Lake Tahoe Resident and Visitor Model

Model Description and Final Results

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PB 100 YEARS ®

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Introduction

CHAPTER 1 – INTRODUCTION

The Lake Tahoe Region is located on the California-Nevada border between the Sierra Nevada Crest and the Carson Range. The Region comprises approximately 501 square miles including the dominant natural feature of Lake Tahoe that is the primary focus of environmental regulation to protect its exceptional water clarity.

Development and urbanization of the basin occurred during and following the 1960 Squaw Valley Winter Olympics. Since that time, the population has increased over five times, with about 80 percent of the population residing on the south shore in California and Nevada. According to the 2000 Census Bureau, the total year round resident population in the Lake Tahoe Region was 63,448. More recently however, it has been estimated that the year round population has decreased to approximately 54,793 as a result of increasing home values and increases in second homeownership.

While the resident population is declining, the area still attracts plenty of visitors. Downhill and cross-country skiing in the winter and camping, boating and hiking in the summer, as well as year round gaming ensure a steady flow of visitors throughout the year.

The Tahoe Regional Planning Agency (TRPA), as part of their Pathways 2007 planning had a need to update their travel-forecasting model. The previous model, a 3-step model developed in the 1980's, was originally developed in Tranplan and was converted to the TransCAD platform during the first phase of model work. While the model was successfully converted, it was not able to address many important policy issues because of the limitations of trip-based models.

Although most of the models in use today are trip-based, there are many weaknesses associated with these models. One of the most profound is the disconnection between socio-demographic variables and non-home-based trips. Non-home-based trips often comprise up to a third of the total trips made within a region and the inability to associate these trips with their producing household, or even to know if the trips are beginning and ending at the appropriate zones has long been acknowledged to be an overwhelming source of error in trip-based travel demand models.

Another weakness of trip-based models is the inability of a traveler to make a substitution further up the 'trip chain', by eliminating the trip or changing the destination or time that the trip begins. Each "decision" is encapsulated within a separate model (generation, destination or mode) and therefore the household is unable to dynamically adjust across models. For example, if a traveler is faced with congestion during mode choice, then

their only choice is to change modes. In reality, that same traveler could choose to leave at a different time period for a work trip, or choose a different destination for a discretionary trip.

In addition, it has been recognized for some time that certain trip choices are conditional upon other trips made during the day. Early attempts to incorporate such behavior into travel models focused on the introduction of trip chains. However, the definition of such chains proved to be too loose, and the aggregate zonal approach did not really allow for the development of operational models using trip chaining.

However, with the definition of a special 'closed' trip chain called a "tour", a more robust modeling approach has been developed. A tour is a series of trips whose origin and final destination is at the same location. In the vast majority of cases, the tour origin is associated with either the residence or workplace. In addition to viewing travel as a tour versus a trip, these models focus on activities that people participate in as the starting point of all subsequent models. Hence a person first decides, "Should I go to work today or not?" Due to micro-simulation the person's decision can hinge on characteristics of the individual in addition to environmental influences such as network congestion or travel costs. Thus tour-based models, which focus on activities and incorporate micro-simulation, are often referred to as "activity-based" and that is the term that will be used throughout this document. This modeling approach, called 'activity-based', is likely to become the dominant form of travel demand modeling within this decade. Some of the ground-breaking research and development has taken place in cities such as Portland (Oregon), New York City, Honolulu, San Francisco and Columbus (Ohio).

The following three features characterize activity-based travel models:

- Modeled travel is derived within a general framework of the daily activities undertaken by households and persons, including in-home activities, intra-household interactions, time allocation to activities, and other aspects pertinent to activity analyses.
- The tour is used as the base unit of travel and is decided at the household level. This structure preserves a consistency across trips that make up a tour, incorporating travel dimensions such as destination, mode, and time of day.
- Tours and trips are chosen at the fully-disaggregate level of persons and households. Micro-simulation is used to convert activity and travel related fractional-probabilities into a series of "crisp" decisions among the discrete choices. This method of model implementation results in realistic model outcomes, with output files that look very much like real travel/activity survey data.

The Tahoe model, described in detail in the following chapters, consists of an activity-based resident model and an activity-based visitor model. Because the number of resident households, employment locations, person activities, and the resident/visitor mix are potentially very different in the region during the summer versus the winter, socio-economic data has been developed for the two seasons. Thus, the user may choose to model an average summer weekday or an average winter weekday, with yearly travel being the sum of the seasonal travel. Thus the current model described in this document is considerably more flexible than the existing model and should be able to assist TRPA in analyzing a variety of planning policies as well as accurately forecast annual VMT in the region.

