Model Validation and Mode Choice Update

Technical Memorandum
for the
Northwest Arkansas Regional Planning Commission

Submitted by:

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1 Introduction

During 2014 and 2015 Parsons Brinckerhoff conducted a mode choice model development and calibration on behalf of the Northwest Arkansas Regional Planning Commission as well as an overall model validation to a 2010 base year. This report will focus on the results of that calibration and on the highway and transit validation for the 2010 Base model. Trip generation and trip distribution will be reviewed and addressed as well. As with planning models in general, the goal is to prepare the Northwest Arkansas Planning Commission model for future year scenario testing. The following key work was conducted:

- Reviewed the model input parameters in the population synthesis, trip generation, and trip distribution models and made adjustments to match observed data.
- Built a transit planning network with accompanying access link system and skimming protocols so as to be able to include transit service characteristics in the mode choice model.
- Built and calibrated a mode choice model that is sensitive to changes in transit service delivery utilizing best practice techniques.
- Conducted transit and highway validation.

This document is divided into the following sections:

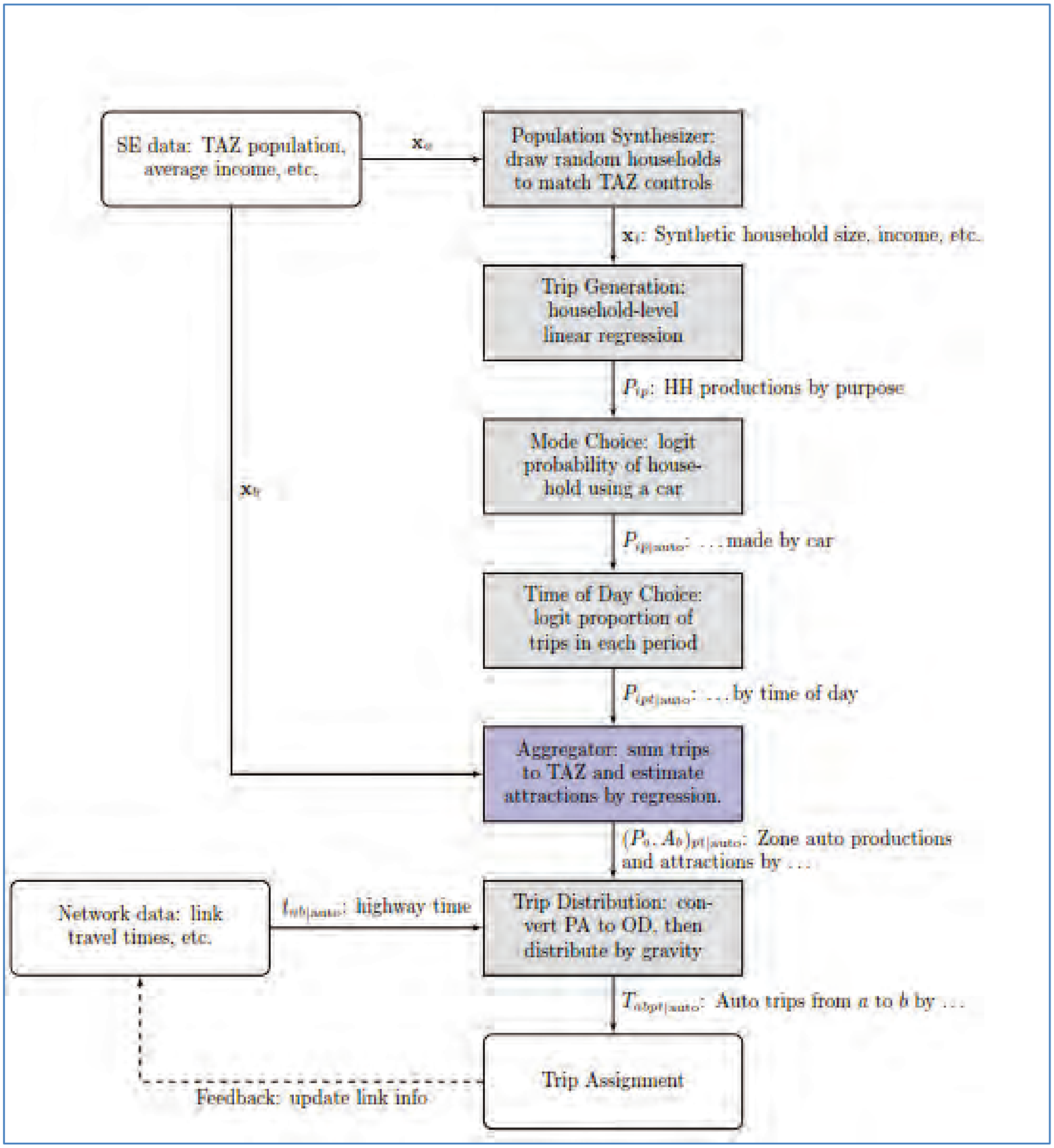
- Section 1 is this introduction
- Section 2 reviews the existing model's strengths and shortcomings, and describes our efforts to assess and improve the sub-models preceding the mode choice model.
- Section 3 describes the mode choice model, including its specification and calibration.
- Section 4 describes the calibration and validation of the revised model to targets in a 2010 base year.
- Section 5 provides a blue-print for future model updates

2 Model Review

2.1 Overview

This section describes our examination of the original NWARPC model process and our update of the household generation, trip generation, and trip distribution steps as necessary to successfully design and implement a state-of-the-practice mode choice model. As part of these tasks it was important to first view a flow chart of the original model structure and to understand the function of each step.

Figure 2-a: Existing Model Structure



In the original model, the process began with the socioeconomic (SE) data which included the population in the Traffic Analysis Zone (TAZ), the average income and other attributes.

- HouseholdGeneration.rsc - The Population synthesizer generated synthetic households i with attributes x_i to match total counts and TAZ average characteristics x_a. The process outputs a file into the HH_Generation directory that contains one record for each HH in the region, listing the HH's TAZ, the number of persons in the households, the number of persons under age 18, the number of persons 65 and older, the number of vehicles, income band, etc. See Section 2.3 for further detail.
- TripGeneration.rsc – For each HH in the HH file, the Trip Generation module calculated P_{ip}, the decimal number of trips of each purpose produced by each household. It did this via regression models estimated on data collected in a 2005 household travel survey. The results were output to the 'TG_*SCENARIO_NAME' file in the TRIP GENERATION output directory. The trip purposes were home-based work, university, school, shopping and personal business and other and non-home-based other and work. See Section 2.4 for more detail.
- ModeChoice.rsc – The original mode choice model calculated the percentage of each trip that would use one of the following modes: car driver (CD), car passenger (CP), public bus (PB), school bus (SB) or non-motorized (NM). The percentages were simply the number of trips by purpose multiplied by the probability of each mode calculated using a logit model. The utility equations used for the logit model considered household characteristics (number of persons, number of vehicles, household income) but did not include service characteristics of the individual modes (such as travel time or travel cost by mode). Only vehicle trips (CD and CP) were carried through the rest of the model.
- TimeOfDay.rsc - Time of Day segmented the household-level trips into three time periods: AM, PM, and Off-peak (OP). A logit model determined the proportion of household trips occurring in each time period, based on the trip purpose and the household demographics.
- TripDistribution.rsc - Trip Distribution contained two major operations. Before the primary gravity model distribution step, this script aggregated the household trip productions by TAZ and determined TAZ trip attractions by purpose and time of day for each TAZ. Figure 2-a shows this as a separate step called Aggregator to highlight its place in the process. The second major operation applied factors to convert productions and attractions into origins and destinations before calculating trip flows with a gravity model.

Changes to the model steps above are listed below and are discussed in more detail throughout this document. The validation of each sub-component is detailed in Section 4.

- Household Generation – revised the curves used to determine the marginal distributions of households by persons, income, workers, children, seniors and vehicles based on the 2010 census data for the region. See Section 2.3 for more detailed discussion of the changes.
- Trip Generation – reviewed the trip generation equations and attempted to re-estimate the HBW coefficients based on weighted survey data to understand how the original equations were developed. Resulting trip generation rates were compared to the rates observed in the household survey (expanded to match the 2010 census data) and to rates observed in other

comparable regions as part of the model validation process. The global trip rates were adjusted using factors specified in the trip_rate_adj_factors based on observed trips and ultimately further adjusted using rates specific to either urban or rural zones. Finally, in the original model, all the trip productions were balanced to attractions but in the revised model, the university, non-home-based other and work productions were balanced to the attractions. See Section 2.4 for more detailed discussion of the changes and Section 4 for the calibration results.

- Mode Choice – replaced with an updated logit model in order to incorporate transit and highway level-of-service variables into the utility equations. The model is now a nested logit model that considers auto, transit and non-motorized as the top level choice and sub-modes of each other those at the next choice level. The mode choice nesting structure is shown in Section 3. In the overall model flow, the original model has mode choice before trip distribution. However, the revised mode choice model uses travel time and cost between the origin and destination in the determination of mode; therefore, it was necessary to implement the mode choice model after the time of day and trip distribution segments. One consequence of this decision is that the mode choice model now requires aggregated socioeconomic information, hence the new path bringing TAZ socioeconomic data X_a into the mode choice step on the revised model flow chart. See Figure 2-d in Section 2.6.
- Time of Day – no change except to move the time of day segmentation up in the process. See See Figure 2-d in Section 2.6.
- Trip Distribution – reviewed the friction factors used in the gravity model to distribute the trips and adjusted based on the observed trip-length frequencies seen in the weighted 2005 household survey. See Section 2.5 for more details of the changes.
- Assignment – added in the transit assignment along with the highway assignment

2.2 Available Travel Behavior Sets

NWARPC conducted a household survey in 2005 that was used to develop and validate the original model. In 2010, NWARPC conducted an on-board transit passenger survey as part of the Transit Development Plan update. These two data sources were reviewed and re-expanded and were used along with tables from the Census Transportation Planning Program (CTPP) to develop the calibration targets for the 2010 base year validation. Below is a description of each data source and how it was used in the revised model.

2.2.1 Census Transportation Planning Program (CTPP)

The United States Census Bureau (Census) conducts an annual survey of households attributes called the American Community Survey (ACS). Census combines the raw ACS responses with information from the Longitudinal Employer-Household Dynamics (LEHD)[1] program to create transportation planning tables referred to as the CTPP. Since the last NWARPC model update, the Census has published a new series of CTPP tables derived from ACS responses in 2007 through 2012[2].

[1] Internal Revenue Service records on household and employer addresses
[2] Five years of aggregation is required to protect confidentiality at the TAZ-level

These CTPP tables were used to revise the population synthesis model, matching the synthetic population to average demographic patterns over the interval 2007 to 2012. District-to-district work flows were created from the LEHD tables as a comparison to the observed flows from the 2005 household survey. These district-to-district flows were also used as another comparison data set to the trip distribution results from the revised model. The tables used from the Census are listed below:

- A112106 - Household size (5)
- A112209 - Household size (5) by Number of workers in household (6)(Households)
- A112101 - Number of Persons under 18 (4) (Households)
- A112201 - Household income in the past 12 months (2010) (9)
- B112104 - Median Household income in the past 12 months (2010)(1)
- A112218C - Number of Workers in the household (6) by Household income in the past 12 months 2010$) (9).
- A112211 - Household size (5) by Vehicles available (6) (Households)

2.2.2 2005 Household Survey

In 2005 MORPACE International conducted a household travel survey that was used in the development of the original NWA model. As is typical of household travel surveys, the data are stored in several tables: a household table with household attributes, a person table with data on each person in the households, and a trips file with detail on each trip. The survey data did not include expansion weights to expand the data to represent the full study area population; however, these are necessary in order to do a direct comparison of modeled results to observed results. We therefore estimated expansion weights by Iterative Proportional Fitting (IPF) using district-level CTPP counts of households by size, number of workers, and vehicle ownership. Expanding by household income would have been done but the survey data was too sparse.

The household survey collected trip information for 675 households, containing 1,546 individuals who collectively made 6,209 trips. Once expanded validation summaries were created for trip generation, trip distribution and mode choice. It should be noted that the survey did not capture many transit users, which is often the case, and so the on-board survey was used in conjunction with the household survey to create the mode choice targets. Also, the survey allowed respondents to select multiple activities at both ends of their trips from a long list of possibilities and therefore we made the assumption that the activity listed first was the primary activity and therefore the trip *purpose.* The survey was summarized based on the following trip purposes:

- HBW - Home-based work
- HBO - Home-based other
- HBU - Home-based university/college
- HBSC - Home-based school
- HBSB - Home-based shopping/personal business
- NHB - Non home-based (this category collapses the 'NHBO' and 'NHBW' trips from the original model.

On a final note, the survey allowed small children to set a "childcare" activity; we classified this as an "other" trip.

We also needed to identify the mode of the trip. We summarized the data according to the following nesting structure:

- Vehicle
  - DA: Drive alone
  - SR2: Shared ride 2
  - SR3+: Shared ride 3+
- Transit: There are three access nests, each with the transit modes listed underneath.
  - Walk: walk-access transit
    - LB: Local bus (Ozark Transit)
    - RT: Razorback Transit, University of Arkansas
  - PNR: park-and-ride
    - RT: Razorback Transit
  - KNR: “kiss-and-ride”/drop-off
    - RT: Razorback Transit
- Non-Motorized
  - Bike
  - Walk

In order to be counted as a non-motorized trip, all trip legs had to be non-motorized. By contrast, if any leg was done on public transit, it was counted as a transit trip. We removed trips completed on modes such as a lawnmower, an airplane, and an ambulance. Additionally, we consider Dial-a-Ride as a paratransit service, and therefore transit. School buses were likewise considered to be transit trips.

In summary, the 2005 household survey records were used to determine targets for trip generation and trip distribution (by purpose) and the auto and noon-motorized targets for mode choice (by vehicle sub-mode, trip purpose, and auto sufficiency/income).

2.2.3 Transit On-Board Survey

As part of the region’s Transit Development Plan, the regional transit authorities sponsored a ridecheck report and an on-board ridership survey of transit passengers on Ozark public transit as well as on Razorback Transit on the University of Arkansas campus. Conducted in September 2010, the survey asked passengers about their origin, destination, and a few household attributes:

- Age
- College student (yes/no, if yes, U of A, NWACC or other)
- Income range
- Household size
- Number of vehicles
- Valid driver’s license

The survey was not expanded, but the ridecheck provided daily boardings by route at the time of the survey that was used to expand the survey and determine the distribution of ridership across the transit sub-modes.

Listed below are several issues related to the survey expansion and the assumptions we made to overcome the limitations of the on-board survey data:

- The access mode (either "walk to transit" or "drive to transit") information was not collected and therefore it was assumed that all the Ozark ridership was "walk to Ozark". For Razorback, survey records on the Green line and the Green Reduced line that had a starting or ending location of "Lot 56" were considered home-based university trips with "PnR to Razorback" as the mode. All other Razorback survey records were assumed to be "walk to Razorback".
- Out of the 185 Ozark records 28 records had at least one of the three attributes missing (hhsize, number of vehicles or income). Out of these 28 records with missing attributes, 15 had only "income" missing and that was imputed using the probabilities based on the vehicle ownership level that are shown in Table 2-a below. Among the remaining 13 records, 2 records had zero cars so they were included in the "0-cars, all income categories" segment. In the end, only 11 out of 185 records were unusable.

Table 2-a: Probability of "High" Income Based on Vehicles in Household

# Vehicles	Probability of being high income
None	0.040
One	0.098
Two	0.150
Three or more	0.182

- For Razorback, 841 surveys were returned but 391 records had size, income and number of vehicles all missing. These records were unusable for determining mode choice targets. Of the remaining 450 records, 415 records had all three attributes and 24 records had at least one attribute present such that the other two could be imputed. These 450 records were expanded to determine the transit targets.
- The survey did not ask details about the person's trip either before they boarded the bus where they are being surveyed or after they got off the current bus. Thus, the transfer rate, which is needed to convert the survey records into person trips by sub-mode, could not be calculated from the data. For Ozark, the assumed transfer rate was 30% and for Razorback, it was assumed to be 15% since most of those routes were circular and started and ended at the Student Union building on campus.

With these assumptions and the boarding data, the Ozark and Razorback transit surveys were expanded by route and summarized for each transit sub-mode by trip purpose. The targets are shown in Section 4 when the mode choice model validation is discussed.

2.3 Population Synthesizer Review

The original NWARPC model determines trip generation, trip distribution and mode choice at the household level, rather than at a zonal level (which is a more typical approach). In order to do this, the first step of the model disaggregates the socio-economic data from zonal averages or totals (provided in the Master TAZ input file) into synthetic households with various attributes – such as size, number of workers, students, retired members, etc. This is easiest to explain by way of example. The following is how the model determines the number of individuals in a household:

1. The model reads the average household size in the zone from the socioeconomic data file.
2. Based on the average household size, the model evaluates the probability that a household will have 1, 2, 3, or 4+ members based on curves estimated from Census data.
3. The model determines how many households of each size should be in the zone based on census distributions.
4. The model randomly assigns the household to one of the sizes.
5. The model decrements the number of households in the randomly chosen size.
6. The model repeats steps 4 and 5 until all households in the zone have been assigned.

For step 2, the original model used curves estimated from the 2005 Census Transportation Planning Package (CTPP), which was derived from the 2000 Census long form sample. As part of this 2014-2015 model update, the curves were updated based on data available in the most recent CTPP; this CTPP is based on responses to the 2007-2012 American Community Survey.

The basic procedure for producing the synthetic households was not changed; thus, the constraints and controls built into the process are still enforced. For example, a household cannot have only children and children cannot be workers, so the maximum number of children is the number of people minus the number of workers. Also, the household income is determined by the median income of the zone as well as the number of workers in the household. The calibration of the curves used in the Population Synthesis procedures is discussed in Section 4.

2.3.1 Auto Ownership Review

The synthetic population process determines the TAZ locations of households in the region and those households have certain characteristics that influence the results of other components of the NWA model. Households with zero cars (0-car HHs) are an important segment of the population to locate properly (put in the correct TAZs) in the base year and in forecast years because they tend to make up a large share of transit ridership in a region. While zero-car households are a relatively small part of the population in most areas, and are therefore difficult to survey, understanding where those households are located and understanding their travel behaviors is an important part of forecasting mode choice reliably. Figure 2-b shows the location of zero-vehicle households reported in the CTPP, and Figure 2-c shows the results of the vehicle ownership model in the revised synthetic population generator.

The major difference between the two figures is that the observed data is more peaked, with certain zones in semi-rural areas showing relatively high levels of zero-vehicle households. Overall, however, both the model and the observed data show the highest level of zero-vehicle households in Fayetteville and Bentonville where transit service, while limited, is available and thus the synthetic population does an adequate job of locating the zero-car households.

