.

Rates are applied to individual TAZs based on the attributes of the TAZ as taken from the household disaggregation model, additional socioeconomic data, externals data, and special generator data (Temple Square, SLC Main Library, colleges, etc.). All rates in this script are expressed in terms of daily rates. Rates are averages and are only applicable at aggregate levels.

The goal of the script is to generate a set of productions and attractions for each TAZ for the following base trip purposes:

» Home-Based Work (HBW)
» Home-Based School – Primary, Kindergarten to 6th Grade (HBSch_Pr)
» Home-Based School – Secondary, 7th to 12th Grade (HBSch_Sc)
» Home-Based Shopping (HBShp)
» Home-Based Other (HBOth)
» Non-Home-Based Work (NHBW)
» Non-Home-Based Non-Work (NHBNW)

Additionally, the script estimates trip generation for the following for external trips:

» Internal-to-External (IX) Productions
» External-to-Internal (XI) Attractions

Productions and attractions are also generated for short-haul trucks based on people movement, goods movement, and services for the following truck types:

» Light Trucks (LT)
» Medium Trucks (MD)
» Heavy-Trucks (HV)

Given the various combinations of trip purposes and possible attributes, there are quite a few steps in the script. These steps can be grouped into the following three categories:

1. Estimate productions
2. Estimate attractions
3. Balance productions and attractions

Following a discussion of these three groups, there is a presentation of the validation results.

5.1 Estimate Productions

Productions for each TAZ are estimated in the following steps:

1. Calculate base productions
2. Calculate internal-to-external productions and adjust base productions accordingly
3. Adjust non-home-based trips to account for visitors
4. Calculate productions for short haul truck trips

5.1 Base Productions

Base productions are generated based on TAZ household attributes including number of workers, household size, and life cycle. Work trips only utilize attributes based on number of workers. The other trip purposes use household size and life cycle. The associated production rates are shown in Table 5.1. As expected, the greater the number of workers or the larger the household size, the higher the rates for any given trip purpose. The highest trip rate is 10.703 for home-based other trips for households of size 6+ in life cycle 2.

The production rates are only estimated for combinations of TAZ variable and trip purpose that are valid. A household with no workers does not generate any work trips. Additionally, households in Life Cycle 1 would not generate any school trips by definition.

Table 5.1: Production Rates by Trip Purpose.

TAZ Variable	HBW	HBSch*	HBShp	HBOth	NHBW	NHBNW
Households with 0 Workers	-	-	-	-	-	-
Households with 1 Worker	1.764	-	-	-	0.856	-
Households with 2 Workers	3.073	-	-	-	1.361	-
Households with 3+ Workers	4.698	-	-	-	1.781	-
Households of Size 1 in Life Cycle 1	-	-	0.443	1.313	-	0.632
Households of Size 2 in Life Cycle 1	-	-	0.706	2.382	-	1.013
Households of Size 3 in Life Cycle 1	-	-	0.757	3.657	-	1.542
Households of Size 4 in Life Cycle 1	-	-	1.088	5.128	-	1.820

TAZ Variable	HBW	HBSch*	HBShp	HBOth	NHBW	NHBNW
Households of Size 5 in Life Cycle 1	-	-	1.548	7.380	-	1.989
Households of Size 6+ in Life Cycle 1	-	-	2.013	9.643	-	2.159
Households of Size 1 in Life Cycle 2	-	-	-	-	-	-
Households of Size 2 in Life Cycle 2	-	0.530	0.681	2.508	-	1.499
Households of Size 3 in Life Cycle 2	-	0.675	1.344	4.437	-	1.738
Households of Size 4 in Life Cycle 2	-	1.117	1.720	6.115	-	2.618
Households of Size 5 in Life Cycle 2	-	2.473	1.818	8.310	-	3.282
Households of Size 6+ in Life Cycle 2	-	3.819	1.916	10.703	-	3.852
Households of Size 1 in Life Cycle 3	-	-	0.561	1.841	-	0.990
Households of Size 2 in Life Cycle 3	-	0.009	1.149	3.673	-	1.928
Households of Size 3 in Life Cycle 3	-	0.067	1.272	4.175	-	2.408
Households of Size 4 in Life Cycle 3	-	0.427	1.404	4.676	-	2.676
Households of Size 5 in Life Cycle 3	-	1.446	1.683	6.450	-	2.890
Households of Size 6+ in Life Cycle 3	-	2.865	1.960	8.958	-	2.997

Note for Table 5.1: HBSch productions for each TAZ are divided into HBSch_Pr and HBSch_Sc based on their respective regional shares of total enrollment.