CHAPTER 2
Residential Models

CHAPTER 2 – RESIDENTIAL MODELS

2.1 Introduction

The resident travel demand model is based on the activity-based model currently in application in Columbus, Ohio. The Mid-Ohio Regional Planning Commission (MORPC) model incorporates the growing body of research on activity-based modeling and micro-simulation. Compared to other activity-based models in use, the MORPC structure represents two significant steps toward a better and more realistic accounting for travel behavior:

- Explicit modeling of intra-household interactions and joint travel that is of crucial importance for realistic modeling of the individual decisions made within a household. The original concept of a "full individual daily pattern" has been extended to incorporate various intra-household impacts of different household members on each other, joint participation in activities and travel, and intra-household allocation mechanisms for maintenance activities.
- Enhanced temporal resolution of 60 minutes with explicit tracking of available time windows for generation and scheduling of tours instead of the 4-5 broad time periods applied in most of the conventional and activity-based models previously developed. The time-of-day choice model is essentially a continuous duration model transformed into a discrete choice form. The enhanced temporal resolution allows the definition of a person time window. This time window and its overlap with other household members' time windows can be used as an important explanatory variable for generation and scheduling of subsequent tours.

The main reason for using an existing resident model instead of developing the Tahoe resident model from scratch is to avoid the cost and time associated with devising a model structure and estimating coefficients for all the associated components. Analyzing the household survey data to define the model structure, preparing data sets, and estimating the model typically takes twice as much time (and therefore costs twice as much) as calibrating and validating the model once it is defined. Because the MORPC model was thoughtfully designed and was able to be calibrated and validated in Columbus, it was hypothesized that the same could be done in Lake Tahoe. Therefore, most of the time on the resident models was spent writing the software necessary to implement the models and calibrating the alternative specific constants of the models in order to match the observed data.

For the most part the hypothesis proved true; the MORPC model could be applied to the Tahoe region and the results would match the observed data. **Figures 2.1 and 2.2** show the mode shares for low-income work tours when applying the MORPC mode-choice model directly (Figure 2.1) and after adjusting the alternative-specific constants (Figure 2.2).

Figure 2.1: Mode-choice results when applying MORPC directly

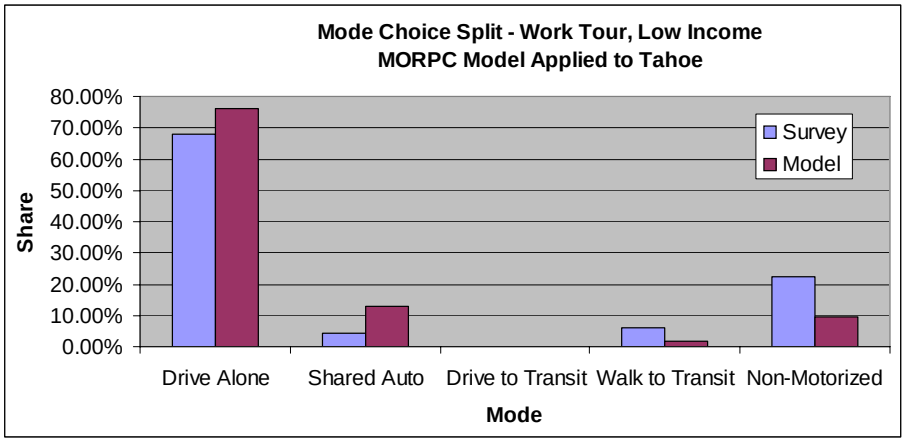
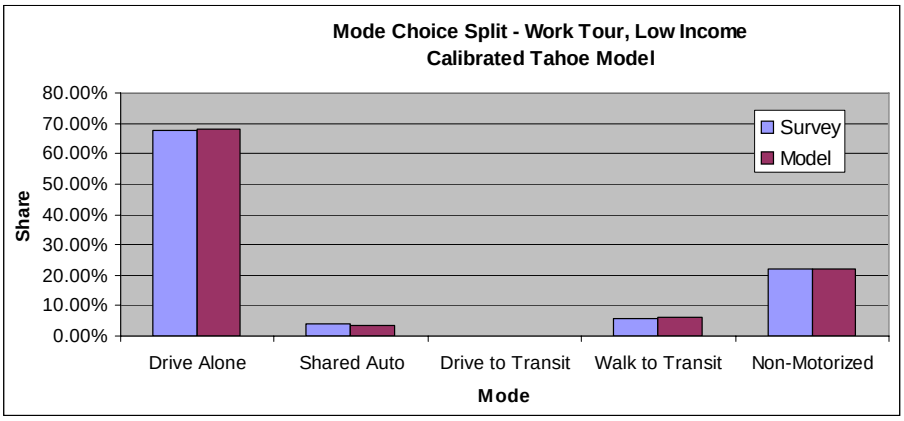