Figure 2-b: Observed Zero-Vehicle Households, CTTP

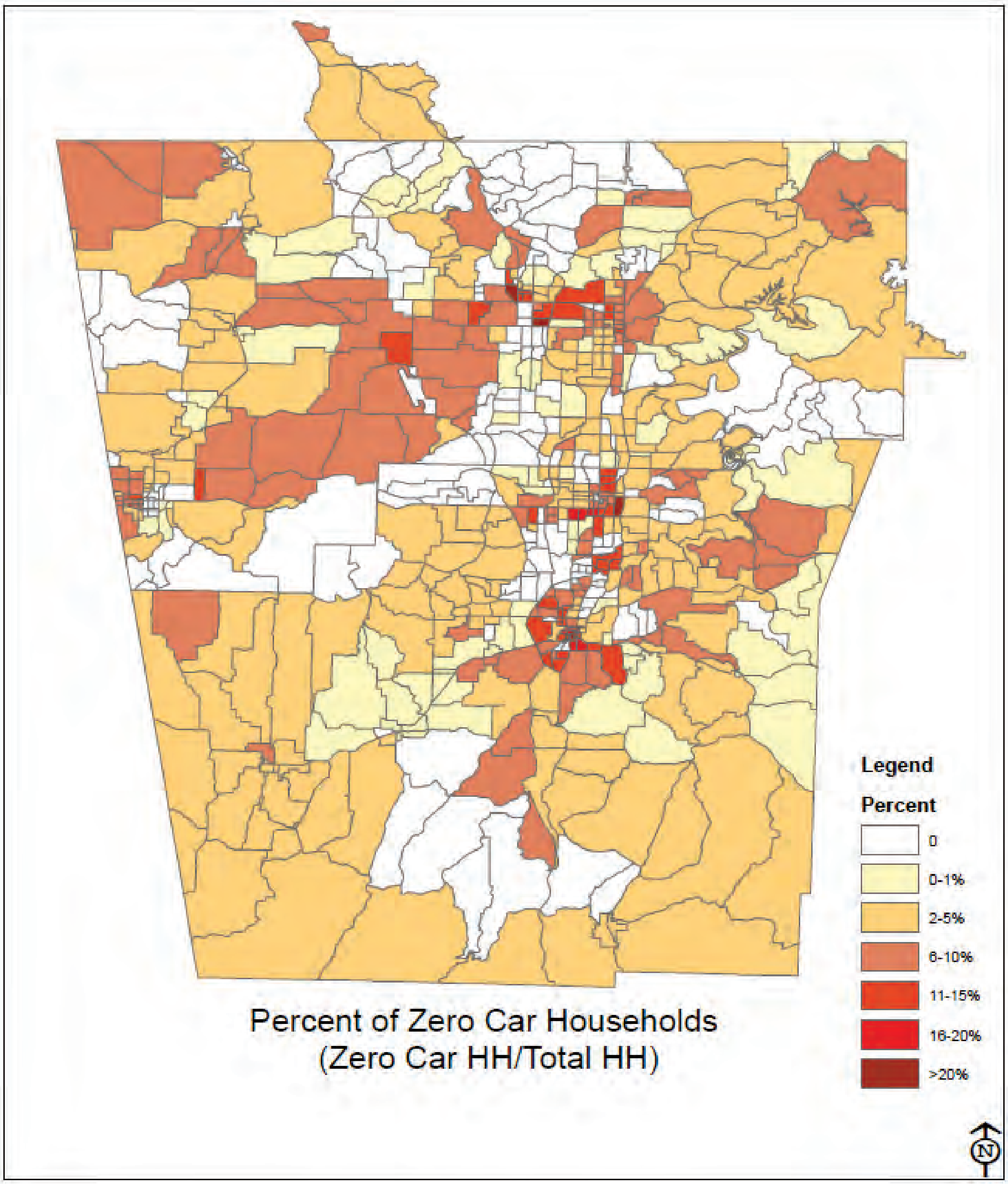
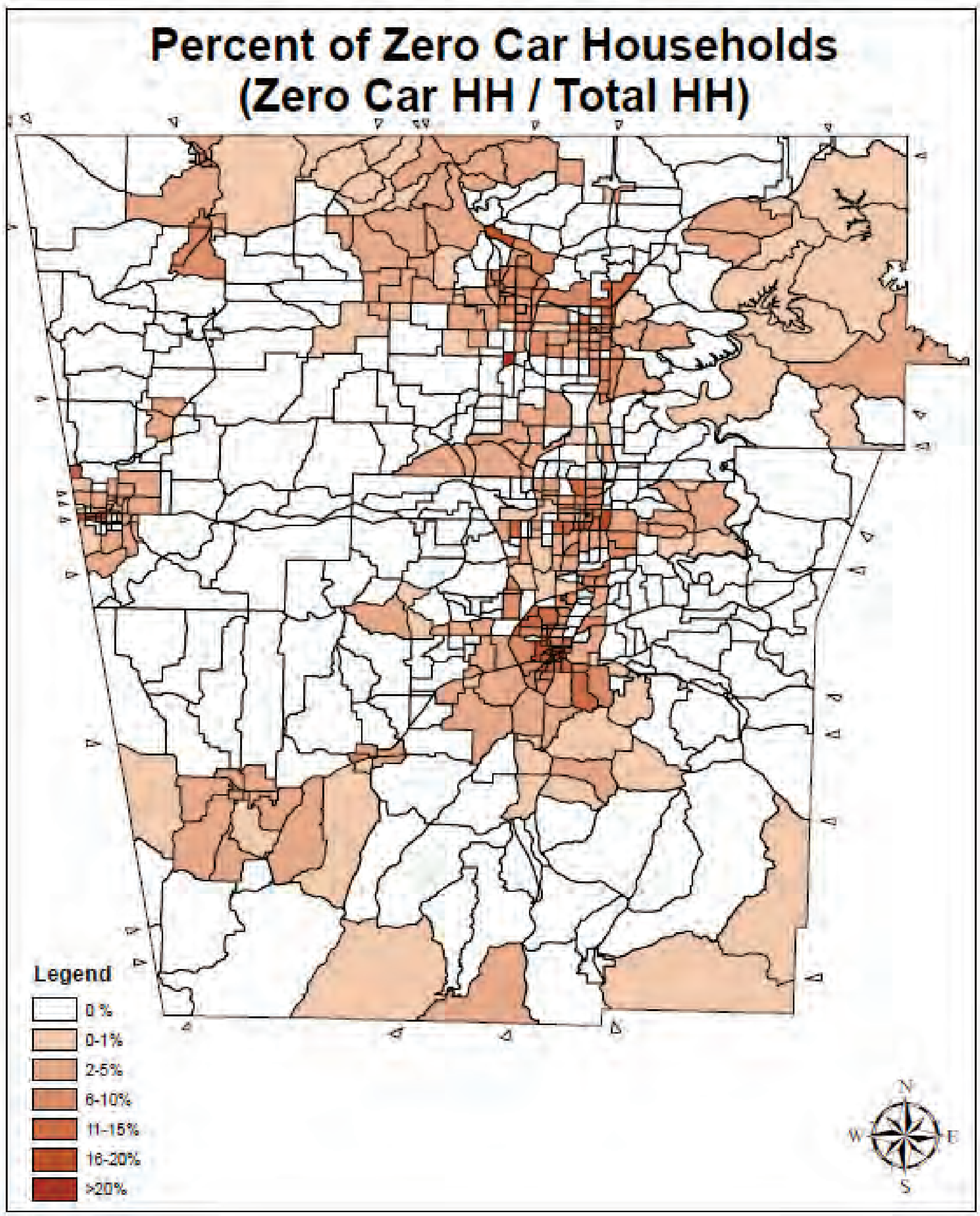


Figure 2-c: Estimated Zero-Vehicle Households, NWARPC model



In summary, the initial step in the model, the population synthesizer which creates a set of households with numerous household and person variables that match the zonal averages, and indirectly determines the location of the 0-car households, is sufficient (after the re-calibration of the curves discussed in Section 4) for adding a new mode choice component to the NWARPC model.

2.4 Trip Generation Review

The original and current model generates trips at the individual household level, which is unusual as trip-based models typically generate trips for a segment (typically based on size and income) of households using average trip rates for the particular segment.

In an attempt to understand the trip generation equations used in the original model, we tried to replicate the estimation of the HBW trip equation provided in the original model report. One difficulty was that the model includes a variable for the number of children in a household, but this variable was not explicitly asked about in the household survey. That is, the survey never asked how many children lived in the home, but rather collected trips on each person; if someone declined to fill in their children's trips, they are listed as having no children.

It was also unclear if the regression equations were estimated from weighted household survey data or used un-weighted (raw) data. "Weighted" means that because not every household in the region can be surveyed, each record gets assigned a value (a weight) that represents the number of households in the region that that record represents. The weights are calculated based on district-level control totals on households by size, number of workers, number of vehicles and income group. Each survey record is then assigned the appropriate weight such that the sum of the weights equals the number of households in the region.

Because there was no evidence of household survey weights in the survey files, it was assumed that the original estimation did not utilize survey weights, but for the revised estimation of the curves, we used both weighted and unweighted survey data.

The coefficients we estimated for the variables defined in the original model (and the t-statistic for each) are shown in Table 2-b below.

Table 2-b: Household HBW Trip Generation Coefficients

	Dependent Variable	
	HBW	
	Unweighted	Weighted
	(1)	(2)
log(WRKRS+1)	0.740	1.017
	(0.744)	(0.735)
log(VEHICLES +1)	1.740**	0.404
	(0.821)	(0.736)
(VEHICLES - WRKRS)	−0.496	0.021
	(0.301)	(0.282)
log(WRKRS + 1) * log(INCOMEVAL + 1)	0.108	0.269**
	(0.126)	(0.128)
log(CHILDREN + 1)	−0.178**	−0.167***

	(0.070)	(0.064)
SENIOR	−0.258	−0.275
	(0.187)	(0.190)
Constant	−0.405	−0.046
	(0.304)	(0.261)
Observations	487	154446
R2	0.384	0.426
Adjusted R2	0.376	0.419
Residual Std Error (df=634)	1.264 (df=480)	25.759 (df=469)
F Statistic (df=3; 634)	49.882∗∗∗ (df=6; 480)	58.081∗∗∗ (df=6; 469)

Note: ∗p<0.1; ∗∗p<0.05; ∗∗∗p<0.01

In general, the signs and magnitudes of the coefficients on our model are reasonable. However, both models are fundamentally different from the one in the documentation. For the most part the coefficients have the same sign and a similar magnitude. But whereas the original model has mostly significant parameters, only two (income times workers and children) are significant in the weighted re-estimation.

The documented models do not include intercepts, meaning that a household with no workers, income, vehicles, children, or seniors will make zero trips. This decision is not supported by the data. In fact, best econometric techniques strongly advise against it. A better methodology would be to not predict HBW trips for households with no workers. Regardless, a model without an intercept also does not replicate the original results.

One important difference between the documented model and the model we present in Table 2-b is the sign on the VEHICLES − WRKRS term. In our weighted model this is positive (though not significant), indicating that all else being equal, if a household has more vehicles than workers, it will make more work trips than a household with less vehicles than workers. In the documented model and in our unweighted model this term is strongly significant and also negative, meaning in some cases an extra vehicle will cause a household to make fewer trips which is not intuitive.

Given our initial review, revising and re-estimating the trip generation equations was not practical given the sparse survey data, our limited understanding of where the original equations came from and the scope, schedule and budget of this project. It was decided that we would continue with the existing equations and make adjustments to the constants if necessary during the model calibration and validation steps.

As shown later in Section 4, the trips produced by the original equations, with the change we implemented regarding the balancing of certain trip productions to attractions and global adjustments to the trip rates by purpose, closely match the weighted survey results. This is the desired outcome and therefore no further adjustments to trip generation were made.

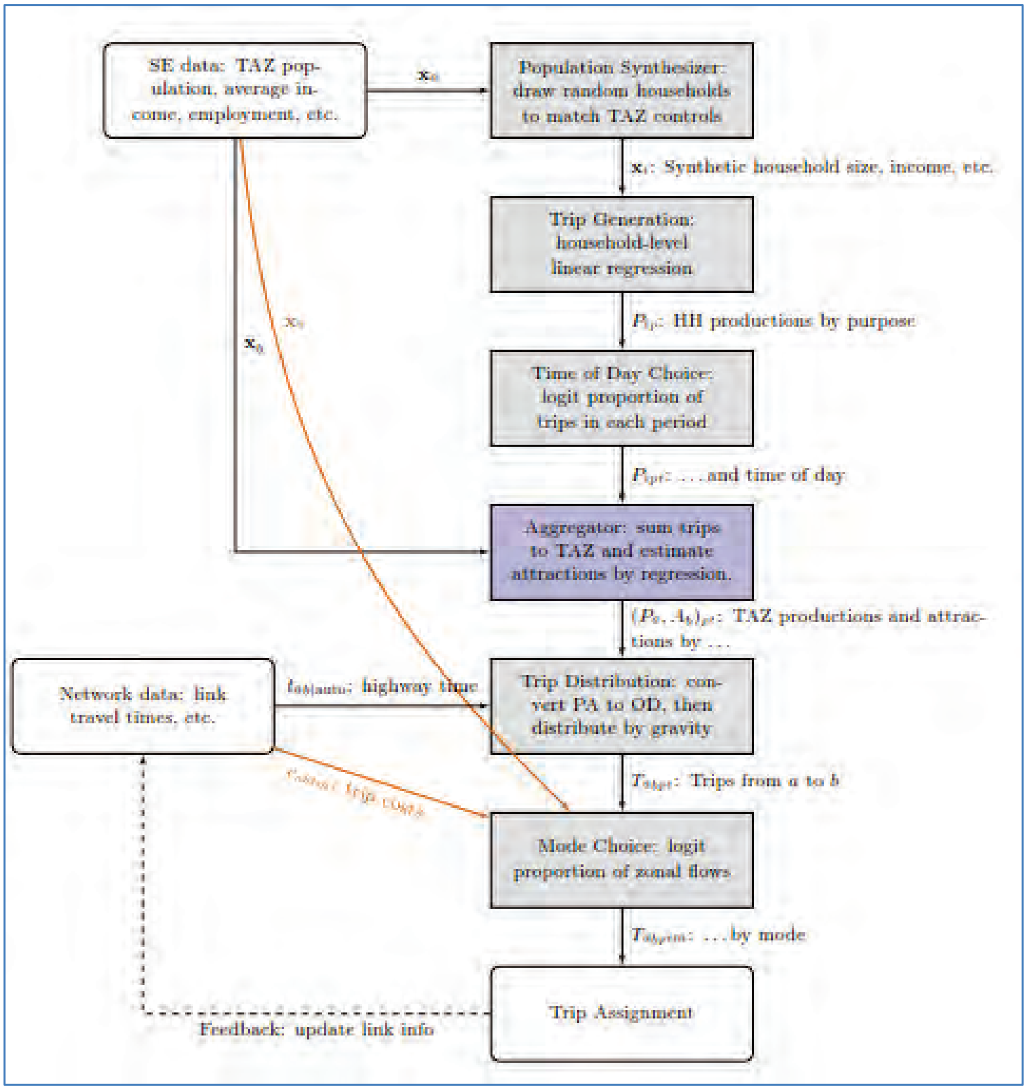
2.5 Trip Distribution Review

The original and current trip distribution model is a gravity model that uses auto friction factors to distribute productions to attraction zones. The model then converts the production and attraction matrices to origin and destination matrices using factors derived from the survey. The structure of this model was not changed but as part of the calibration of this model, the friction factors were adjusted and the trip generation calibration was further refined to include an urban and rural adjustment factor to better match district to district flows. This is discussed in Section 4.

2.6 Summary of Model Review

As a result of our review, we made the changes and re-ordered some of the model components leading up to the mode choice model as described in the sections above. The revised model flow chart is shown below in Figure 2-d. In addition, we noted other improvements that were outside the scope of this particular project but that should be considered in future updates. These are listed in Section 5.

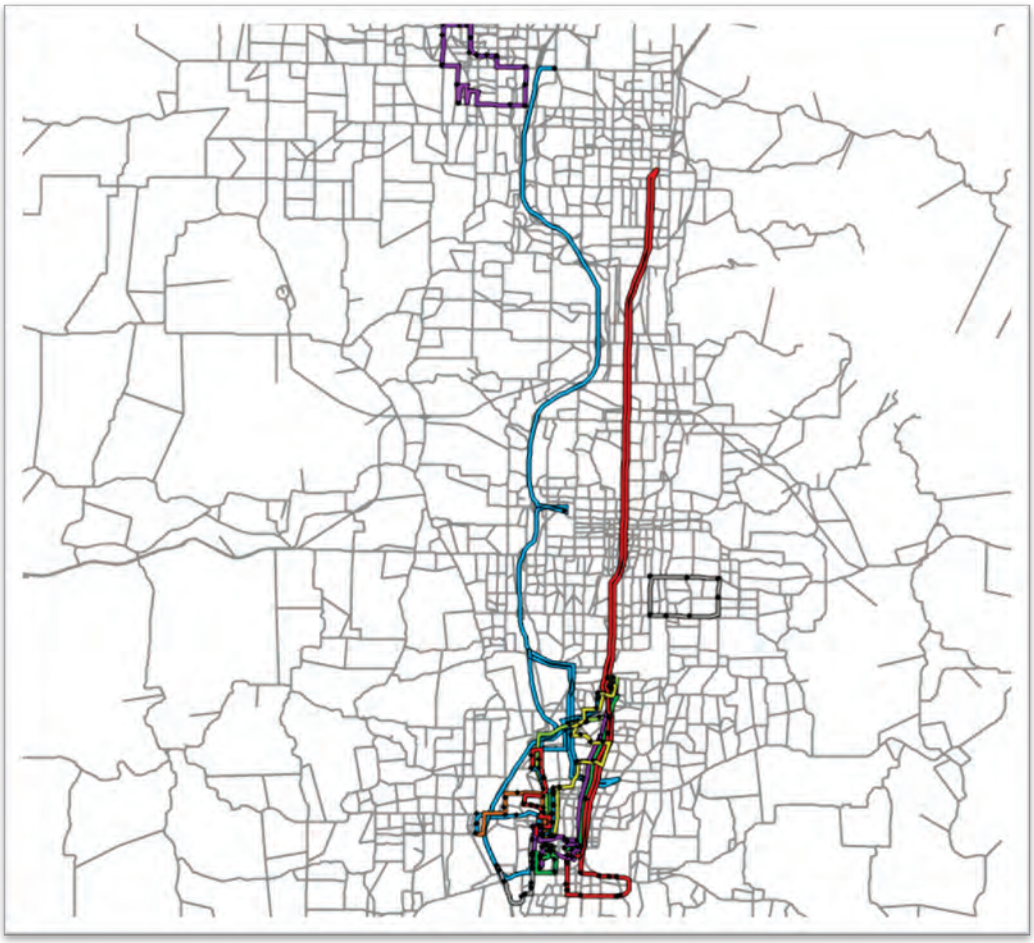
Figure 2-d: Newly Implemented Model Structure with New Input Pathways in Orange



3 Mode Choice Model Development

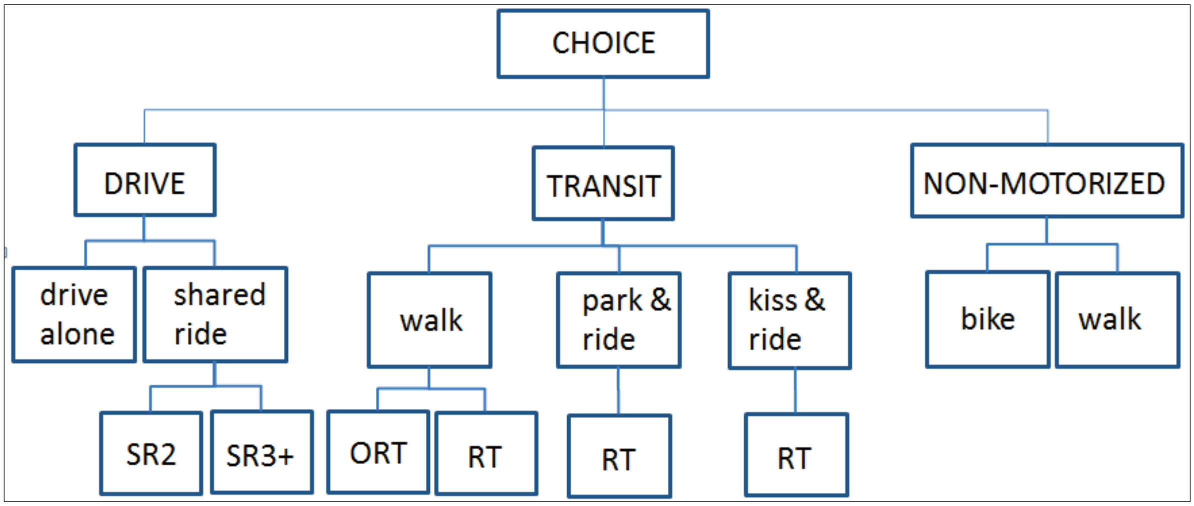
The primary purpose of this model enhancement project was to develop a state-of-the practice mode choice model. This required the development of a transit network in TransCAD that defines each available transit route in the Northwest Arkansas model's study area and the operating characteristics (headways, fares, and stops). The transit route system was created by NWA staff and is shown below in Figure 3-a.

Figure 3-a: Transit Route System for Northwest Arkansas



Whereas the original mode choice model used a logit model to calculate the probabilities of using an auto, transit or non-motorized mode based on the characteristics of the household (size, income, auto availability), the updated mode choice model considers these household characteristics along with the characteristics of the various modes. In other words, a high-income household that has a car might choose to drive, an additional consideration might be to take transit if a route is available and the travel time is comparable to driving. The original model did not include the additional consideration but the current model does. Furthermore, the current model includes the choice not only to drive, take transit or use a non-motorized mode, but there is a further choice to drive alone or share a ride (with 2 people – SR2 or 3 or more people – SR3+) if the choice is auto, to walk to transit or park-n-ride to transit or get dropped off to transit (kiss-n-ride) if the choice is transit or to walk or bike if the choice is non-motorized. The nesting structure for the current mode choice model is shown below in Figure 3-b.