To calculate the total productions by trip purpose for each TAZ, the value of each variable is multiplied by the associated rate for that trip purpose and then summed over all the variables. Further division of Home-Based School trips into Primary and Secondary is done based on their respective regional shares of total enrollment. Productions for non-home-based trip purposes are further adjusted by the visitor adjustment factors in Table 5.2, which were taken from the 2012 Household Survey.

Table 5.2: Visitor Adjustment Factors.

Trip Purpose	Visitor Adjustment Factor
NHBW	1.046
NHBNW	1.049

5.1 External Trip Productions

Productions for internal-to-external (IX) trips are estimated by the model since the production occurs within the model space. The IX productions are taken as a share from the base productions and reassigned to the IX category. Ultimately, IX trips are not separated by trip purpose. But for the estimation of IX trip productions, trips are separated into two general trip purposes: work and non-work trips. Work trips include HBW. Non-Work trips include all other purposes except for school trips, which are excluded from external trips.

The share of productions that are IX work/non-work trips is shown in Table 5.3. Typically shares of productions are in the 1% to 4% range for all counties except Box Elder, which ranges from 5% to 20% of all trip productions being IX trips.

Table 5.3: Internal-to-External Shares (2012 HH Survey)

County	Share IX Work Productions	Share IX Non-Work Productions
Box Elder	0.196	0.052
Weber	0.035	0.016
Davis	0.009	0.011
Salt Lake	0.018	0.015
Utah	0.017	0.01

After calculating the number of IX productions using the share values, these trips are removed from the base productions. Additionally, since IX productions are in vehicle-trips the final step in calculating IX productions is to multiply the person trips by vehicle occupancy rate of 1.54.

When calculating productions for the opposing direction, external-to-internal (XI), the TAZ values come directly from the *External_TripEnds.dbf* file as generated in the Input Processing scripts.

5.1 Short-Haul Trucks Productions

Short-Haul truck productions are calculated as a function of ecommerce variables, residential variables, and employment variables that vary by truck type. The overall formula used to calculate truck productions is as follows,

Equation 1: Short-Haul Truck Productions

- $Good\_p_{(TR)} = Share\_Ecom_{(TR)}$ $(ResRate_{(TR)} * TOTHH * Fac\_ECom\_HH_{(TR)} + EmpRate_{(TR)} * TOTEMP * Fac\_ECom\_Emp_{(TR)}) + (1 - Share\_ECom_{(TR)}) * (ResRate_{(TR)} * TOTHH)*$

where,

- *TR* represents truck type (light, medium, or heavy),
- *Share_ECom* represents the proportion of truck trips that apply to eCommerce factors (See Table 5.4),

- *ResRate* represents the residential variable (See Table 5.4),
- *EmpRate* represents the employment variable (See Table 5.4),
- *TOTHH* represents the total number of households in a given TAZ,
- *TOTEMP* represents the total employment in a given TAZ,
- *Fac_ECom_HH* represents the ecommerce factor applied to households (See Table 5.5),
- and *FAC_ECom_Emp* represents the ecommerce factor applied to employment (See Table 5.5).

Table 5.4: Proportion of Truck Trips to apply E-Commerce Factors

Variable	Light Truck Factor	Medium Truck Factor	Heavy Truck
Share_Ecom	0.55	0.8	0.8
ResRate	0.74745	0.44427	0.17481
EmpRate	0.25703	0.1875	0.11021

The *Fac_ECom_HH* variable corresponds to the values in the *Households* rows in Table 5.5. The *Fac_ECom_Emp* variable is computed as a function of the sum of the other variables in Table 5.5 multiplied by their corresponding employment types.