Figure 2.2: Mode-choice results after adjusting alternative-specific constants



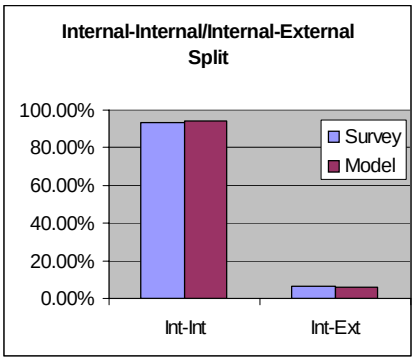
As can be seen in Figure 2.1, the mode share distribution seen in the observed data is essentially captured, indicating that the explanatory variables used do a reasonable job of explaining the choices low-income residents make regarding how to get to work. By simply adjusting the alternative-specific constants, which account for unobserved and unmeasured factors that influence decision making, the modeled results match the observed data within tolerance. **Table 2.1** shows the adjustments that had to be made in the alternative specific constants so that the model results matched the observed data.

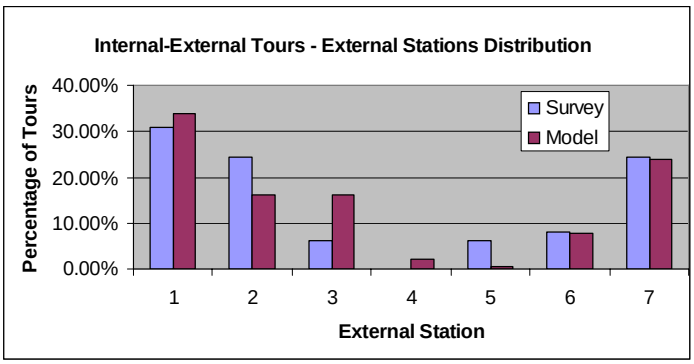
Table 2.1: Comparison of alternative-specific constants

	Drive Alone	Shared Auto	Walk to Transit	Drive to Transit	Non motorized
MORPC alternative-specific constant	1.23	-1.80	1.60	-1.50	3.46
Tahoe alternative-specific constant	1.48	-0.40	-0.18	-1.48	2.05

Similar comparisons can be made for the other components of the resident model. In addition to these adjustments, it was necessary to add special terms to the destination choice models to accurately reflect the travel from inside the region to locations outside the region through the seven external stations. There is a significant amount of travel through the external stations for both work and non-work related purposes that needs to be accurately reflected. While the model predicts the correct total travel it does not predict the correct distribution amongst the seven stations until the additional terms are added. **Figures 2.3 and 2.4** compare the destination choices for persons making a 'maintenance' trip (i.e. grocery shopping, escorting children, etc.) before and after making adjustments and **Table 2.2** below shows the additional terms used in the model.

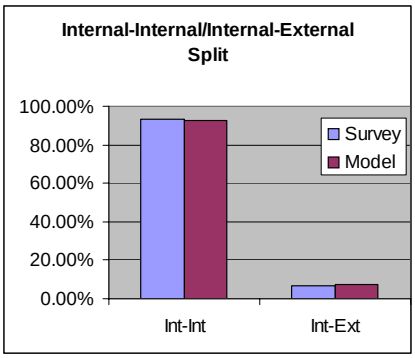
Figure 2.3 External destination choices for maintenance tours when applying MORPC directly

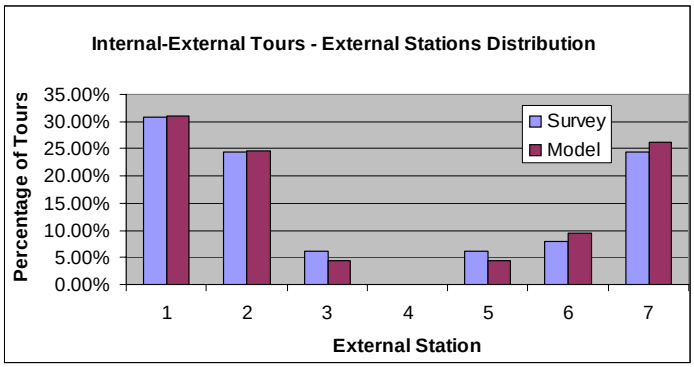




Note that the internal-external split matches the observed data but the model shows too many people leaving through zone 3 and not enough leaving through zone 2.