Figure 3-b: Current Mode Choice Nesting Structure



The mode choice model parameters can be found in the reference directory. The coefficients listed in this file should not be modified as they are calibrated values, but for informational purposes first column lists the variables and the columns give the coefficient values for each purpose. 'Nest' refers to the nesting coefficient which is a parameter used in the nested logit model. 'Asc' is the alternative specific constant which is simply a number that represents un-included attributes of each mode (for example, feelings of safety on a particular mode). 'Value_of_time' captures the sensitivity of the traveler to travel time. The parameters file also includes the coefficients on in-vehicle time (ivt) and coefficients on the various transit attributes such as wait_time and walk_time to and from the transit stop to the final destination. Additional parameters used in the mode-choice model such as sr2 and sr3 are used to convert person trips into vehicle trips prior to assignment.

Note that for the home-based work purposes, there are different coefficients for income and auto sufficiency segments. For income segmentation, the 2010 Census puts Washington County's median income at $41,000 and Benton County's at $53,000. The survey also allows people to select "above $50,000" or "below $50,000" if they do not wish to disclose their income more precisely, so we decided to use $50,000 as the division between low and high incomes. "Sufficient" means that the number of autos in a household is either greater than or equal to the number of workers in the household. "Insufficient" means that the number of vehicles is less than the number of workers. For the home-based work trip, the trips are segmented by both income and sufficiency categories and the number of trips in each segment are calibrated to the observed values in the survey using the 'hhlf' parameter in the file.

The coefficients in the model are based on models developed for Indianapolis, IN and Austin, TX. It is considered best practice by the FTA to assert mode choice coefficients instead of estimating them since numerous studies have shown that the nesting, in-vehicle time, and wait-time coefficients do not vary widely from region to region. In fact, the FTA has published a set of acceptable ranges for the coefficients and thus it is unnecessary and a waste of resources to estimate these values. As is common practice, the NWA mode choice model was calibrated by adjusting the alternate specific constants.

For each trip purpose, the mode choice model chooses a mode (the choices are represented in Figure 3-b as the lowest box in each nest) for all trips for a given origin/destination by calculating the utility (the desirability) of each mode using the variables and the coefficients defined in the model. The calculated utilities are then converted into a probability of each trip using each particular mode for a given origin/destination pair using the nested logit model formulation. The probabilities are then multiplied by the total number of trips for that purpose for that origin/destination pair, thus determining the total trips by mode for each trip purpose in each origin/destination pair.

Figure 3-c: General Formula of a Logit Model

$$P_i = \frac{e^{U_i}}{\sum_m e^{U_i}}$$

where :

P_i = Probability of Choosing Mode i

U_i = Utility for mode i

e = natural logarithm

$\sum_m$ = sum across all modes m

The updated mode choice model is now sensitive to changes in the highway network as well as the transit network. In the original model, transit shares would have only been affected by changes in the population distributions (more low income households or more households without a vehicle for example) but would not have changed if more transit routes were added to the system or if highway congestion increased. With the current mode choice model, congestion levels, which result in slower auto times, will affect the transit shares, as will additional routes, more frequent service on existing routes, or any combination of transit and/or highway network changes. This allows NWARPC to test numerous scenarios that the original model would not have been sensitive to.

Additionally, while there are not currently HOV lanes present in the NWA highway network, the mode choice model is able to forecast potential users of such a system if it is introduced since all trips using SR2 or SR3 modes are eligible to use an HOV lane. To use this feature, the network will have to have HOV lanes coded and the network and assignment procedures will need to be modified, but the basic capability is there. Similarly, while the Ozark and Razorback transit systems do not currently offer light-rail or bus-rapid-transit options, the updated mode choice model can be modified to include these modes. The transit route system would need to be coded appropriately and the assignment routine modified, but again, the basic capability is there.

4 Base Year Model Calibration and Validation

As part of the review of each model component and in conjunction with the validation of the 2010 base year model, certain parameters were re-calibrated based on the CTPP (ACS) data, the household survey data and/or the ride-check data. Below is a discussion of those changes and the resulting comparisons to observed data.

4.1 Calibration of Population Synthesis

Figure 4-a shows the observed distribution of household sizes in the most recent CTPP; specifically Table A112106 Household size (5), which provides the distribution of households by size in each TAZ. Figure 4-b shows the distribution of household sizes resulting from the original NWARPC household generator. Both figures are shown with third-degree polynomial least squares regression lines.

To improve the model fit, we revised the probability curves estimated from the most recent CTPP data using the regression equations of the curves shown in Figure 4-a as the new curves. These equations are given in Table 4-a. Though we estimated curves for each household size, we drop the model with the worst fit based on its adjusted R2 value. For example, the curve for HH3 has the worst fit, so instead of using this curve, the number of three-person households in a zone is defined as the number of households that are not 1, 2, or 4 or more. The third-degree polynomial least squares regression line and dropping the worst fit curve and simply assigning the remainder to that category is the process used for all the re-estimation of the curves.

Figure 4-a: Observed (CTPP) Household Size Distribution as a Function of Mean TAZ Household Size

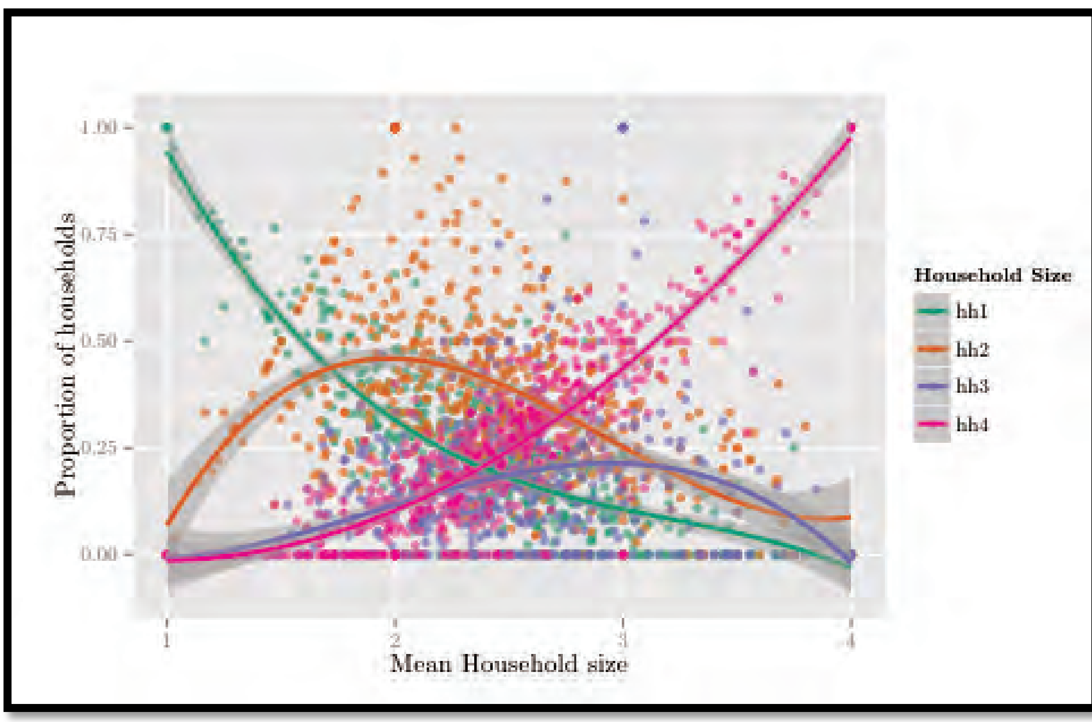


Figure 4-b: Synthetic Population Household Size Distribution from Original Model

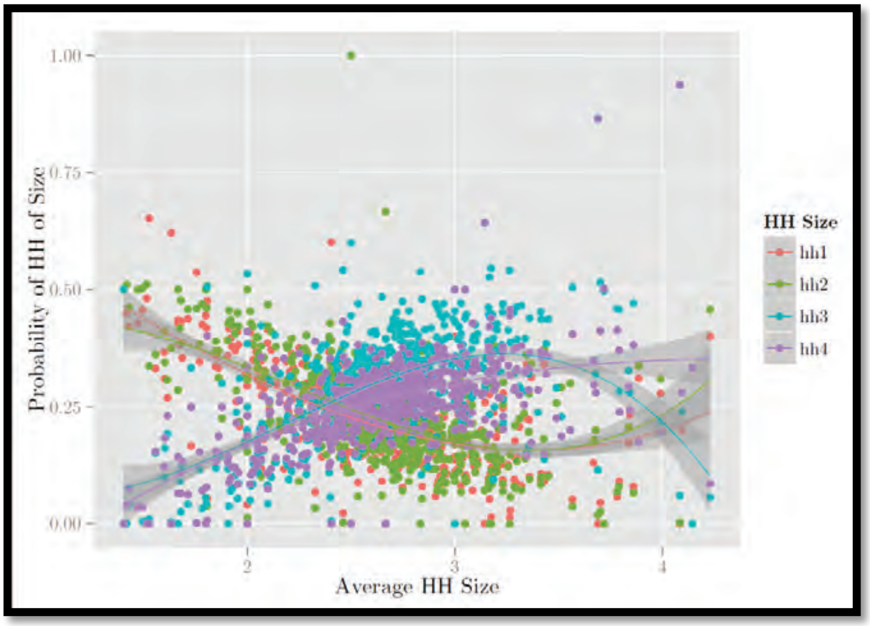


Figure 4-c and Table 4-a show the updated equations used to determine the probability of a household being of size 1, 2, 3 or 4+ based on the average household size in any given zone. Though these curves, and the ones that follow, do not perfectly replicate the observed values, they more closely match the shape of the more recently observed distributions.

Figure 4-c: Synthetic Population Household Size Distribution from Revised Model

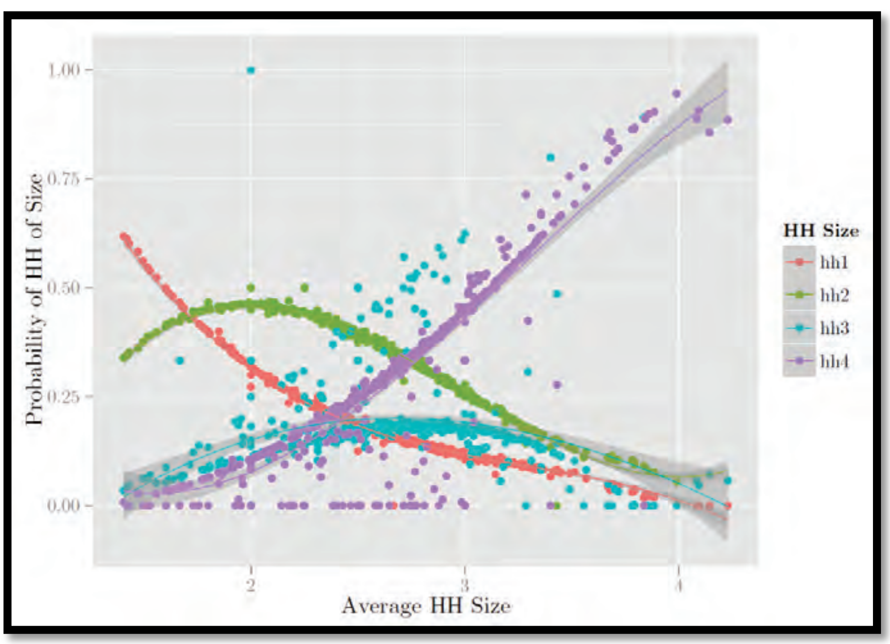


Table 4-a: Household Size Models

	Dependent Variable			
	HH1	HH2	HH3 (suppressed)	HH4+
	(1)	(2)	(3)	(4+)
Mean	−1.908∗∗∗	2.464∗∗∗	−0.378	−0.222
	(0.206)	(0.331)	(0.261)	(0.175)
Mean squared	0.562∗∗∗	−0.940∗∗∗	0.285∗∗∗	0.116
	(0.085)	(0.136)	(0.107)	(0.072)
Mean cubed	−0.058∗∗∗	0.107∗∗∗	−0.050∗∗∗	−0.001
	(0.011)	(0.018)	(0.014)	(0.009)
Intercept	2.350∗∗∗	−1.562∗∗∗	0.132	0.094
	(0.160)	(0.258)	(0.203)	(0.136)
Observations	641	641	641	641
R2	0.634	0.227	0.131	0.784
Adjusted R2	0.633	0.223	0.127	0.783
Residual Std Error (df=637)	0.119	0.192	0.151	0.101
F Statistic (df=3; 637)	368.348∗∗∗	62.224∗∗∗	32.144∗∗∗	770.216∗∗∗

Note: ∗p<0.1; ∗∗p<0.05; ∗∗∗p<0.01

The next several tables and figures show the remainder of the population synthesis calibration efforts. Figure 4-d and Table 4-b shows the equations used to determine the probability of a household having 0, 1, 2 or 3+ workers based on the average number of workers per household in any given zone.

Figure 4-d: Number of Workers as a Function of Mean TAZ Workers per Household

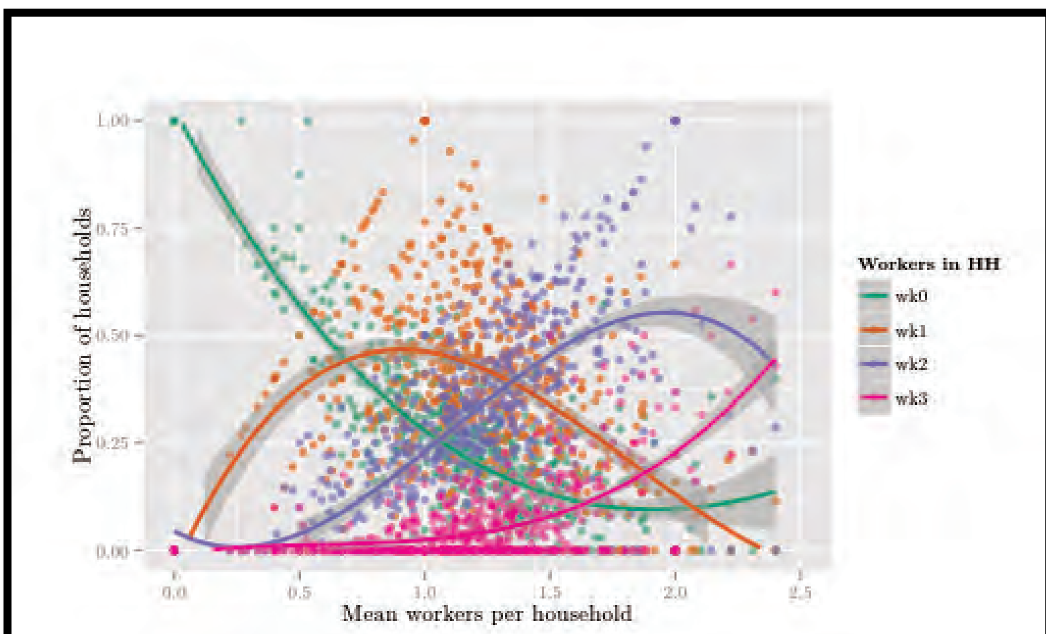


Table 4-b: Household Workers Models

	Dependent Variable			
	Wk0	Wk1 (suppressed)	Wk3	Wk4
	(1)	(2)	(3)	(4+)
Mean	−1.096∗∗∗	1.264∗∗∗	−0.320∗∗	0.083
	(0.104)	(0.167)	(0.133)	(0.065)
Mean squared	0.384∗∗∗	−0.926∗∗∗	0.722∗∗∗	−0.117∗
	(0.097)	(0.157)	(0.125)	(0.061)
Mean cubed	−0.034	0.169∗∗∗	−0.217∗∗∗	0.067∗∗∗
	(0.028)	(0.045)	(0.036)	(0.017)
Intercept	1.026∗∗∗	−0.043	0.045	−0.009
	(0.036)	(0.058)	(0.046)	(0.023)
Observations	638	638	638	638
R2	0.611	0.223	0.448	0.376
Adjusted R2	0.609	0.219	0.445	0.373
Residual Std Error (df=634)	0.123	0.197	0.157	0.077
F Statistic (df=3; 634)	332.053∗∗∗	60.657∗∗∗	171.397∗∗∗	127.239∗∗∗

Note: ∗p<0.1; ∗∗p<0.05; ∗∗∗p<0.01

Figure 4-e and Table 4-c show the equations used to determine the probability of a household having 0, 1 or 2+ children based on the average number of children per household in any given zone.

Figure 4-e: Number of Children as a Function of Mean TAZ Children Household

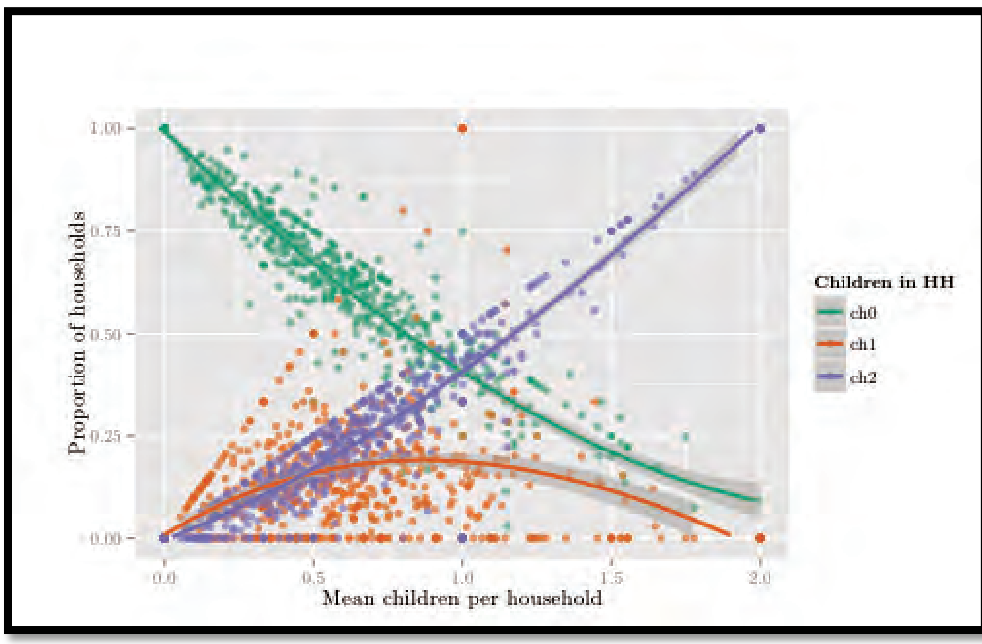


Table 4-c: Household Children Models

	Dependent Variable		
	Ch0	Ch1 (suppressed)	Ch2+
	(1)	(2)	(3)
Mean	−0.697∗∗∗	0.445∗∗∗	0.278∗∗∗
	(0.044)	(0.069)	(0.034)
Mean squared	0.099	−0.302∗∗∗	0.151∗∗∗
	(0.062)	(0.097)	(0.049)
Mean cubed	0.012	0.035	−0.018
	(0.023)	(0.036)	(0.018)
Intercept	0.993∗∗∗	0.008	−0.004
	(0.009)	(0.013)	(0.007)
Observations	642	642	642
R2	0.868	0.181	0.897
Adjusted R2	0.867	0.178	0.897
Residual Std Error (df=638)	0.087	0.137	0.068
F Statistic (df=3; 638)	1,398.900∗∗∗	47.118∗∗∗	1,855.420∗∗∗

Note: ∗p<0.1; ∗∗p<0.05; ∗∗∗p<0.01

Figure 4-f and Table 4-d show the equations used to determine the probability of a household having 0, 1, 2, or 3+ vehicles based on the average number of vehicles per household in any given zone.

Figure 4-f: Household Vehicles as a Function of Mean TAZ Vehicles

Table 4-d: Household Vehicle Models

	Dependent Variable			
	Veh0	Veh1	Veh2 (suppressed)	Veh3+
	(1)	(2)	(3)	(4+)
Mean	−1.435***	2.010***	−0.778***	0.148
	(0.074)	(0.169)	(0.218)	(0.107)
Mean squared	0.684***	−1.556***	1.091***	−0.170**
	(0.051)	(0.117)	(0.150)	(0.074)
Mean cubed	−0.110***	0.315***	−0.293***	0.076***
	(0.011)	(0.025)	(0.033)	(0.016)
Intercept	1.037***	−0.098	0.084	−0.018
	(0.036)	(0.081)	(0.105)	(0.051)
Observations	596	596	596	596
R2	0.646	0.556	0.330	0.664
Adjusted R2	0.644	0.554	0.326	0.662
Residual Std Error (df=634)	0.066	0.151	0.195	0.096
F Statistic (df=3; 634)	359.987***	247.028***	97.014***	389.219***

*Note: *p<0.1; **p<0.05; ***p<0.01*

4.1.1 Joint Household Attributes

Variables such as household size, autos and children are considered primary attributes, because the household generator model computes them directly from the observed probability curves. Household income, however, considers the household's primary characteristics in addition to the TAZ marginal probability curves. For determining the income group of a household, the model considers the *median* income of the zone, its relative position against the regional *median* (which was calculated as $50,000), as well as how many workers the household has. The zone probability based on the relative median (zonal median divided by regional median gets at whether the zone is relatively wealthy or poor) is adjusted based on another probability curve relating the number of workers to income group.