Table 5.5: Employment Factors by Scenario and Truck Type

Scenario	Scenario Name	Goods Movement Category	Light Truck Factor	Medium Truck Factor	Heavy Truck Factor
1	Base	Industrial	1	1	1
1	Base	Retail	1	1	1
1	Base	Other	1	1	1
1	Base	Households	1	1	1
2	Low	Industrial	1.15	1.05	1.1
2	Low	Retail	1.15	1.05	1
2	Low	Other	1.15	1.05	1
2	Low	Households	1.25	1.2	1
3	Medium	Industrial	1.2	1.1	1.15
3	Medium	Retail	1.2	1.1	1.05
3	Medium	Other	1.2	1.1	1
3	Medium	Households	1.35	1.25	1
4	High	Industrial	1.25	1.15	1.2
4	High	Retail	1.25	1.15	1.1
4	High	Other	1.25	1.15	1
4	High	Households	1.45	1.3	1

An additional adjustment factor is used during the calibration process to further tune the model results for trucks to match observed truck traffic. These adjustments are made at the three main groupings for short-haul productions and are shown in Table 5.6. A factor of 1 means there is no adjustment.

Table 5.6: General Short Haul Truck Production/Attraction Factors

Short-Haul Truck Category	Light Truck Factor	Medium Truck Factor	Heavy Truck Factor
People	1.8	1.85	1.65
Goods	1.8	1.85	1.65
Services	1.8	1.85	1.65

5.2 Estimate Attractions

The Trip Generation script estimates attractions for all trip purposes. Attractions are defined as the end of the trip that is serving as the attraction for a trip. For home-based trips (trips produced at a home location), attractions could include work locations, retail centers, restaurants, schools, colleges, etc. For non-home-based trips (trips produced at work or another locations), attractions could include delivery locations, restaurants, etc. The attractions for each TAZ are estimated in the following steps:

1. Calculate base attractions.
2. Calculate telecommuting attractions.
3. Calculate external-to-internal attractions and adjust base productions accordingly.
4. Adjust attractions based on CBD or area type.
5. Adjust truck attraction based on county.
6. Calculate attractions for short haul truck trips.
7. Calculate attraction adjustments for special generators.

5.2 Base Attractions

Attractions are generated based on TAZ employment, enrollment, and household attributes. Whereas productions were mostly based on household attributes, attractions are primarily based on employment for most trip purposes with exceptions for HBSch that is based on enrollment and for HBOth, NHBW, and NHBNW with some household attractions. Attraction rates are shown in Table 5.7.

Table 5.7: Attraction Rates by Trip Purpose.

TAZ Variable Description	TAZ Variable	HBW	HBSch_Pr	HBSch_Sc	HBShp	HBOth	NHBW	NHBNW
Retail Employment	RETL	0.957	-	-	3.660	-	1.132	3.419
Food Employment	FOOD	1.017	-	-	3.058	-	1.620	3.264
Manufacturing Employment	MANU	1.136	-	-	-	0.019	0.231	0.037
Wholesale Employment	WSLE	1.136	-	-	-	0.126	0.410	0.103

TAZ Variable Description	TAZ Variable	HBW	HBSch_Pr	HBSch_Sc	HBShp	HBOth	NHBW	NHBNW
Office Employment	OFFI	1.196	-	-	-	0.219	0.178	0.054
Gov./Ed. Employment	GVED	1.196	-	-	-	2.455	0.250	0.452
Health Employment	HLTH	1.136	-	-	-	1.135	0.185	0.446
Other Employment	OTHR	1.136	-	-	-	0.902	0.200	0.242
Agricultural Employment	FM_AGRI	1.136	-	-	-	-	0.200	-
Mining Employment	FM_MING	1.136	-	-	-	-	0.200	-
Construction Employment	FM_CONS	1.136	-	-	-	-	0.200	-
Total Households	TOTHH	-	-	-	-	2.553	0.179	0.589
Elementary Enrollment	ENROL_ELEM	-	1.000	-	-	-	-	-
Middle School Enrollment	ENROL_MIDL	-	-	1.000	-	-	-	-
High School Enrollment	ENROL_HIGH	-	-	1.000	-	-	-	-