Figure 2.4: External destination choices for maintenance tours after adjustments





However, once the external terms were applied to the model, not only did the split match but the distributions did as well.

Table 2.2: Variables used in the maintenance destination choice model

Variable	MORPC Model	Calibrated Tahoe Model
Distance - Adult (Mandatory Daily Activity Pattern)	-0.1819	-0.4419
Distance - Adult (Non-Mandatory Daily Activity Pattern)	-0.1368	-0.3568
Distance - Child	-0.2348	-0.4948
Mode Choice Logsum for Non-Mandatory Daily Activity Pattern	1.0000	1.0000
Mode Choice Logsum forMandatory Daily Activity Pattern	1.0000	1.0000
Size variable	0.8417	0.8417
Binary for urban at origin, urban at destination	0.4332	0.4332
Binary for rural at origin, suburban at destination	-0.2494	-0.2494
No cars in household & short walk to transit	2.1730	2.1730
Number of cars less than workers - short walk to transit	1.6330	1.6330
Number of cars less than workers - long walk to transit	0.5508	0.5508
Preschool child at home & destination within 3 miles	0.8743	0.8743
School child (pre-driving) at home and destination within 3 miles	0.7665	0.7665
No Attractions	-999.0000	-999.0000
Dummy for ext zone 1		3.6500
Dummy for ext zone 2		3.5000
Dummy for ext zone 3		1.9000
Dummy for ext zone 4		-3.0500
Dummy for ext zone 5		4.2500
Dummy for ext zone 6		3.2500
Dummy for ext zone 7		3.0500

Overall, the hypothesis that a well-defined model could be transferred from one region to another proved true and therefore the remaining section of this chapter is an overview of the Tahoe model structure as adopted from the MORPC model.

2.2 Tahoe Resident Model Structure

The resident model is actually a series of models that attempt to capture multiple aspects of household, person and tour level travel making decisions. When applied these components essentially take the place of trip generation, trip distribution and model split that are the more familiar steps from the aggregate 4-step model. However because this is an activity-based model, the components cannot be grouped the same way since "trip generation" is done on a person-by-person basis with "trip distribution" and "modal split" integrated along the way.

Instead of calculating a matrix of home-based work or home-based other trips based on generalized household trip rates, each person in the model area gets to explicitly choose whether to leave the house on the model day and if so whether to go to work and/or school (**mandatory tours**) or do some other kind of non-mandatory travel (**joint and/or individual non-mandatory tours**). If work/school travel is chosen, the person then decides where to go to work (**D**estination choice), when to go to work, how long to stay and when to return home (**T**ime-of-day choice) and how to get to and from work (**M**ode choice). At the end of the daily activity pattern and mandatory DTM components, trip generation, distribution and modal split for home-based work trips has been done.