Figure 4-g and Table 4-e shows the equations used to determine the probability of a household being in the below $25K, below $50K, below $75K, below $100K or $100K+ range based on the relative median income. The observed relationship between workers and household income is shown in Figure 4-h and also listed in Table 4-f.

Figure 4-g: Median Income as a Function of Mean TAZ Income and Region Median

Table 4-e: Household Income Models

	Dependent Variable				
	Inc25	Inc50	Inc75 (suppressed)	Inc100	Inc A 100
	(1)	(2)	(3)	(4)	(5)
Mean	−2.260∗∗∗	2.313∗∗∗	0.101	−0.254∗∗	0.010
	(0.140)	(0.171)	(0.170)	(0.126)	(0.123)
Mean squared	1.487∗∗∗	−2.178∗∗∗	0.294∗	0.407∗∗∗	0.075
	(0.136)	(0.166)	(0.165)	(0.122)	(0.119)
Mean cubed	−0.321∗∗∗	0.566∗∗∗	−0.159∗∗∗	−0.122∗∗∗	0.010
	(0.039)	(0.048)	(0.048)	(0.035)	(0.035)
Intercept	1.260∗∗∗	−0.353∗∗∗	0.013	0.081∗∗	0.033
	(0.043)	(0.053)	(0.052)	(0.039)	(0.038)
Observations	592	592	592	592	592
R2	0.659	0.323	0.190	0.207	0.420
Adjusted R2	0.657	0.319	0.186	0.203	0.417
Residual Std Error (df=637)	0.129	0.158	0.157	0.116	0.113
F Statistic (df=3; 637)	378.178∗∗∗	93.476∗∗∗	45.941∗∗∗	51.285∗∗∗	141.993∗∗∗

Note: ∗p<0.1; ∗∗p<0.05; ∗∗∗p<0.01

Figure 4-h: Revised Model Relationship Between Household Workers and Income Group

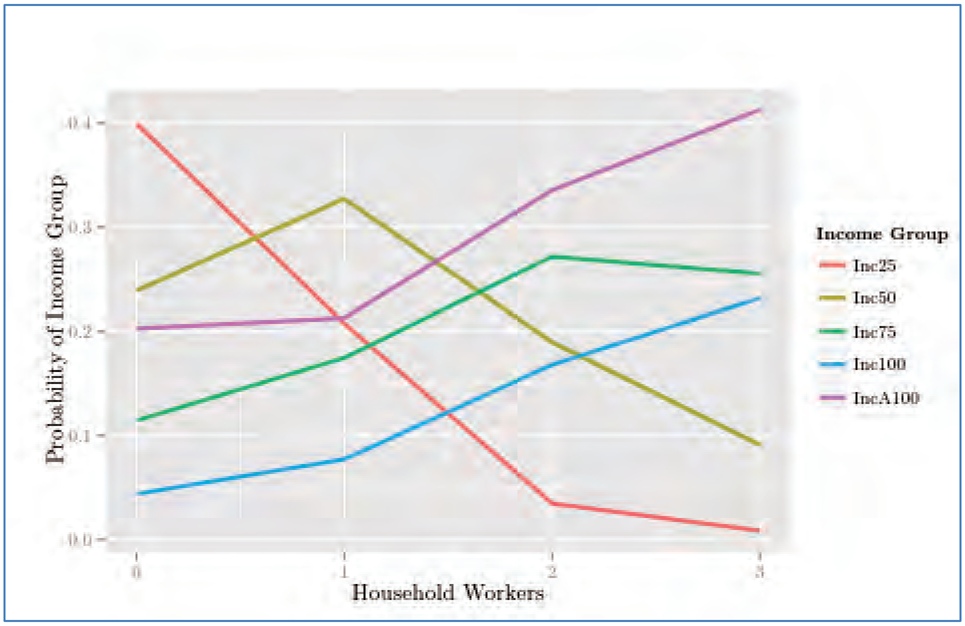


Table 4-f: Probability of Income Group Given Workers

	0 workers	1 worker	2 workers	3 workers	4 or more workers
Inc25	0.531	0.273	0.060	0.026	0.027
Inc50	0.265	0.361	0.229	0.125	0.094
Inc75	0.116	0.174	0.274	0.250	0.150
Inc100	0.045	0.078	0.176	0.253	0.319
IncA100	0.043	0.113	0.262	0.347	0.411

The zonal averages of household size, average number of workers per household, average number of autos per household, average number of children per household and median income for each TAZ in the model area is what needs to be included in the socio-economic data. For a census year, those values can be obtained by summarizing the CTPP data. For future years, absent better information, the values for each zone can remain the same.

The equations calculated as part of this model update will not need to be revisited until new Census information is available and the model's base year is updated.

4.2 Calibration of Trip Generation

The first step in the trip generation calibration was a comparison of the total number of trip productions by purpose to the household survey data, the relevant TAZ data and trip rates by household and by person in other regions.

The initial 2010 model run produced the trips shown in Table 4-g below. Ratios such as work productions per job (employment), school productions per student and shopping productions per retail worker were calculated based on the number of household and persons produced by the population synthesis model for 2010. The productions were also compared to the weighted household survey data.

Table 4-g: Trip Productions for Initial 2010 Model Run

TOTALS BY PURPOSE	
	Productions
HBW	251,422
HBU	67,092
HBSC	54,355
HBSB	304,322
HBO	396,000
NHBW	225,957
NHBO	588,434
ALL	**1,887,582**

After several rounds of calibration, whereby the trip productions were adjusted to match the observed data using trip_rate_adjustment factors, the resulting trip productions closely match the observed data. The trip generation calibration was further refined during the trip distribution and the assignment validation to include trip rate adjustments for rural and urban TAZs separately. The purpose of this was to better match the district to district flows and the rural versus urban link flows. The final results are shown in Table 4-h below along with the final trip_rate_adjustment values.

Table 4-h: Final Trip Generation Results Compared to HH Survey Data

Purpose	Model	Observed	Diff	Pct Diff	rate_adj	urban_adj	rural_adj
HBW	218,190	217,214	976	0%	0.745	1	0.9
HBU	18,894	5,926	12,968	219%			
HBSC	79,168	26,990	52,179	193%	1.501	1.1	0.9
HBSB	130,619	130,083	536	0%	0.355	1.1	0.9
HBO	435,178	434,629	550	0%	1.064	1.1	0.9
NHBW	441,246	441,883	(637)	0%	1.25	1.1	0.9
NHBO	177,630	177,887	(256)	0%	1.25	1.1	0.9
ALL	**1,500,925**	**1,434,611**	66,314	5%			

While the overall trip generation results are within 5% of the observed value, the HBU (university) and HBSC (school) clearly do not match the observed data. Thus, the second step in the calibration was to look at the unbalanced productions and attractions produced by the equations in the model. Table 4-i shows those values.

Table 4-i: Unbalanced Productions and Attractions from 2010 Model Run

TOTALS BY PURPOSE				
Unbalanced PAs	**Productions**	**Attractions**	**Difference**	**% Difference**
HBW	218,190	143,916	(74,274)	-34%
HBU	67,092	18,894	(48,199)	-72%
HBSC	79,168	42,481	(36,688)	-46%
HBSB	130,619	53,063	(77,556)	-59%
HBO	435,178	228,592	(206,586)	-47%
NHBW	327,678	441,246	113,568	35%
NHBO	789,942	177,630	(612,312)	-78%
ALL	**2,047,868**	**1,105,822**	**(942,046)**	**-46%**

It is not expected that productions equals attractions initially since production rates are based on household characteristics whereas attraction rates are based on employment and land-use characteristics. However, once the number of productions and attractions are calculated, the model balances the productions to the attractions (or vice versa) so that the trip distribution model can match each production with an attraction, thus forming the trip flows.

As noted earlier, in the original model the attractions were balanced to (set equal to) the productions for each purpose. For work, shopping and other trips this is typical since there is a greater level of confidence about the number of trips *households produce* compared to the number of trips that TAZ-level *employment attract*. However, in the case of school and university trips, it is more typical to balance the productions to the attractions since the number of attractions is essentially equal to the school/university enrollment so the confidence in the number of attractions is higher than the confidence in the productions. Similarly, with non-home-based trips, there is more confidence in the number of attractions, based on employment, than on the productions which are calculated based on the households in their home TAZ even though they are NON-home-based trips.

In the case of the university trips, the model calculated ~67,000 (Table 4-g) productions and 18,000 attractions (Table 4-i). Based on the university enrollment of 26,282, the 5,926 (Table 4-h) observed home-base university trips, and in the absence of better data, it was decided to balance the university trip productions to the trip attractions.

For school trips, the model originally calculated ~54,000 productions (Table 4-g), ~42,000 attractions (Table 4-i) and the number of observed trips was ~26,000 (Table 4-h). With a school enrollment of 77,742 all of these values seemed too low. The final calibration value of 79,168 was based on a school production to school enrollment ratio of approximately 1%.

Finally, it was decided based on the typical range of non-home-based trips to total trips in a region, that the non-home-based work (NHBW) and non-home-based other (NHBO) trip productions would be balanced to (set equal to) trip attractions. By combining the HBU, HBSC, HBSC and HBO into "HBO"; NHBW and NHBO into "NHB" and keeping the HBW trips as "HBW", a comparison was made of the percent of these trips to total trips to percentages in other regions as published in NCHRP Report 365. Table 4-j below shows this comparison.

Table 4-j: Percentage of HBW, HBO and NHB Trips to Total Trips

Purpose	# of Productions	% Prods of Total	Typical
HBW	218,190	15%	18 to 21%
HBO	663,859	44%	47-54%
NHB	618,877	41%	22-32%
Total	**1,500,925**	**100%**	

Final validation of the trip generation model included a comparison of the household and person trip rates, calculated using the TAZ household and person population and the trip generation results, to those seen in other regions. As shown in Table 4-k below the trips produced by the NWA model mostly fall within the typical range.

Table 4-k: NWA Model Trip Rates Compared to Other Regions

Ratios for Validation Checks		
HH and Person Trip Rates	NWA Model	Typical Range*
Total Productions per HH	12.86	8 to 18
Total Productions per Person	4.80	3.5 to 4.0
Other Measures		
HBW Productions per HH	1.4	1.7 to 2.3
HBO Productions per HH	4.2	3.5 to 4.8
NHB Productions per HH	3.9	1.7 to 2.9
Workers per Household	1.3	

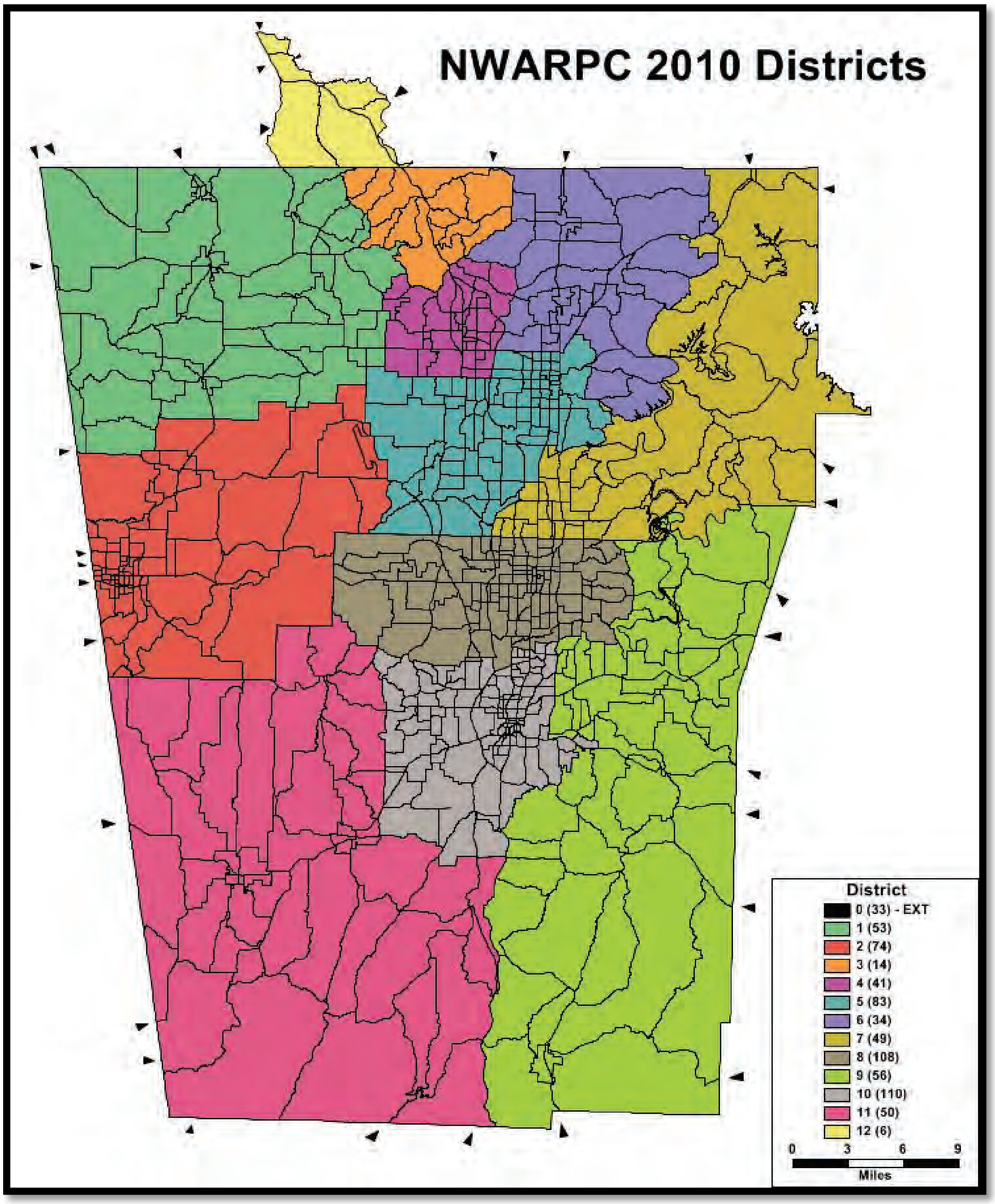
* Source of Typical Ranges: NCHRP Report 365 and FHWA Survey

In summary, with the trip rate adjustments and the change in the productions to attractions balancing for the university, school and non-home-based trips, the NWA trip generation model replicated the 2005 household survey data and the results were reasonable when compared to typical household and person trip generation rates in other regions.

4.3 Calibration of Trip Distribution

The Trip Distribution model attempts to match trip productions (the home end of a trip) to trip attractions (the non-home end of a trip). There are two aspects of trip distribution that are important to validate: the district-to-district work flows and the average trip-lengths for each trip purpose. Figure 4-i below shows the 13 districts in the model. The survey data did not include the external stations (district 0) or the Missouri TAZs (district 12), thus the following comparisons only show data for districts 1-11.

Figure 4-i: The Grouping of TAZs into Districts



Work Flows

The CTPP uses ACS and LEHD data to create home-to-work flows at a disaggregate zonal (Traffic Analysis District (TAD) level. Table 4-l was generated for the districts established in the model and compared to the survey data to establish a basis for the trip distribution calibration targets.

Table 4-l: District to District Work Flows from 2010 Census

	01	02	03	04	05	06	07	08	09	10	11
01	2040	780	360	3240	1370	170	285	430	15	220	15
02	290	8795	4	675	620	135	200	805	15	455	50
03	175	195	1565	3640	1425	220	285	550	0	370	0
04	235	185	340	8960	2905	430	525	590	70	340	30
05	300	500	230	6345	13445	1620	1660	3575	80	1275	215
06	100	160	105	2525	3795	1700	275	735	4	375	80
07	195	85	30	970	2195	385	1415	2920	40	1290	160
08	185	485	120	1695	2230	200	1230	19955	310	6145	135
09	0	245	0	375	315	115	250	3270	1515	5090	255
10	25	370	15	1735	1795	275	965	7265	895	23785	590
11	10	410	4	170	105	45	255	1640	230	4315	2460

Table 4-m: Observed District to District Work Flows from the Weighted Household Survey

	1	2	3	4	5	6	7	8	9	10	11
1	4,837	165	848	3,137	1,515	0	82	799	0	264	0
2	0	10,855	0	0	136	0	0	632	385	926	0
3	511	214	2,415	1,911	1,725	0	223	284	0	266	0
4	0	428	483	14,064	3,249	0	0	961	0	0	0
5	1,615	0	0	13,654	15,813	1,579	548	5,028	0	1,278	0
6	0	0	0	3,794	2,155	1,473	0	1,800	0	0	0
7	0	0	0	507	1,111	983	2,534	6,512	0	281	0
8	0	0	0	237	6,010	179	4,665	18,363	0	9,518	0
9	162	1,369	0	226	660	180	238	4,212	735	4,666	329
10	0	363	0	3,075	1,187	1,138	784	9,109	1,737	25,562	559
11	0	737	0	1,031	801	0	120	1,482	101	3,206	2,493

The defined districts within the NWA study area are fairly large so it is not surprising the diagonal (intra-district flows) are so pronounced. Districts 5, 8 and 10 represent the heart of the study area, from Bentonville down to Fayetteville along the I-49 corridor and in both the census data and the household survey data it is seen that these districts produce the greatest number of trips.

While the household survey does have numerous cells with 0 trips, those represent only a small fraction of the overall trips in the region and therefore do not raise much concern.
The final observation of the comparison between the census data and the household survey data is that overall the survey district to district flows compare favorably to the census flows; however, the survey data for district 4 (both the district 4 to 4 and district 4 to 5 flows) are much higher than the observed flows. This may be a result of slightly different district boundaries (district 4 is directly north of district 5) or a result of survey bias.

Before comparing the district to district flows from the model to the observed data, the trip length frequency calibration was done for each trip purpose. Because the survey data reasonably match the census data, the targets for the trip length frequency distribution were based on the household survey. The adjustments are made by changing the friction factors that are used by the gravity model. As the travel time between a production zone and a potential attraction zone increases, the "pull" of that zone decreases. Friction factors represent this function in the gravity model.   Figure 4-j through Figure 4-o show the results of the trip-length frequency distribution calibration.