5.2 Telecommuting and Home-based Attractions

Telecommuting and home-based jobs for each employment category are the calculated by applying the telecommuting rates taken from the model input files. Work-at-home jobs (HBJ) are added back into each employment category for the attraction calculations when calculating telecommuting. Telecommuting attractions are specified as either home-based work or non home-based work. Table 5.8 shows the rates applied to each job portion of the telecommutting function.

Table 5.8: Telecommuting Rates applied to each Job portion of the Telecommuting Function

Job Type	Factor for HBW Telecommuting	Factor for NHBW Telecommuting
RETL	0.957	1.132
FOOD	1.017	1.62
MANU	1.136	0.231
WSLE	1.136	0.41
OFFI	1.196	0.178

Job Type	Factor for HBW Telecommuting	Factor for NHBW Telecommuting
GVED	1.196	0.25
HLTH	1.136	0.185
OTHR	1.136	0.2
AGRI	1.136	0.2
MING	1.136	0.2
CONS	1.136	0.2

For performing scenario testing, the 1ControlCenter.block file for the model scenario contains a telecommuting factor that serves as a multiplier to all employment-based telecommuting calculations. The default value for this factor is 1. A value less than 1 decreases the telecommuting share and a value greater than 1 increases the telecommuting share.

An additional adjustment factor is used during the calibration process to further tune the model results for telecommuting to match the base year target. This model uses a telecommuting calibration factor of 1.

5.2 External Trip Attractions

The TAZ attractions for external-to-internal (XI) attractions is set to the number of total households (TOTHH) plus the total employment (TOTEMP). Since XI attractions are scaled to match productions, this means that XI attractions will be proportionally distributed by households plus employment amongst all TAZs.

Additional adjustment factors applied to XI attractions include county factors and a scaling factor. The county adjustment factors are shown in Table 5.9. The scaling factor used for the model is 0.010957.

Table 5.9: IX Attraction County Adjustment Factors

Job Type	XI Adjustment Factor
Box Elder	8.5741
Weber	1.0061
Davis	0.5437
Salt Lake	0.9974
Utah	0.8972

When calculating attractions for the opposing direction, internal-to-external (IX), the values come directly from the External_TripEnds.dbf file as generated in the Input Processing scripts.

5.2 CBD and Area Type Adjustments

Some trip purposed are further adjusted by select geographies. This allows for localized nuances to be applied when attraction rates may be atypical of regional rates. Two sets of adjustments are made. First, an adjustment of 0.5 is made to home-based shopping trips attracted to the CBD in Salt Lake County. Thus, shopping trips attracted to the CBD are half of what a non-CBD rate would be. Second, there are adjustments based on select area types for Davis and Salt Lake Counties. These adjustments are shown in Table 5.10. Attractions for urban area types are reduced 70% to 80% for select trip purposes. For CBD-like area types in Salt Lake County, there is an increase of 25% for home-based work trips showing a greater number of attractions compared as compared to similar areas in the rest of the region.

Table 5.10: Adjustment Factors for Select Counties/Area Types

County	Area Type	HBW	HBShp	HBOth	NHBNW
Davis	Urban	0.8	-	-	-
Salt Lake	Urban	-	0.75	0.7	0.8
Salt Lake	CBD-Like	1.25	-	-	-

5.2 County Truck Adjustments

An additional adjustment factor is used during the calibration process to further tune the model results for medium and heavy trucks to match observed truck traffic. These adjustments are made at the three main groupings for short-haul attractions. Light trucks were low in Box Elder, Weber, Davis, and Utah County and high in Salt Lake county. Medium trucks were low in Box Elder and Davis county and high in Weber, Salt Lake, and Utah county. Heavy trucks were low in Box Elder, Davis, and Utah county and high in Weber and Salt Lake County. The factors as shown in Table 5.11 were set to help offset these differences.