Figure 4-j: Home-based Work Trip Length Frequency in Miles

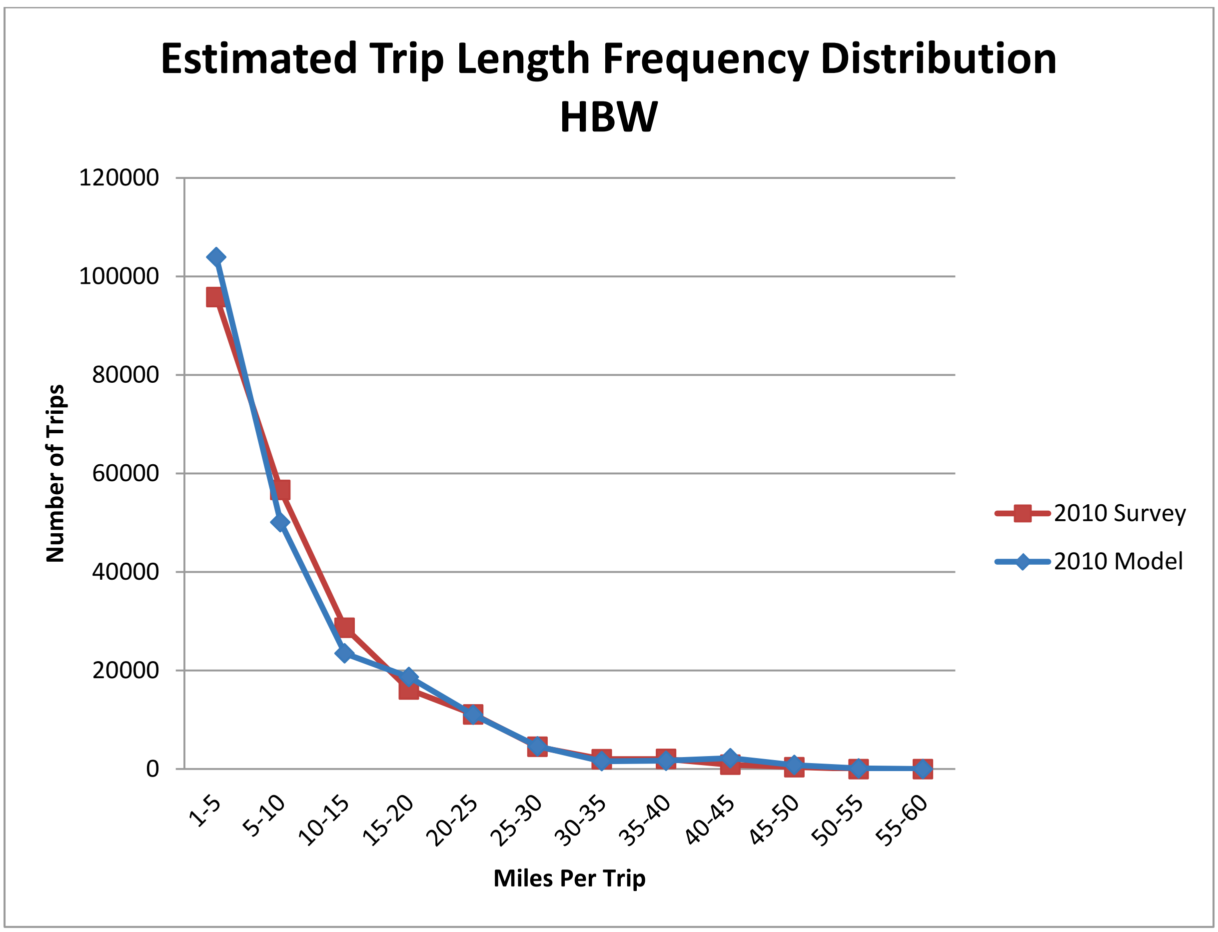


Figure 4-k: Home-based University Trip Length Frequency in Miles

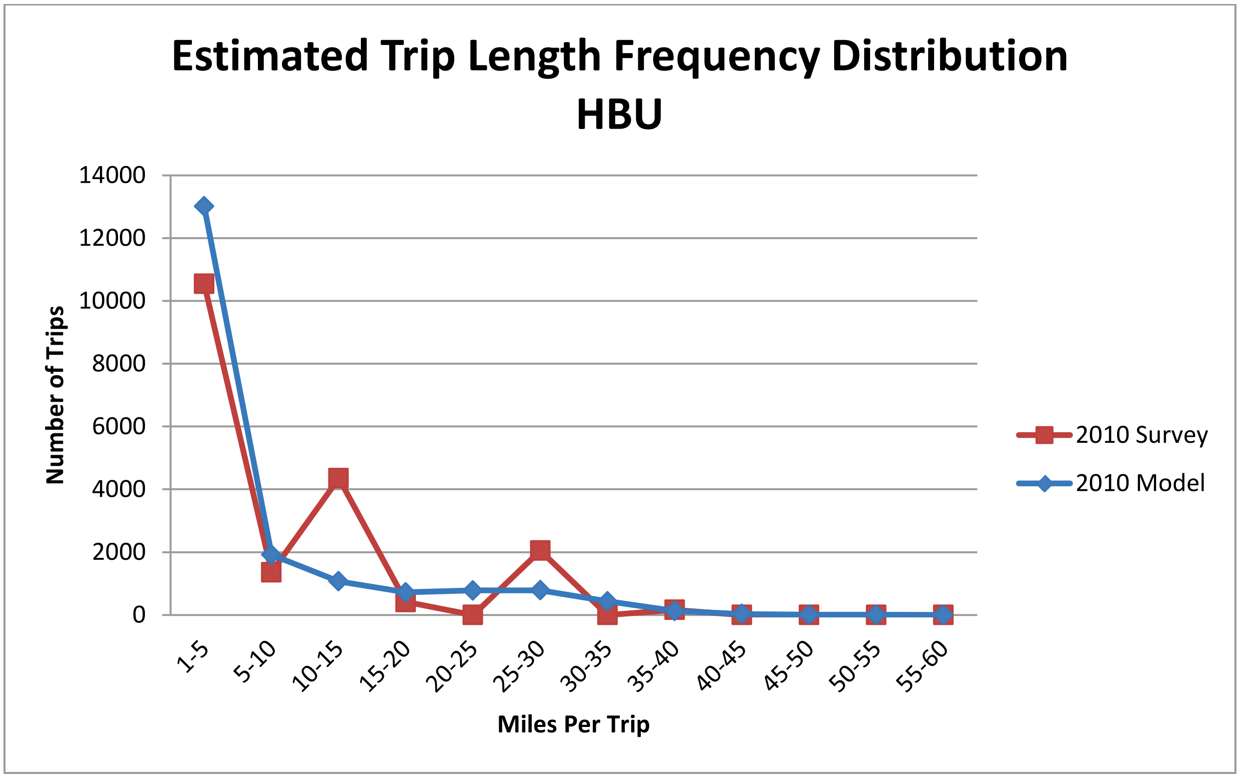


Figure 4-l: Home-based School Trip Length Frequency in Miles

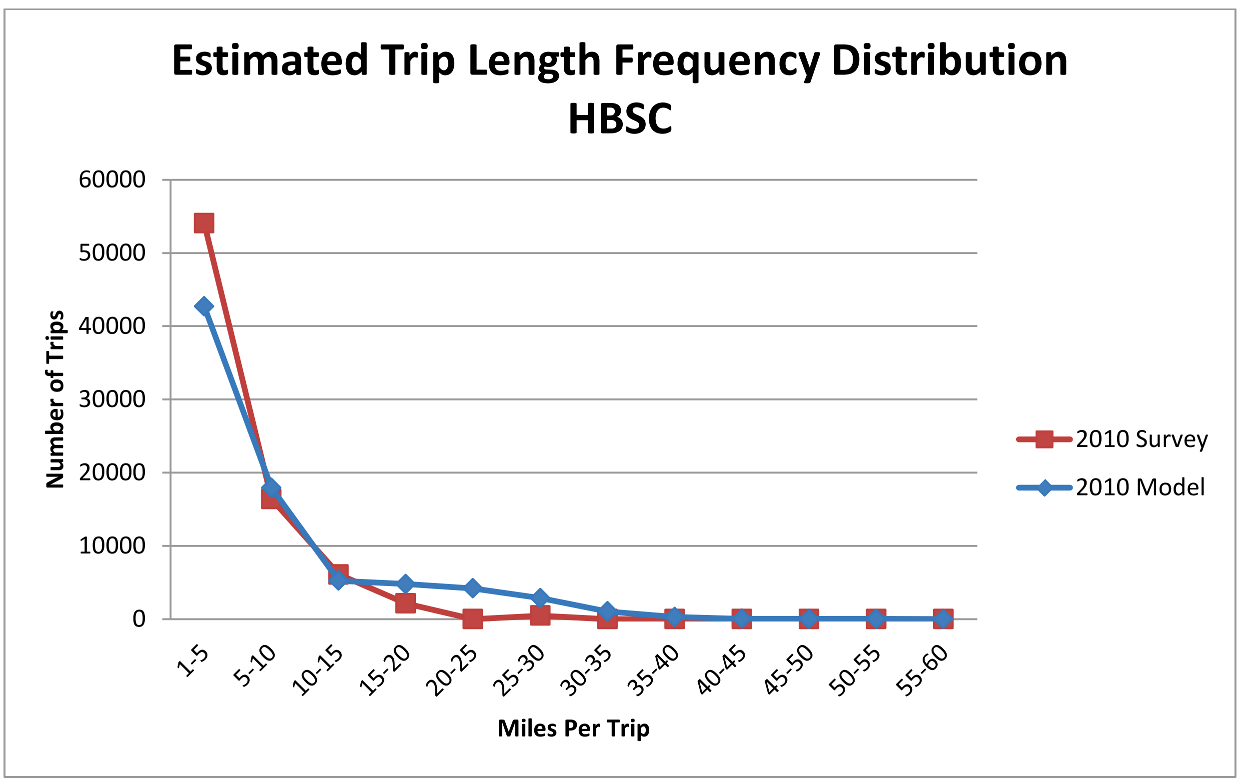


Figure 4-m: Home-based Shopping and Personal Business Trip Length Frequency in Miles

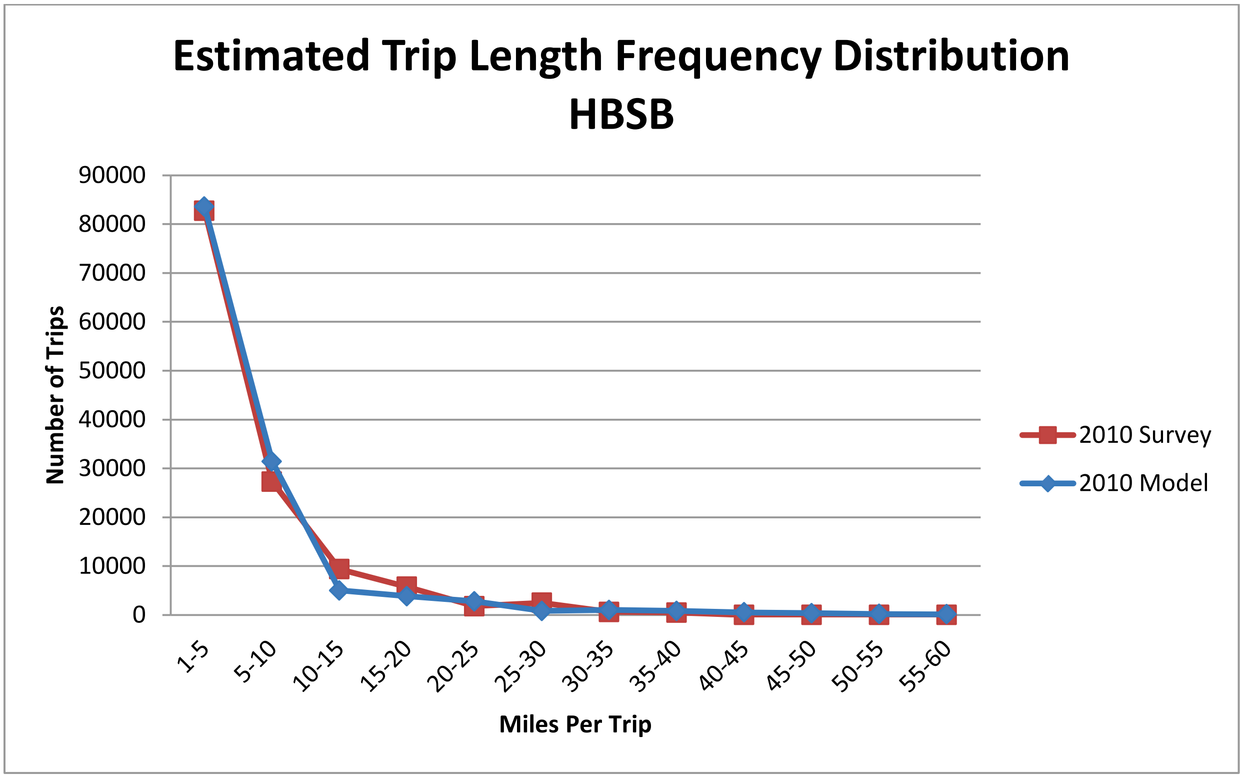


Figure 4-n: Home-based Other Trip Length Frequency in Miles

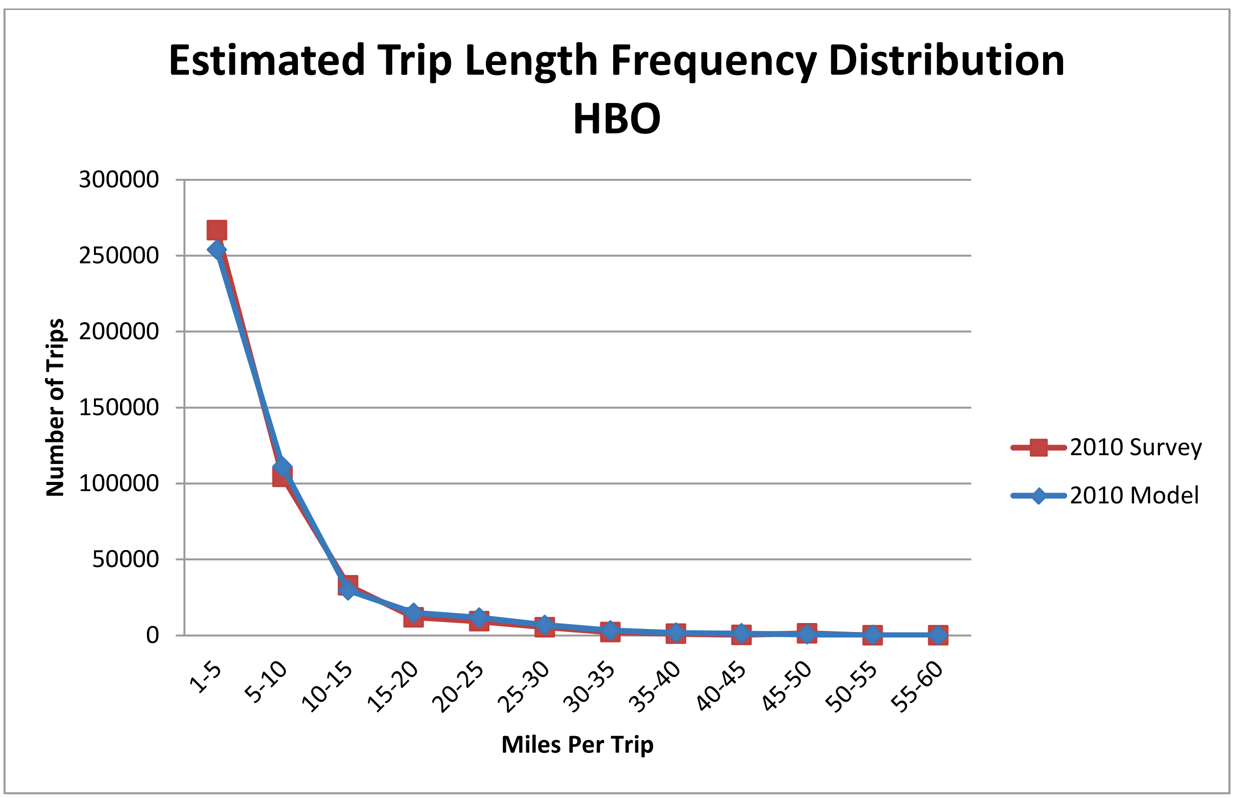


Figure 4-o: Non-home-based (Work and Other) Trip Length Frequency in Miles

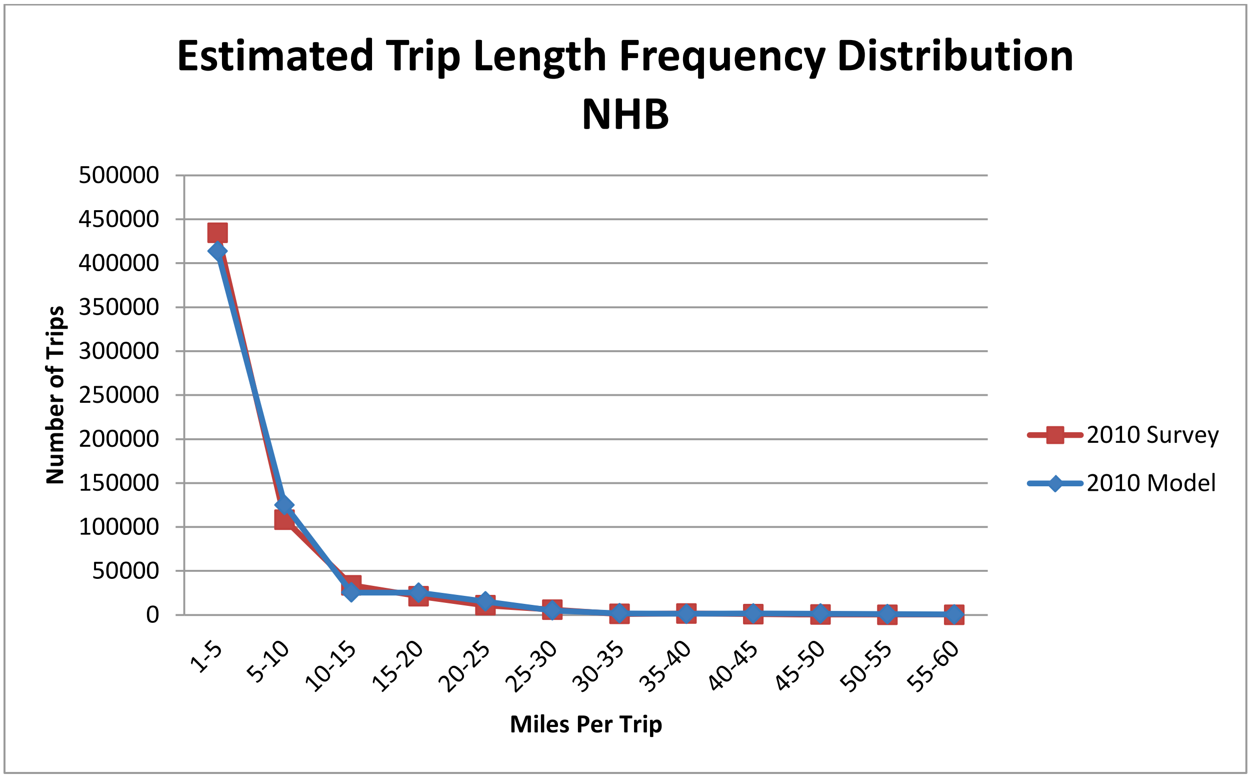
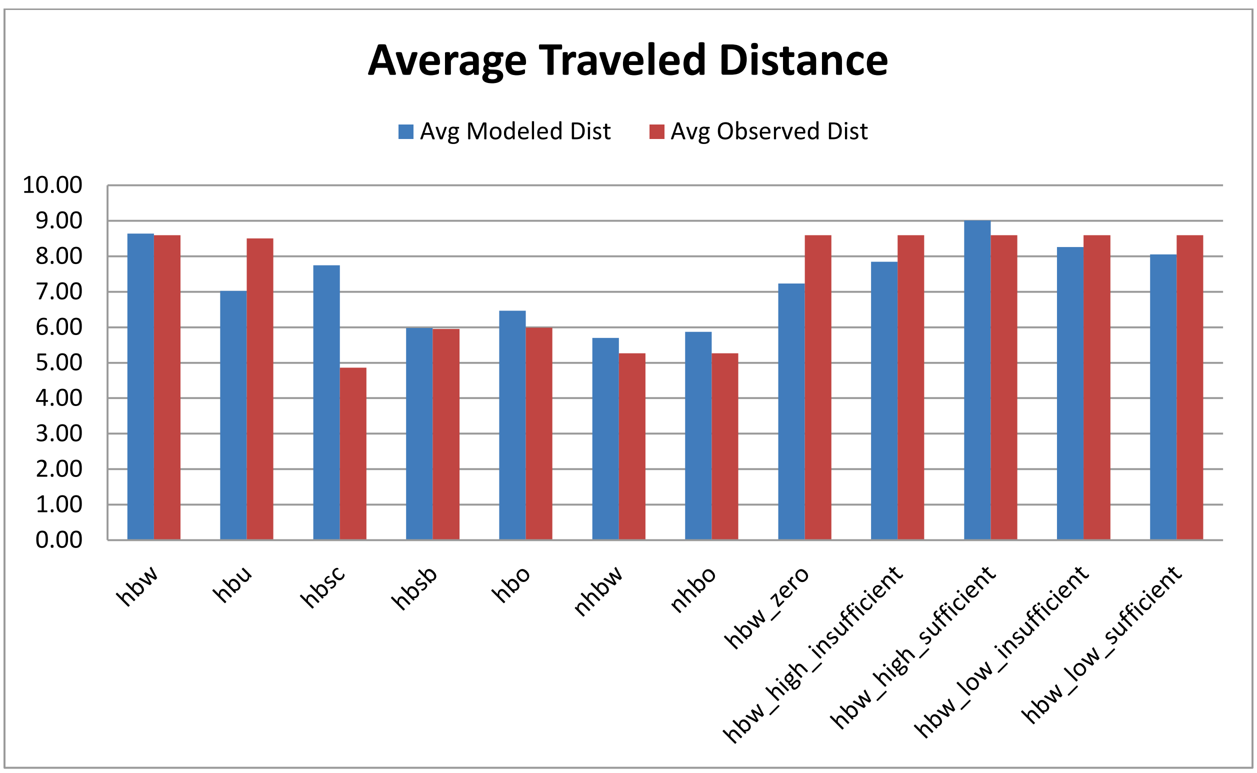


Figure 4-p: Average Trip Length by Purpose after Calibration



With the calibration of the trip length frequencies, the district to district work flows were again re-evaluated and compared to the observed values (see Table 4-l and Table 4-m above).

Table 4-n: Final District to District Work Flows for 2010 Model

	1	2	3	4	5	6	7	8	9	10	11
1	1,214	1,393	309	2,146	1,516	128	181	652	26	345	27
2	231	6,059	20	351	702	37	236	2,035	45	547	127
3	162	146	1,945	2,889	2,532	457	441	654	34	191	25
4	213	310	361	8,417	8,800	1,191	719	2,355	25	521	15
5	66	464	104	5,855	16,390	1,024	3,476	4,457	65	1,378	17
6	20	70	106	1,941	4,739	1,383	431	798	24	164	13
7	10	55	14	362	2,166	224	974	3,932	65	588	8
8	5	196	9	302	971	47	1,763	23,591	457	6,483	65
9	2	41	5	57	189	14	175	3,418	1,303	5,153	153
10	4	80	3	119	484	16	339	8,774	1,075	24,332	413
11	10	361	6	104	191	19	86	1,685	234	3,881	1,820

In general, the work trips are not as concentrated within the district (along the diagonal) as the observed data showed. The trip distribution model, while closely matching the observed trip lengths, is too often matching productions to attractions in neighboring districts. In particular, the model should better replicate the number of work trips originating from zones 5, 8 and 10 and either staying within the district or going to other districts since those are the largest trip producing/attracting districts.

Figure 4-q: Percent of Trips Originating From and Remaining in Districts 1-11

Total_Observed

	1	2	3	4	5	6	7	8	9	10	11
1	59%	4%	13%	16%	5%	0%	0%	1%	0%	0%	0%
2	4%	83%	0%	2%	1%	1%	1%	3%	1%	3%	0%
3	11%	0%	51%	17%	11%	4%	1%	2%	0%	1%	0%
4	6%	1%	7%	58%	20%	4%	0%	1%	0%	2%	0%
5	1%	1%	1%	12%	68%	5%	3%	5%	0%	3%	0%
6	0%	2%	4%	18%	27%	34%	3%	6%	0%	5%	1%
7	0%	0%	1%	3%	16%	3%	18%	50%	1%	8%	0%
8	0%	1%	0%	1%	4%	1%	8%	69%	2%	12%	1%
9	0%	2%	0%	0%	1%	0%	1%	15%	26%	55%	1%
10	0%	1%	0%	1%	2%	0%	1%	14%	9%	68%	3%
11	0%	1%	0%	1%	3%	1%	0%	8%	1%	19%	65%

Total_Modeled

	1	2	3	4	5	6	7	8	9	10	11
1	32%	12%	4%	26%	10%	1%	1%	4%	1%	3%	0%
2	3%	72%	0%	1%	3%	0%	1%	6%	0%	3%	1%
3	4%	1%	40%	23%	12%	4%	2%	5%	0%	3%	0%
4	2%	1%	1%	44%	34%	8%	1%	5%	0%	3%	0%
5	0%	1%	0%	17%	58%	5%	7%	7%	0%	3%	0%
6	0%	1%	1%	17%	39%	29%	3%	5%	0%	3%	0%
7	0%	1%	0%	3%	20%	3%	17%	46%	2%	5%	0%
8	0%	1%	0%	1%	2%	0%	4%	69%	2%	22%	0%
9	0%	1%	0%	0%	1%	0%	1%	21%	27%	42%	3%
10	0%	0%	0%	0%	1%	0%	0%	16%	4%	78%	2%
11	0%	5%	0%	1%	1%	0%	1%	10%	3%	36%	40%

In Figure 4-q above, the percentage of intra-district trips (all purposes) is highlighted, with the top table showing the observed weighted household survey results and the bottom table showing the trip distribution results.

The overall calibration, while sufficient for the update to the mode choice model, indicates that the trip distribution model is not adequately capturing the flow of travel in the NW Arkansas model area. In particular, the model is not getting the proportion of intra-district trips correct; it is sending trips that should be staying within the originating district to other districts, which is not consistent with either the CTPP or the household survey data.

To improve the calibration of the trip distribution model, NWARPC should consider moving to a destination choice logit model in lieu of trying to improve the existing trip distribution gravity model. See Section 5 for further discussion.

4.4 Mode Choice

The mode choice component was the focus of this model update. The structure of the model follows best practice and allows for testing of transit alternatives – both in terms of changes to the existing transit service (more routes, increased service) as well as new modes (bus rapid transit, light rail, etc) – as discussed earlier. The model was calibrated to the 2005 weighted household survey data (for all non-transit modes) as well as the 2012 expanded ride-check survey data (for transit modes). The calibration targets are shown in Table 4-o below. That there are no observations of park-n-ride or kiss-n-ride to Ozark transit is a short-coming of the survey, not necessarily a true reflection of how Ozark riders are accessing transit. The same is true for the Razorback totals. The survey data did not indicate the access mode (walk, drive or get dropped off) and so assumptions were made when the targets were being developed. In Section 5, there is further discussion about the need for an on-board survey that would focus on collecting data necessary for a transit alternatives analysis.

Table 4-o: Observed Mode Shares in NW Arkansas

Mode	Observed	
	Trips	*Percent*
da	1,016,816	68%
sr2	192,814	13%
sr3	246,879	16%
walk_ozark	635	0%
pnr_ozark	0	0%
knr_ozark	0	0%
walk_razorback	7,643	1%
pnr_razorback	729	0%
knr_razorback	0	0%
walk	33,704	2%
bike	1,692	0%
Total	**1,500,912**	100%

Auto	1,456,509	97%
Transit	9,007	1%
Non-Motorized	35,396	2%
Total	1,500,912	100%

The mode choice model was also calibrated to match the mode split for work trips segmented by auto sufficiency categories as well as income brackets. Members of households without access to a car (zero autos) must either carpool (sr2 or sr3), choose transit or walk/bike. When studying transit alternatives, it is important to see the effects on this particular transit-captive market. Additionally, households that have more workers than available vehicles (insuffcient) must typically carpool or have one worker drive alone while the other takes transit or walks/bikes. Sufficient households, on the other hand, have more vehicles than workers and therefore they are more likely to choose to drive alone. The auto sufficiency categories are futher broken into high income (above $50,000) and low income (below $50,000) as this segmentation is useful when considering modes such as bus-rapid transit and light rail. Table 4-p below shows the observed mode shares of home-based work trips. As the household survey did not explicity target these household segmentations, the observed data was sparse, so the targets are a blend of observations seen in the NW Arkansas survey, the Austin, Texas survey and the Indianapolis, Indiana survey.

Table 4-p: Home-based Work Income and Auto Sufficiency Calibration Targets

	HBW - Zero Autos	HBW - Low Insufficient	HBW - High Insufficient	HBW - Low Sufficent	HBW - High Sufficient
Drive Alone	0	5,598	29,235	23,507	131,984
Shared Ride 2	641	3,739	5,791	3,205	4,487
Shared Ride 3	214	470	555	2,136	2,136
Walk_to_Ozark	60	17	-	21	2
PnR_to_Ozark	-	-	-	-	-
KnR_to_Ozark	-	-	-	-	-
Walk_To_Razorback	172	269	-	187	21
PnR_to_Razorback	-	-	-	-	-
KnR_to_Razorback	-	-	-	-	-
Walk	-	628	-	1,867	930
Bike	-	-	18	293	-
Total	**1,087**	**10,721**	**35,599**	**31,216**	**139,560**

To calibrate the mode choice model for each trip purpose, several adjustments were made to the mode choice parameters including the recalculation of the value of time parameters based on the median income in NW Arkansas ($50,000) and adjustments to the alternative specific constants for each of the sub-modes. The mode choice model calibration should be revisited when new on-board survey data becomes available and before the model is used for studying transit alternatives that seek to increase drive-to-transit options (such as the development of a formal park-n-ride lot for Ozark routes for example).

The results of the mode choice model calibration are shown in Figure 4-r through Figure 4-cc below.

Figure 4-r: Home-based Work (All Household Segments) Calibration Results

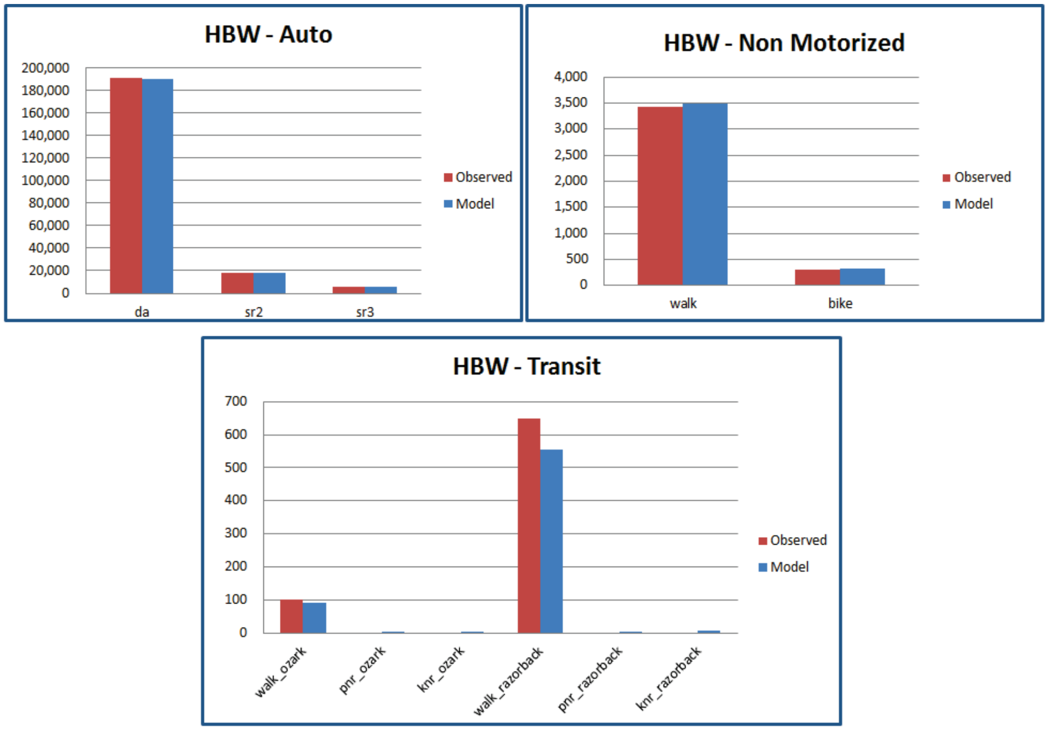


Figure 4-s: Home-based Work for Zero-car Households Calibration Results

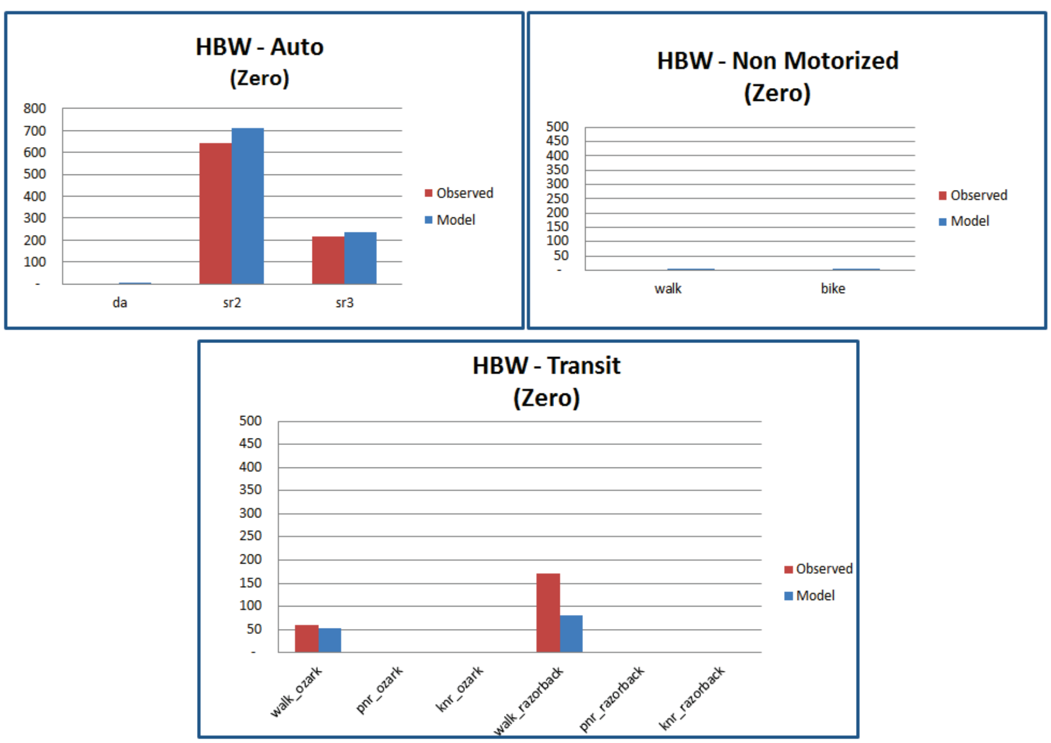


Figure 4-t: Home-based Work for Low Income, Auto Insufficient Households Calibration Results

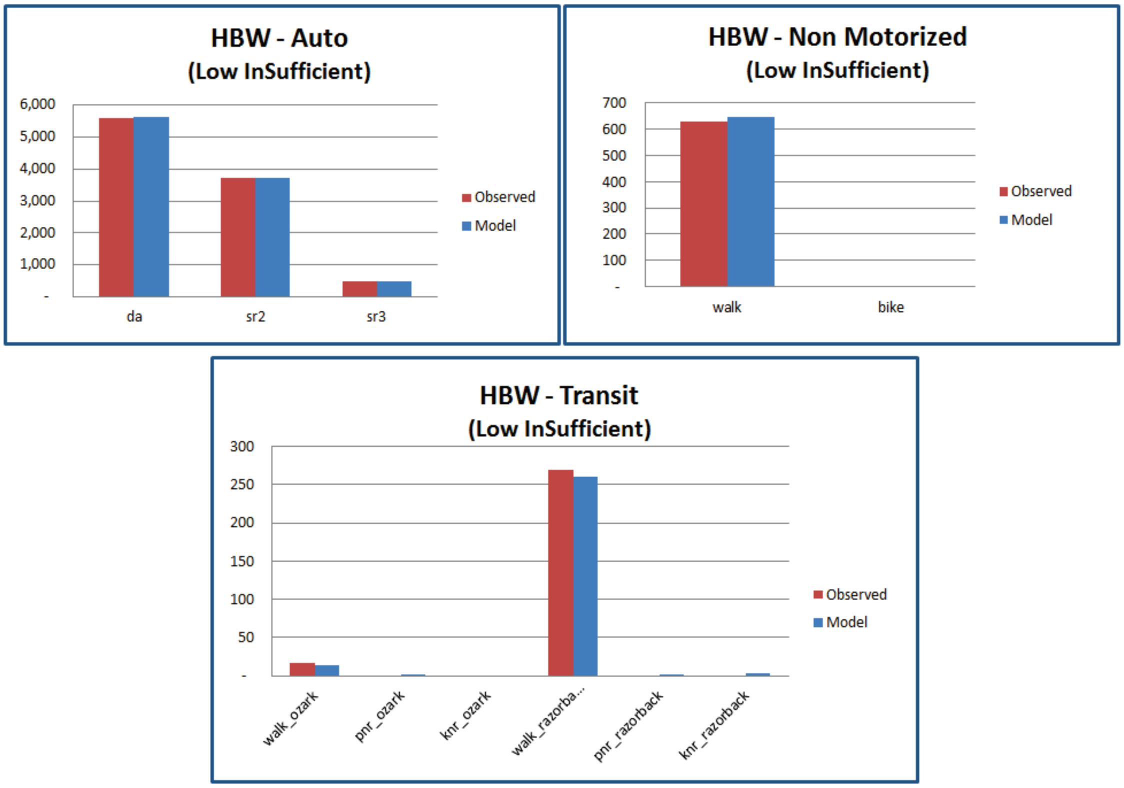


Figure 4-u: Home-based Work for High Income, Auto Insufficient Households Calibration Results

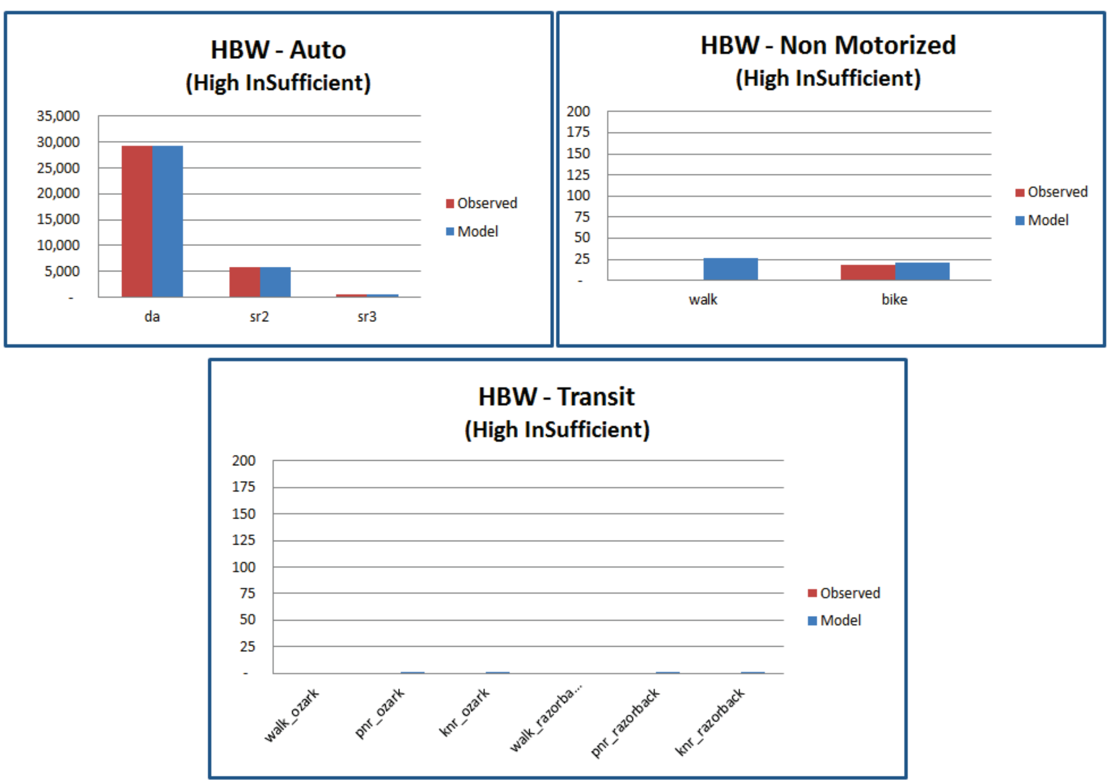


Figure 4-v: Home-based Work for Low Income, Auto Sufficient Households Calibration Results

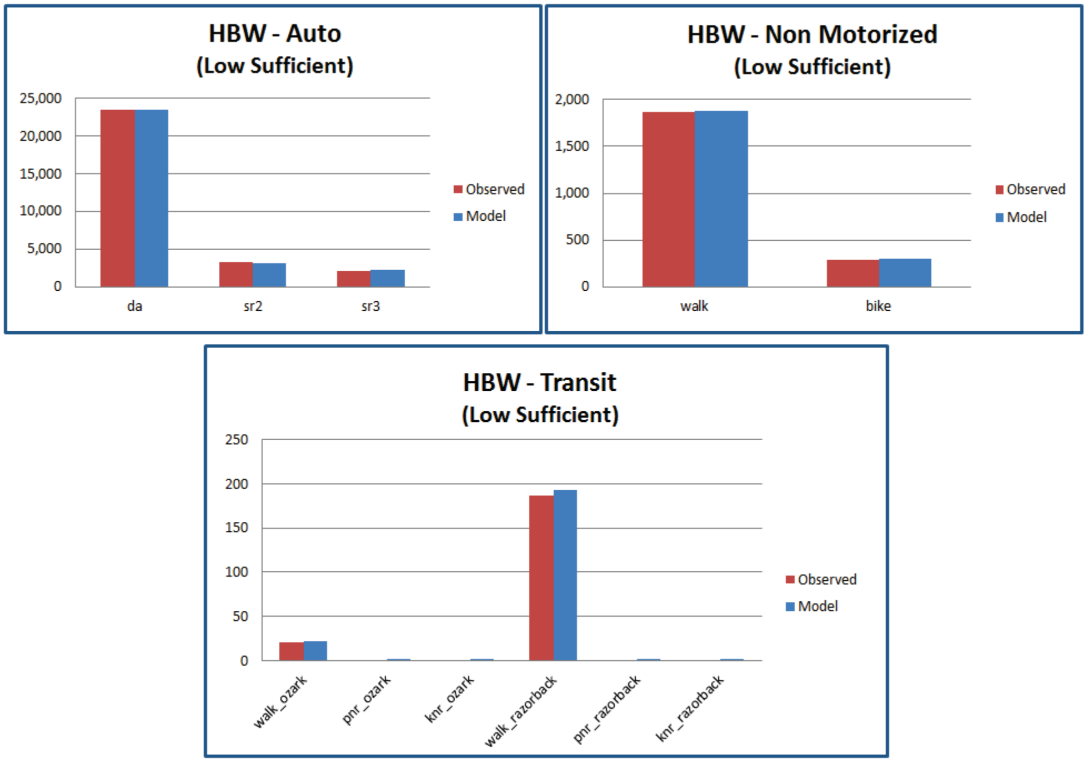


Figure 4-w: Home-based Work for High Income, Auto Sufficient Households Calibration Results