Table 5.11: Area Specific Short Haul Truck Production/Attraction Factors

Short-Haul Truck Category	Area	Light Truck Factor	Medium Truck Factor	Heavy Truck Factor
People	Urban Spaces	1.03	0.9	0.9
Goods	Urban Spaces	1.03	0.9	0.9
Services	Urban Spaces	1.03	0.9	0.9
People	Box Elder	1.5	1.17	1.12
Goods	Box Elder	1.5	1.17	1.12
Services	Box Elder	1.5	1.17	1.12
People	Weber	1.22	0.96	0.96
Goods	Weber	1.22	0.96	0.96
Services	Weber	1.22	0.96	0.96
People	Davis	1.14	1.08	1.1
Goods	Davis	1.14	1.08	1.1
Services	Davis	1.14	1.08	1.1
People	Salt Lake	0.59	0.62	0.54
Goods	Salt Lake	0.59	0.62	0.54
Services	Salt Lake	0.59	0.62	0.54
People	Utah	1.19	0.95	1.01
Goods	Utah	1.19	0.95	1.01

Short-Haul Truck Category	Area	Light Truck Factor	Medium Truck Factor	Heavy Truck Factor
Services	Utah	1.19	0.95	1.01

5.2 Adjustments for Special Generators

There are two groups of special generators that have adjustments for trip attractions. Temple Square and the SLC Library are in one group and colleges are in another.

5.2.6.1. Temple Square and SLC Library

Trip attractions for Temple Square and the SLC Library are generated using a base year daily visitation numbers and then increasing by an annual growth rate to estimate trip ends in the model year. The values used for estimation are shown in Table 5.12. Temple Square had an estimated five million visitors in 2013, which translates to roughly 13,700 visitors per day and 27,400 trip ends per day. The SLC library is the second most popular destination in Salt Lake with approximately four million visitors per year or roughly 11,000 visitors and 22,000 trip ends per day.

Table 5.12: Adjustment Factors for Select Counties/Area Types

Special Generator	Base Year	Base Year Daily Trip Ends	Annual Growth Rate
Temple Square	2013	27400	1.0%
SLC Library	2005	22000	1.0%

After calculating model year attractions for the two special generators, the total attractions are then added to TAZ attractions proportionally amongst the trip purposes HBOth and NHBNW for the TAZ including Temple Square and HBOth, NHBW, and NHBNW for the TAZ including SLC Library.

5.2.6.2. Colleges

???CHECK ENTIRE SECTION - we updated this but I forgot what we did

There are several locations with the TDM where trips to and from colleges are estimated. Home-based college (HBC) trips are separately generated and distributed as part of the Input Processing scripts and are found in `TripTable.mtx`. HBC trips are those of enrolled students traveling to and from campus. These trips bypass Trip Generation and Trip Distribution scripts. The attractions for other trip purposes to colleges are generated together with the other trips within the containing TAZ. Adjustments are then made to account for additional attractions to colleges for the three trip purposes of HBOth, NHBW, and NHBNW.

HBOth, NHBW, and NHBNW trip adjustments are calculated through the following steps:

1. Calculate the number of full-time-equivalent (FTE) students per campus by multiplying the enrollment control total for a college campus from TripTableControlTotal.csv by the FTE rate for the college campus from College_Factors.csv.
2. Calculate the total attractions that should be generated based on the number of FTE students. This is done by multiplying the number of FTE students (step 1) by 2.4 vehicle attractions per student **(based on all purposes from ITE, exact reference not included)** multiplied by 1.7 person trips to vehicle trips **(source not stated, is it the HHSurvey??)**.
3. Calculate HBW trips associated with college campus in its containing TAZ with the following steps:
    a. Multiply FTE students (step 1) by the college employment factor (see Table 5.13) to get the estimated number of employees for a college campus.
    b. Divide the estimated number of employees for a college campus by the total employment (TOTEMP) for the containing TAZ to obtain a college employment ratio. The ratio is capped at 1.0.
    c. The college employment ratio is then multiplied by the number of HBW trips to determine which portion of HBW are associated with the college.
4. Calculate the number of non-HBC/HBW attractions to add to the TAZ by subtracting the college associated HBW trips (step 3) and HBC trips (TripTable.mtx) from the total attractions (step 2).
5. Distribute the additional attractions (step 4) proportionally amongst HBOth, NHBW, and NHBNW.