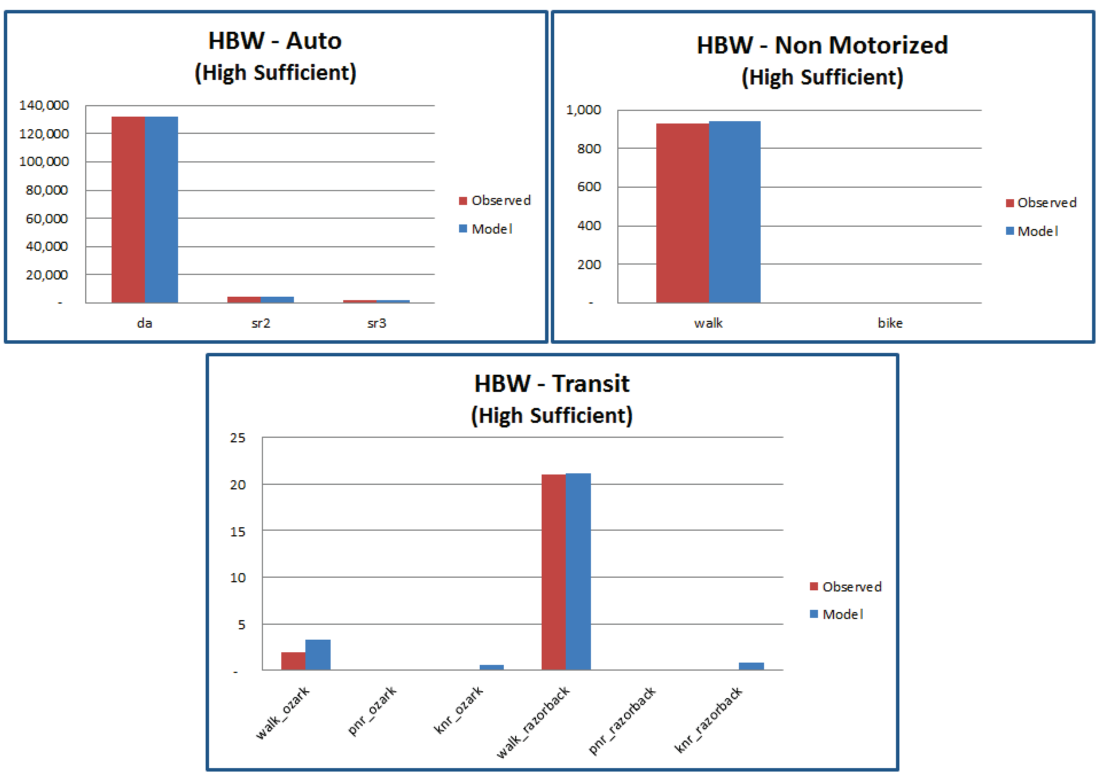


Figure 4-x: Home-based University (All Household Segments) Calibration Results

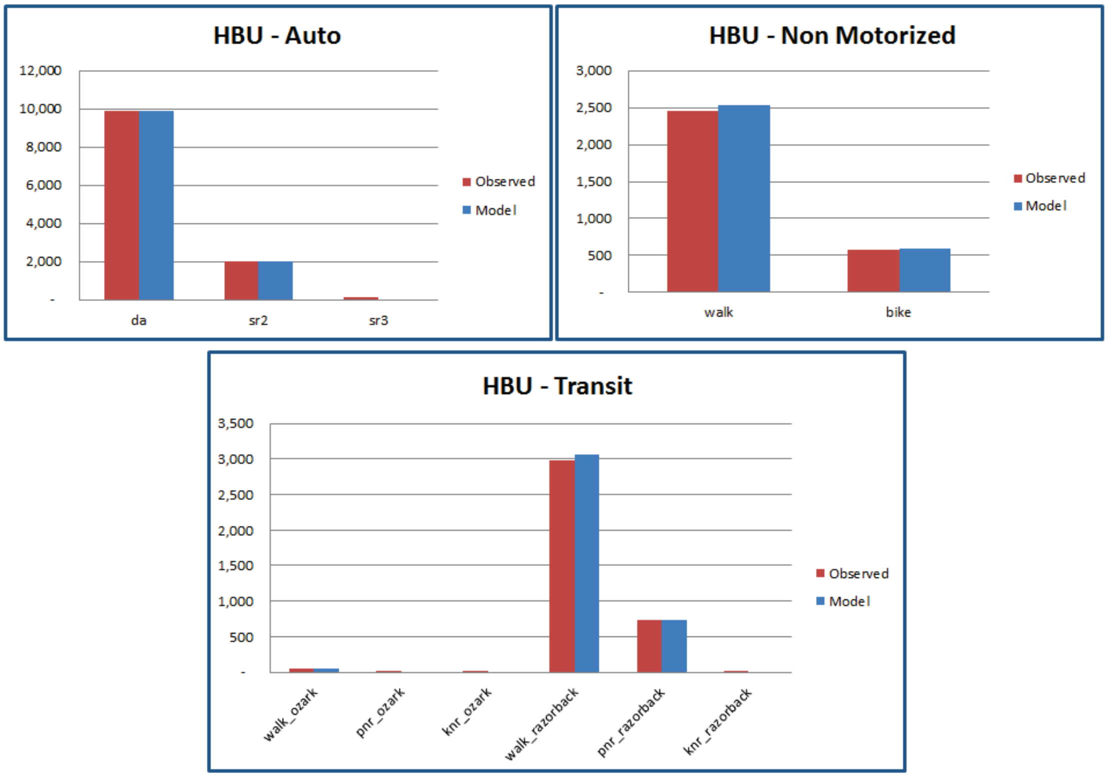


Figure 4-y: Home-based School (All Household Segments) Calibration Results

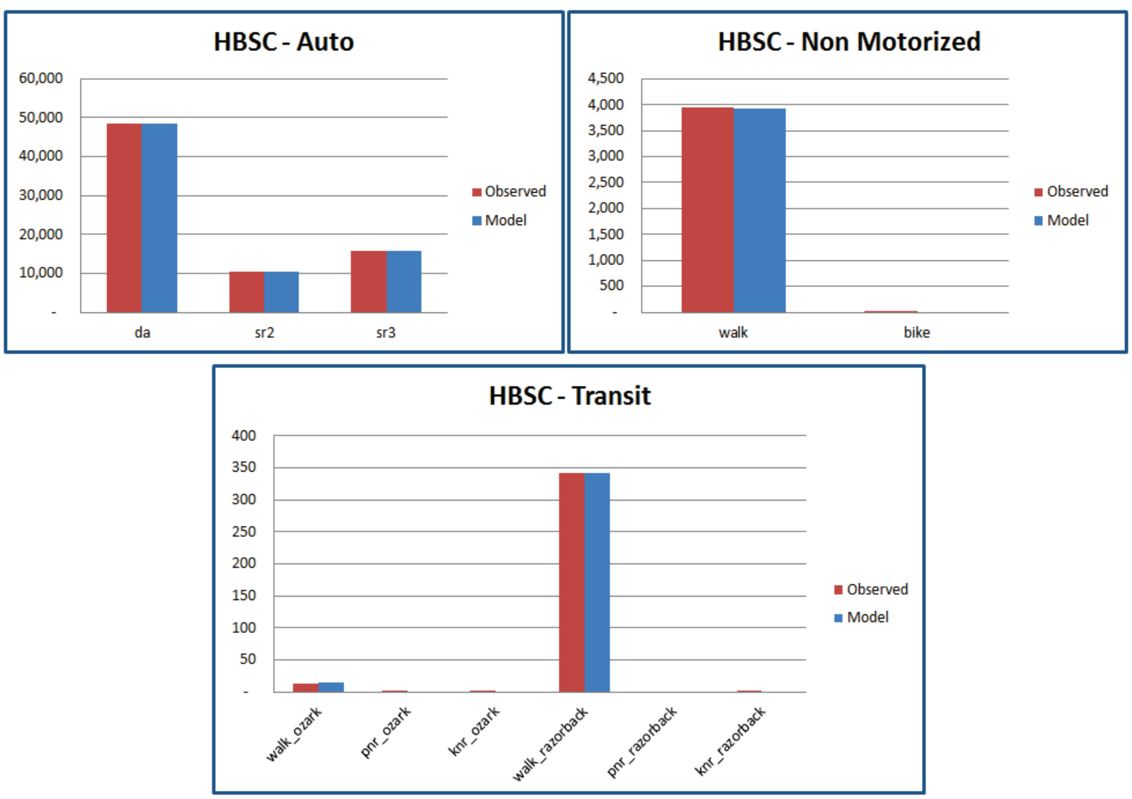


Figure 4-z: Home-based Shopping and Personal Business (All Household Segments) Calibration Results

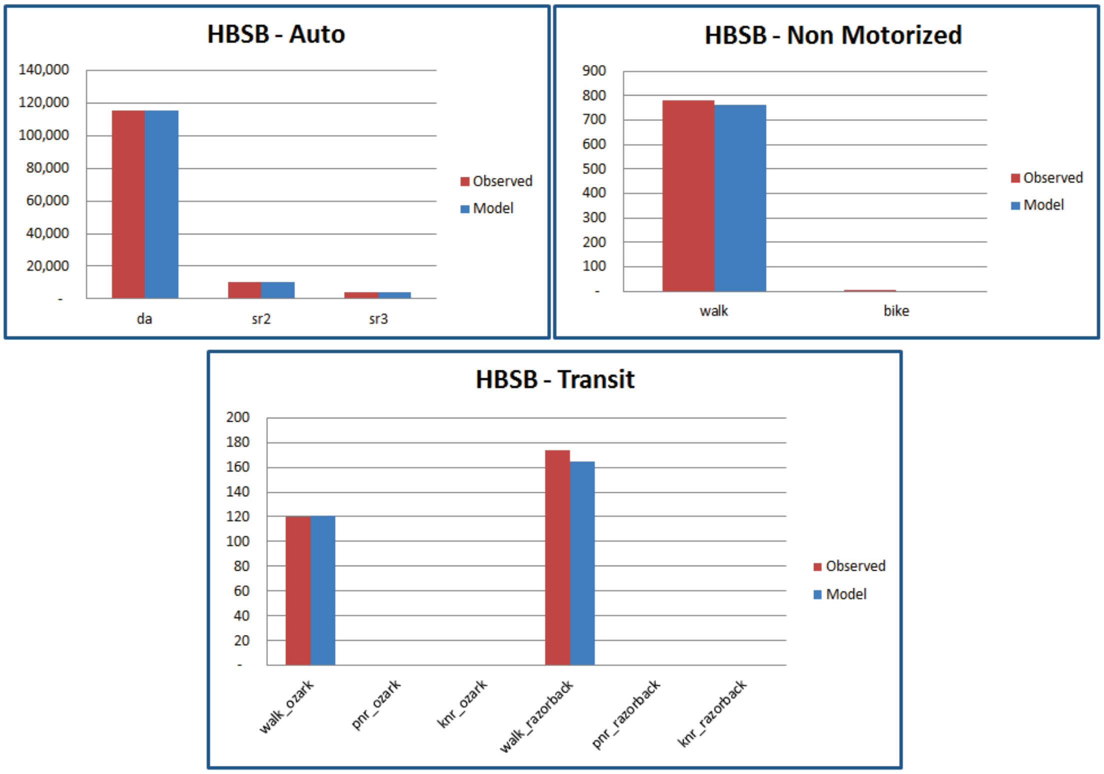


Figure 4-aa: Home-based Other (All Household Segments) Calibration Results

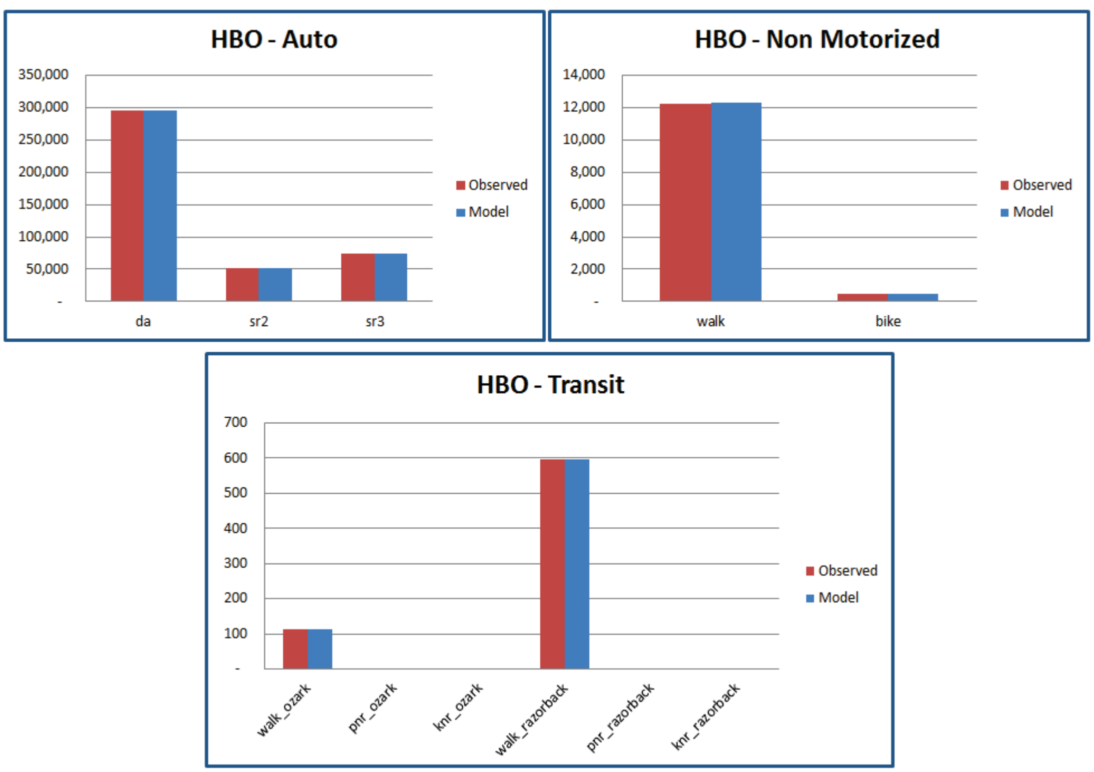


Figure 4-bb: Non-home-based (All Household Segments) Calibration Results

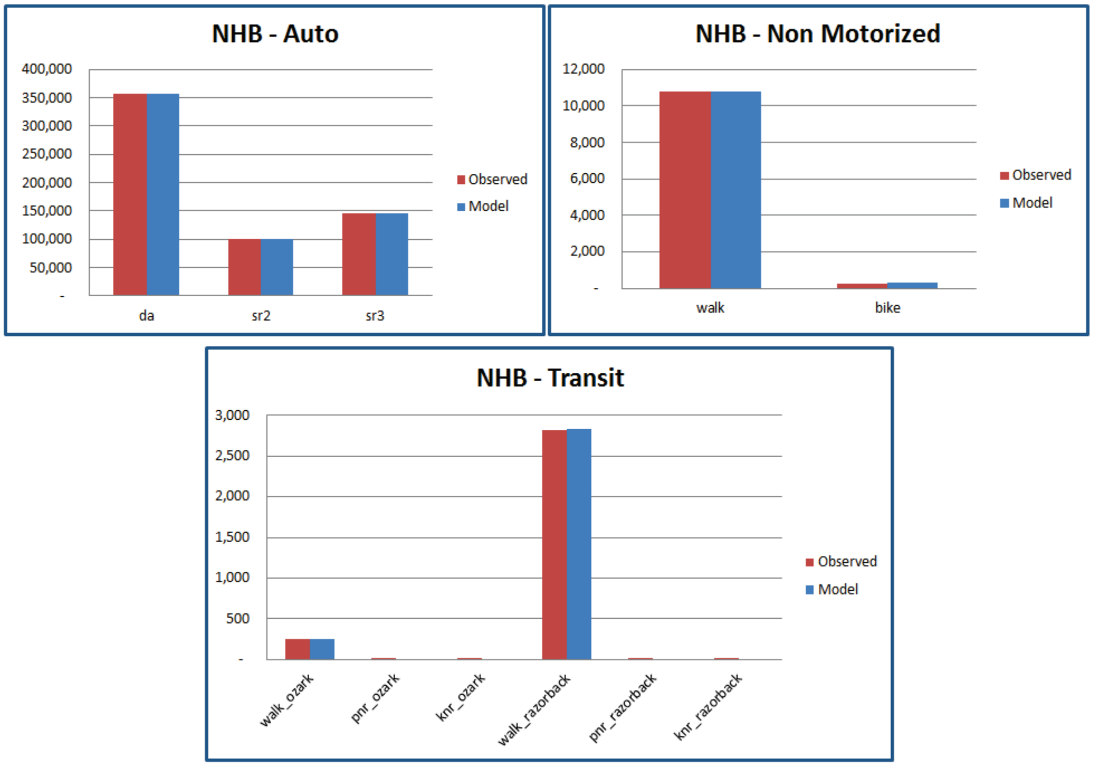
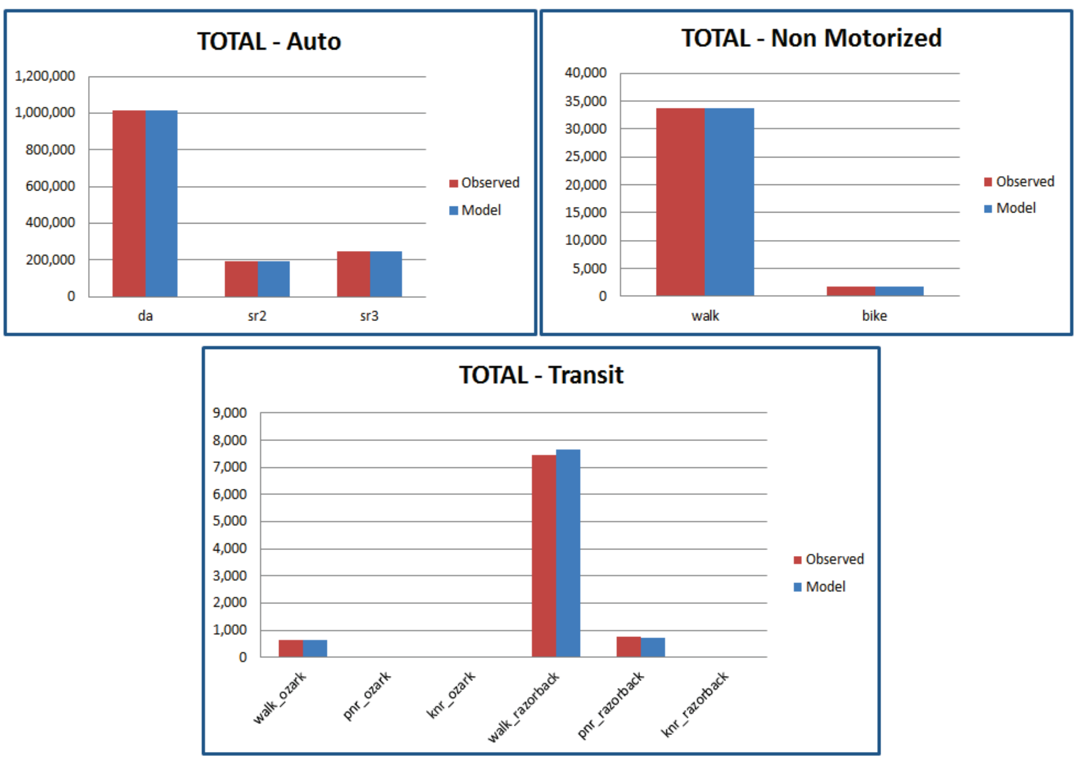


Figure 4-cc: All Purposes, All Household Segments Calibration Results



While some of the individual purposes and the particular sub-modes do not match exactly, the overall calibration of the mode choice model is sufficient to replicate the observed mode shares in the base year. Table 4-q shows the final model (estimated) results compared to the targets for each mode.