Table 5.13: College Employment Factors

College	College Employment Factor
Weber State University	0.25
Utah Valley University	0.25
Salt Lake Community College	0.29
LDSBC	0.33
Westminster	0.33
University of Utah	0.71
Brigham Young University	0.71
Unspecified	0.48

5.3 Balance Productions and Attractions

The final step of Trip Generation is to balance the productions and attractions. Balancing takes place by proportionally increasing or decreasing productions/attractions across the entire model space to match regional totals. For trips internal to the model space (non-externals) the attractions are balanced to match the productions. External trip productions and attractions are balanced in the WFRC/MAG model space. The IX productions are balanced to the IX attractions and the XI attractions are balanced to the XI productions.

???Truck trips are already balanced since TAZ attractions were set equal TAZ productions.** –**really?**???

There is also an important distinction to be understood regarding non-home-based trips. While non-home-based productions are based on household characteristics of a TAZ, the trips are not actually being produced in the home TAZ location. They are produced at another location, hence the term non-home-based. Non-home-based productions, thus, are only used to get total values that are then used to balance non-home-based attractions. After attractions are balanced to match productions, TAZ productions are set equal to TAZ attractions. So, non-home-based productions are used to get the quantity of trips, but attractions are used to get the distribution of trips.

5.4 Validation Results

The validation results for the Trip Generation portion of the model are shown in this section.

???All the 2012 Household Survey results are scaled to the 2010 Census.– is the scaled to the 2020 census now???

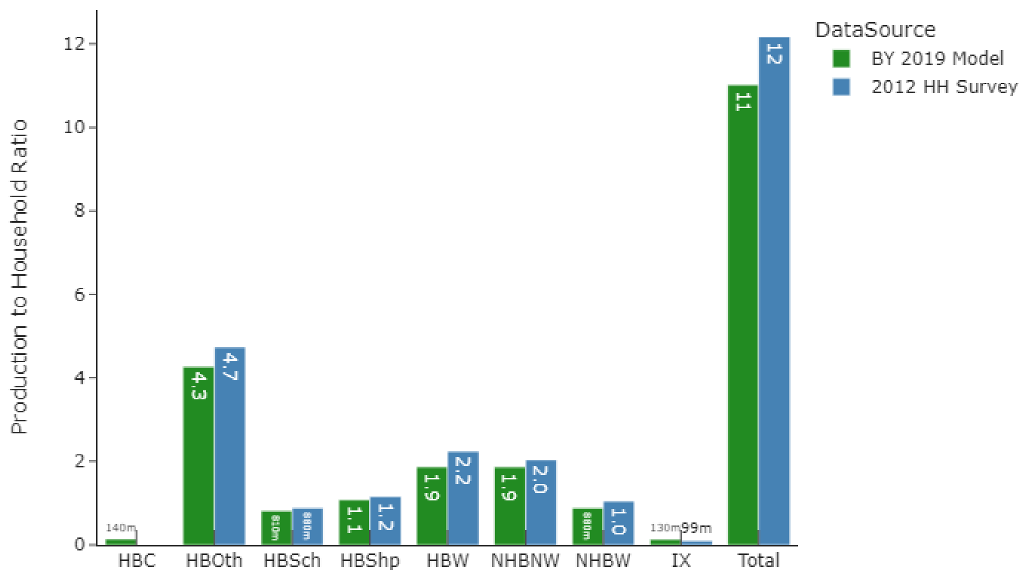

Figure 5.1: Productions to Households Ratios – Total Trip Ends (II + IX).

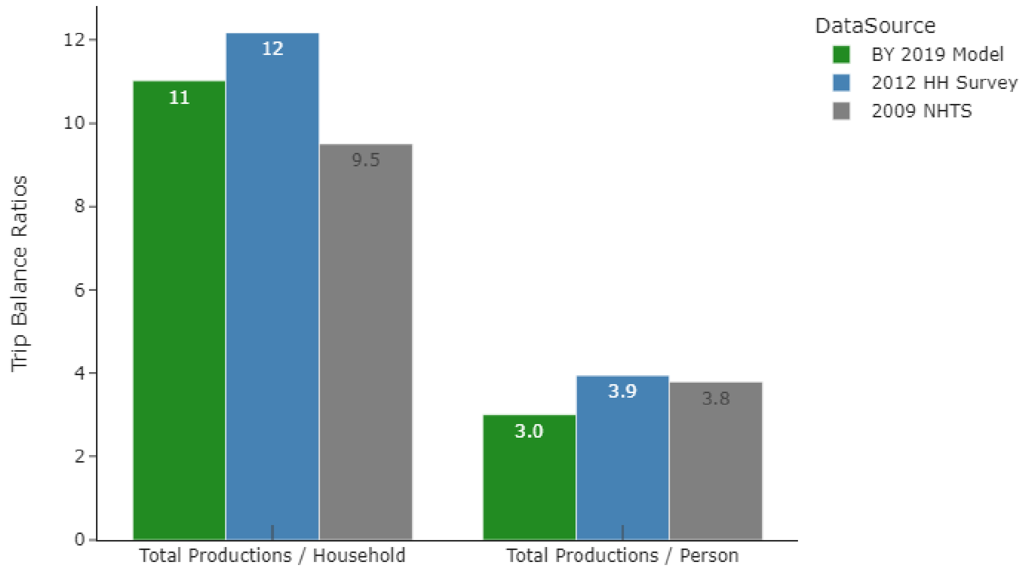

Figure 5.2: Total Trip Validation.

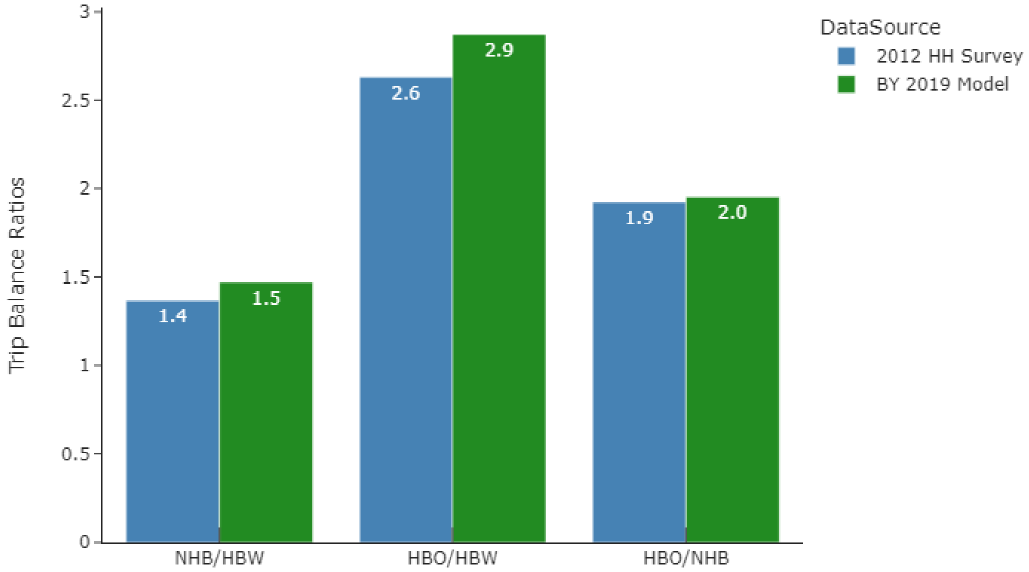

Figure 5.3: Trip Balance Ratios.