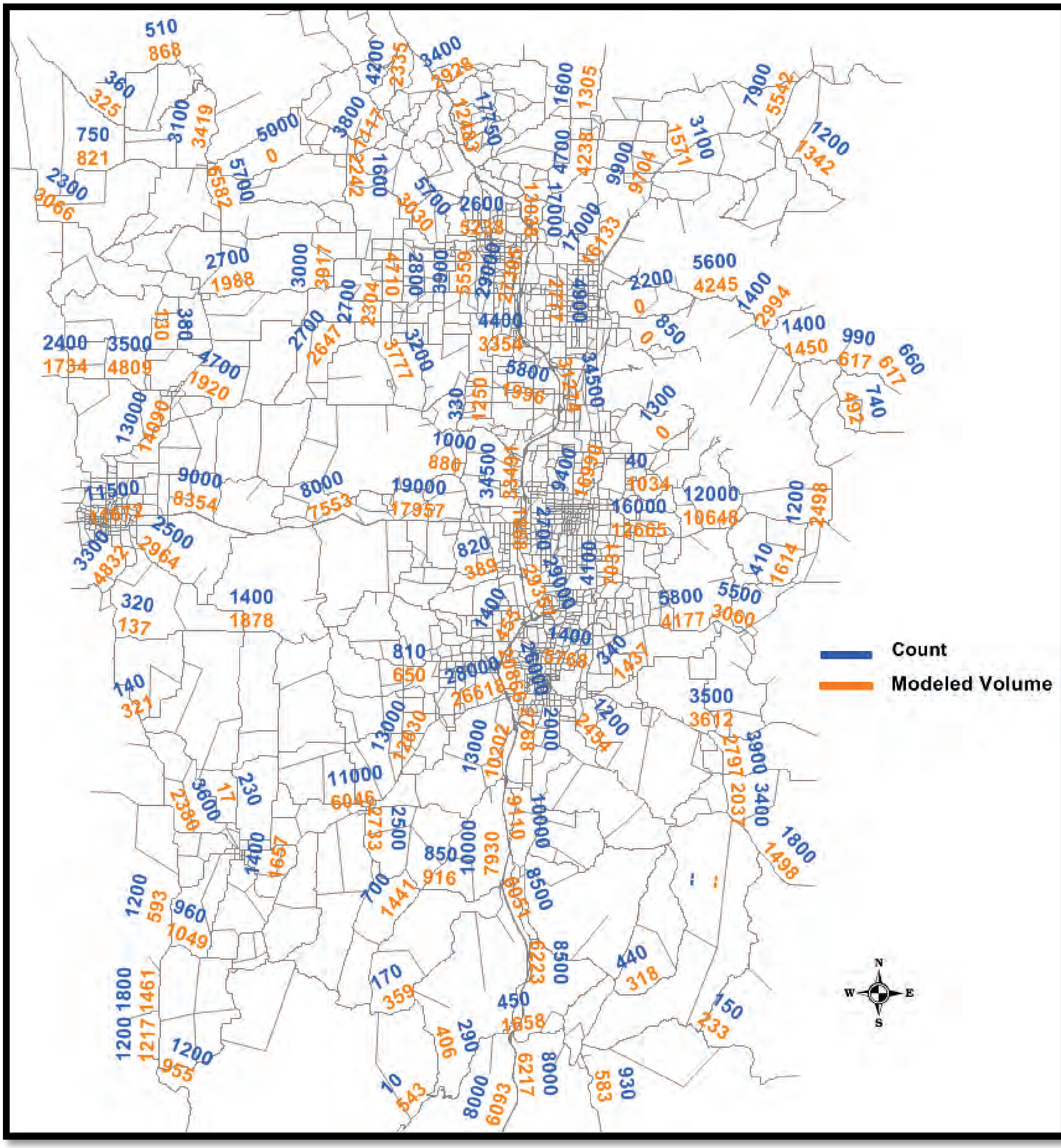
Table 4-q: Comparison of Observed Mode Shares to Modeled Shares for 2010 Base Year

Mode	Observed		Estimated	
	Trips	*Percent*	*Trips*	*Percent*
da	1,016,816	68%	1,016,662	68%
sr2	192,814	13%	192,786	13%
sr3	246,879	16%	247,279	16%
walk_ozark	635	0%	624	0%
pnr_ozark	0	0%	1	0%
knr_ozark	0	0%	3	0%
walk_razorback	7,643	1%	7,455	0%
pnr_razorback	729	0%	737	0%
knr_razorback	0	0%	9	0%
walk	33,704	2%	33,677	2%
bike	1,692	0%	1,692	0%
Total	**1,500,912**	100%	**1,500,926**	100%

4.5 Highway Assignment Validation

The trip generation, trip distribution and mode choice models were calibrated to observed data and the resulting trips were assigned to either the highway or the transit network, depending on the mode chosen. The map in Figure 4-dd below gives an overall view of the 2010 counts compared to the 2010 base year assigned values. More detailed validation statistics are presented in tables below.

Figure 4-dd: NWA Study Area – 2010 Counts vs. Highway Volumes



The most recent publication of the Travel Model Improvement Program's Travel Model Validation and Reasonableness Checking Manual was published in 2010. The acceptable ranges for the percent difference and for %RMSE are used to evaluate the validation statistics for the NWARPC 2010 base year model. Overall, there were 824 count locations to compare the model results to. Table 4-r below shows the number of observations by facility type within rural and urban TAZs, the sum of the counts on those links, and the corresponding modeled volumes.

Table 4-r: Observed vs. Modeled Volumes by Facility Type

SUMMARY BY FACILITY TYPE							
Description	FHWA_FC	# Observations	Volume Comparison				
			Observed Count	Model Volume	Difference	Pct Difference	% RMSE
Rural Interstate	1	8	79,000	62,850	-16,150	-20.4%	21.1%
Rural Principal Arterial	2	31	387,430	293,547	-93,883	-24.2%	29.4%
Rural Minor Arterial	6	54	349,550	305,948	-43,602	-12.5%	34.8%
Rural Major Collector	7	120	465,420	427,436	-37,984	-8.2%	63.3%
Rural Minor Collector	8	22	35,590	36,517	927	2.6%	108.3%
Rural Local	9	4	8,120	8,235	115	1.4%	24.6%
Urban Interstate	11	42	1,147,000	1,022,166	-124,834	-10.9%	15.1%
Urban Principal Arterial	14	197	3,414,070	3,404,172	-9,898	-0.3%	38.7%
Urban Minor Arterial	16	87	655,950	620,405	-35,545	-5.4%	42.4%
Urban Collector	17	159	746,320	610,527	-135,793	-18.2%	71.1%
Urban Local	19	6	29,590	29,579	-11	0.0%	61.6%
Off-Ramp	71	41	204,480	172,548	-31,932	-15.6%	43.8%
On-Ramp	72	44	215,160	184,611	-30,549	-14.2%	37.3%
Generic Ramp	75	5	51,700	47,562	-4,138	-8.0%	19.3%
Median Cross-Over	81	4	9,980	8,612	-1,368	-13.7%	23.4%
TOTAL		**824**	**7,799,360**	**7,234,715**	**-564,645**	**-7.2%**	

The model does not match the rural volumes as closely as it does the urban volumes. The trip generation rural and urban trip rate calibration partially addressed this issue but to further reduce the percent difference, the calibration of the trip distribution model will need to be addressed. However, combining the rural and urban facilities and comparing the model to the counts summarized by volume group shows that for the interstate facilities, which typically carry 30-40,000, the percent difference is below 10%, with an RMSE value of 20%, which is well within FHWA's accepted criteria as shown in Figure 4-ee and Figure 4-ff (red boxes on figures focus in on the ranges for typical NWA roadway volumes). Acceptable results are also achieved for the region's principal arterials. Table 4-s shows the validation statistics by volume group.

Figure 4-ee: Florida, Ohio and Oregon Department of Transportation Targets for %RMSE

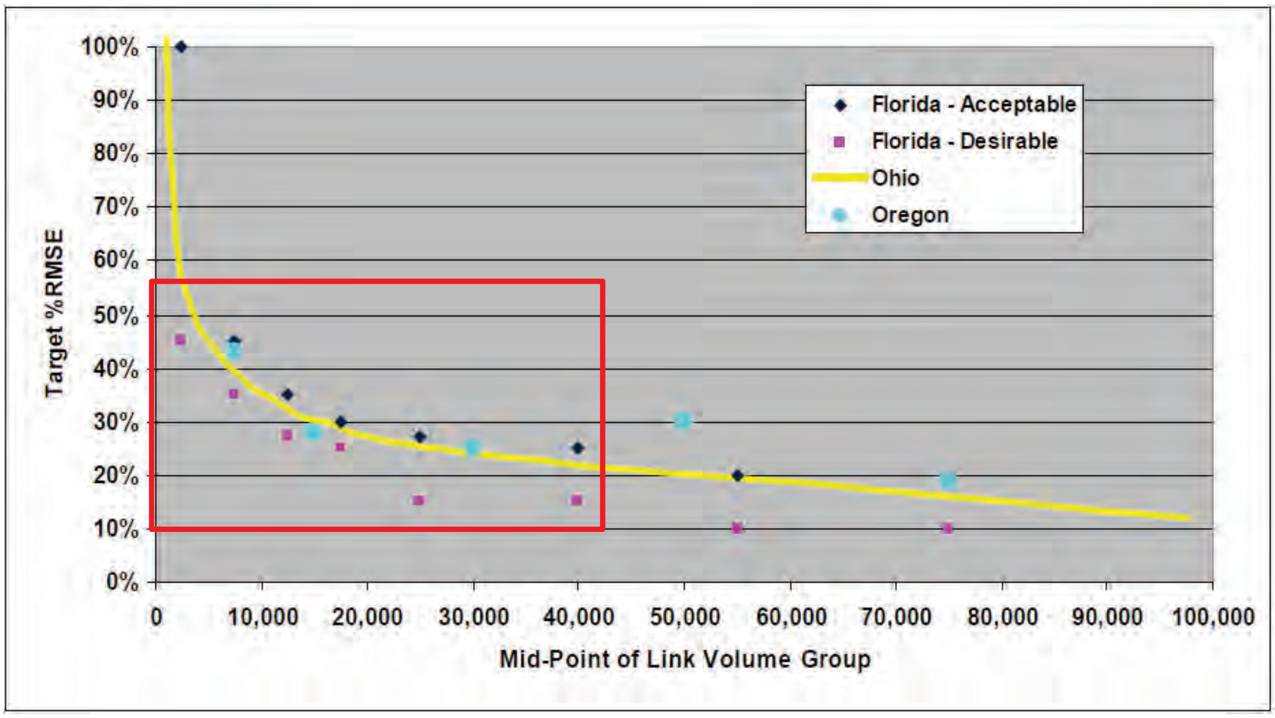
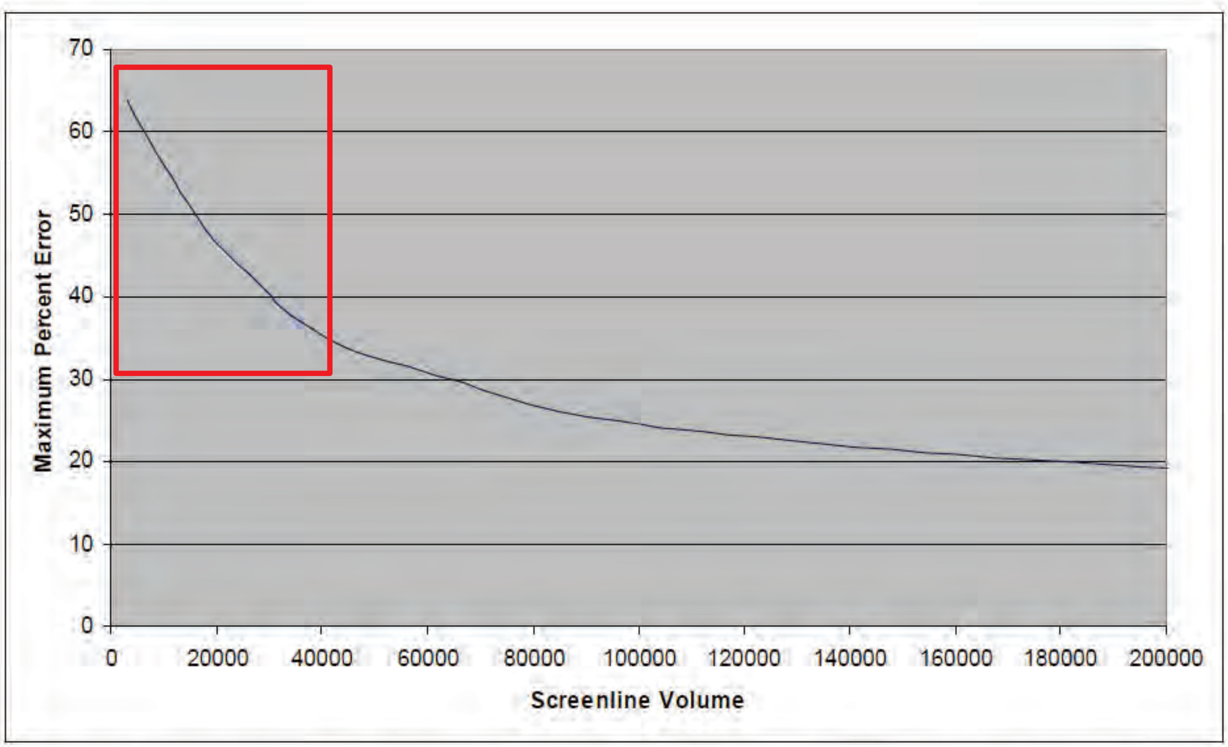


Figure 4-ff: FHWA Guidelines for Maximum Percent Error



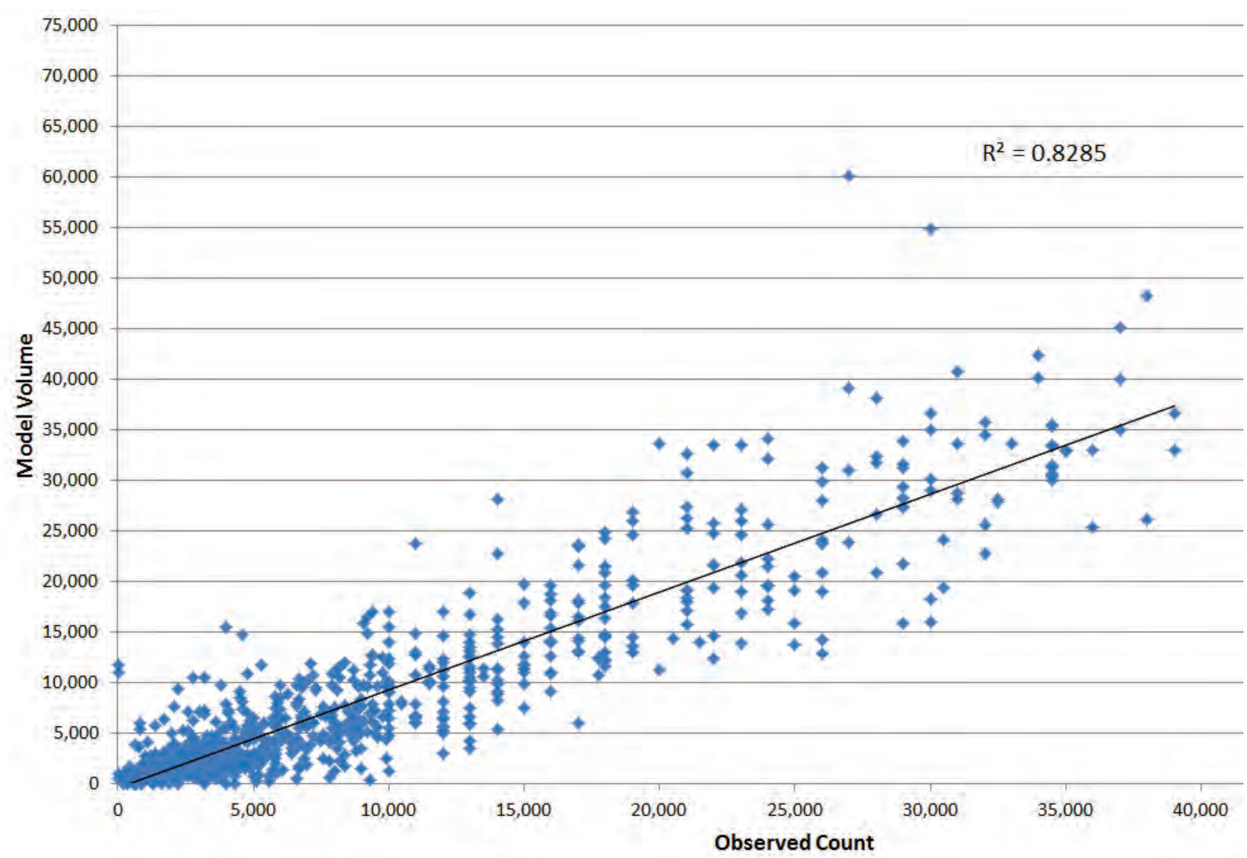
Source: Calibration and Adjustment of System Planning Models, FHWA, December 1990.

Table 4-s: Observed vs. Modeled by Volume Group

SUMMARY BY VOLUME GROUP								
Volume Range	Vol Range ID	# Observations	Volume Comparison					
			Observed Count	Model Volume	Difference	Pct Difference	% RMSE
< 5000	1	401	1,379,450	857,143	-522,307	-37.9%	82.6%
5,000-10,000	2	165	1,310,460	1,168,610	-141,850	-10.8%	42.4%
10,000-20,000	3	156	2,323,950	2,178,764	-145,186	-6.2%	33.3%
20,000-30,000	4	55	1,327,500	1,362,360	34,860	2.6%	22.9%
30,000-40,000	5	40	1,227,000	1,336,207	109,207	8.9%	19.7%
40,000-50,000	6	5	174,000	216,560	42,560	24.5%	24.8%
> 50,000	7	2	57,000	115,071	58,071	101.9%	102.9%
TOTAL		824	7,799,360	7,234,715	-564,645	-7.2%	

The percent difference is simply the difference between the observed count and the modeled volume divided by the observed count; whereas the % RMSE is the square-root of the average **squared error**. This means that for the RMSE calculation, large deviations in the observed to modeled volume greatly impact the calculation. The scatterplot in Figure 4-gg below shows the observed count vs. the modeled volume at each count location. If the model replicated the observed counts exactly, then the points on the graph would all lie on the regression line and the R-squared value would be 1.0.

Figure 4-gg: Scatterplot and R-squared Value for the 2010 Base Year Model



4.6 Transit Assignment Validation

A typical transit validation will look at boardings by route, boardings by time period, number of transfers, transit travel times and various other measures to see how closely the transit assignment is replicated observed behavior. The most important piece of information needed to validate a transit assignment is the actual observed behavior.

NWARPC does have some on-board survey data but the questions asked of each rider delved more into questions about the quality and the satisfaction with transit service than into the travel behavior. As mentioned earlier, the survey did not ask how the riders got to the transit stop; it did not ask if the rider had transferred to the current bus or would transfer to another bus during their trip; it did not gather much information about the rider. Finally, data was not collected so that the survey could not be expanded by time of day and by route, only by daily boardings.

Table 4-t below shows the daily "On"s, "Off"s and "Total" riders for each route on the day of the survey compared to the NWA transit assignment results.

Table 4-t Observed "On"s and "Off"s Compared to 2010 Model Results

Route No.	Route Description	Survey			Model		
		Ons	Offs	Total	Ons	Offs	Total
1	Blue	2334	2334	4668	1108	1108	2216
2	Brown	492	492	984			
3	Grey	439	439	878	679	679	1358
4	Green	2345	2345	4690			
5	Maple Hill	249	249	498	18	18	36
6	Pomfret	737	737	1474			
7	Purple Hill	456	456	912	369	369	738
8	Red	549	549	1098	2611	2611	5222
9	Route 56	478	478	956	474	474	948
10	Tan	783	783	1566	2345	2345	4690
11	Yellow	463	463	926			
12	Blue Reduced	187	187	374	0	0	0
13	Green Reduced	128	128	256	2471	2471	4942
	TOTAL	9640	9640	19280	10075	10075	20150

The table has a complete set of data for the survey but not all of the surveyed routes are represented as separate lines (or represented at all) in the 2010 model. When looking at the results by route, there are large differences in the totals; however the total boardings and alightings match very well. A more in-depth, model-focused on-board survey will be required for improved transit validation.

It should be noted however that the model is successfully forecasting the correct number of transit riders which means that the model can be used to test transit alternatives as long as the analyst is looking at the change in route ridership as a percent change over the base condition and/or the absolute change in the total transit boardings, but not using the absolute numbers by route.