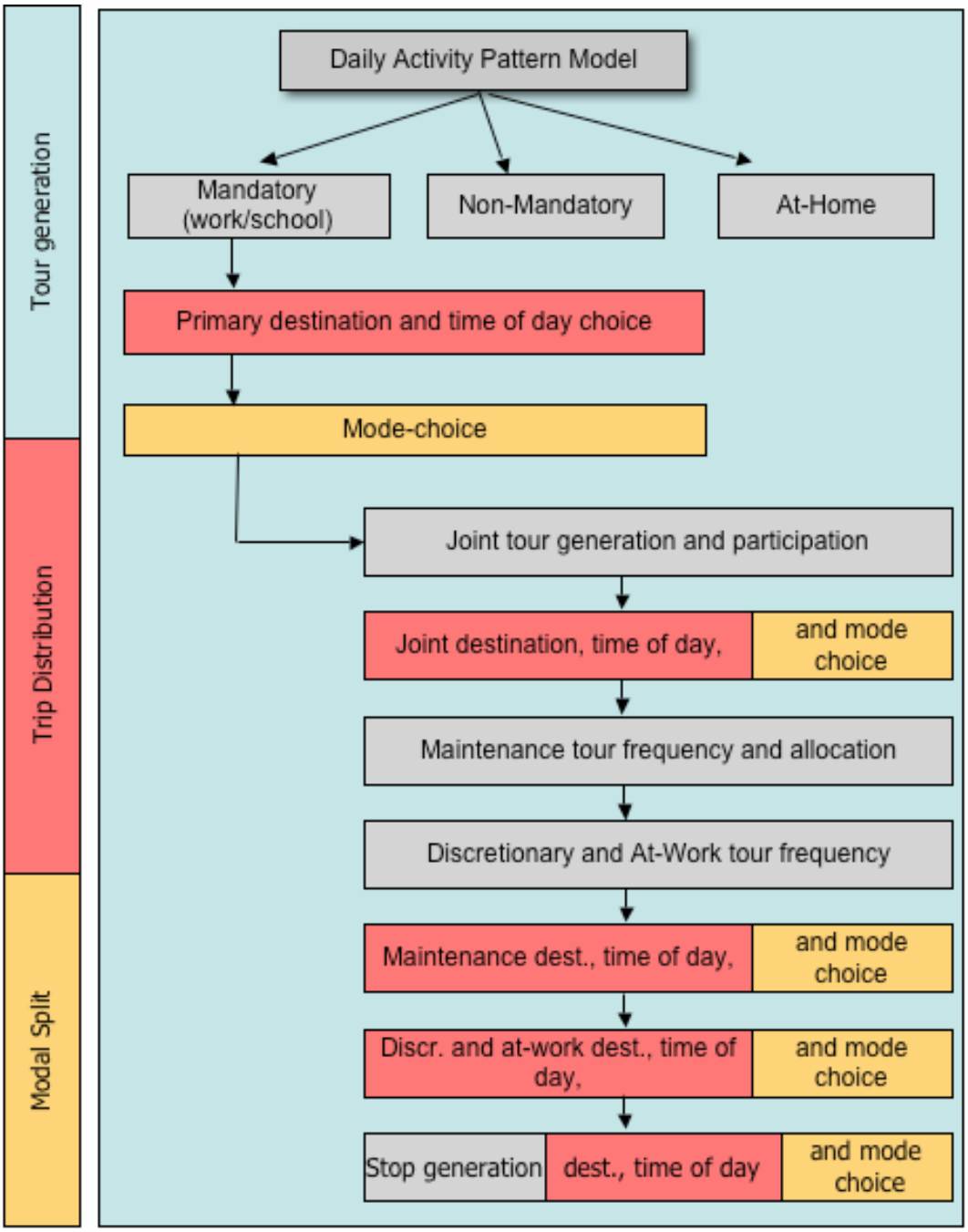
With the knowledge of everyone in the households' schedule, it can now be determined if there is an opportunity for anyone in the household to take a tour together – perhaps to shop or eat dinner (joint tour frequency). If there are several people at home at the same time, it is determined who will make up the tour party (kids and adults, just adults) and who will ultimately participate in the joint tour (joint tour composition and tour participation). Finally for each joint tour, the destination, time of day and mode choice is chosen. The set of joint-tour components generates home-based other trips that are behaviorally consistent with observed data.

Each time a person makes a choice regarding when to leave, how long to stay and when to return, her daily schedule is updated to reflect the decision. However as in all households no matter how busy everyone is, someone still has to find time to go to the grocery store or the post office or take themselves to the doctor. These decisions are made in the individual non-mandatory tours model. First, it is determined whether the household needs someone to run the household errands on the model day and how many errands there are (maintenance frequency). If so, schedules are checked and the person most available is most likely chosen to run the errand/s (maintenance allocation). Next each person in the household decides to make or not make 'discretionary tours' – doctor visit, seeing friends, etc (discretionary frequency). In addition, persons at work choose whether to leave work during the day to eat or shop before returning to work to finish up their day (at-work frequency). As before, the destination, time of day and mode for any tours that were chosen most now be decided (non-mandatory DTM and at-work DTM).

The final set of models (stop frequency, stop location and stop mode) determines whether stops are made along the way, where they are made and how they are made for each of the main tour types chosen above (mandatory, joint, non-mandatory and at-work). These stops make up what is thought of as the "non-home-based" other trips in the four step process. The benefit of the activity-based models is that so much is known about the travel that occurs immediately before this non-home-based trip and after, that a much more reliable trip matrix can be produced.

Once all decisions are made, trip matrices can be produced for each time period and assigned to the network. Because network congestion is factored into many of the travel decisions, the entire process must be run several times in order to reach a convergent solution.

Figure 2.5: Core Travel Demand Model Flow-chart



What variables are used in the utility equations that allow the choices to be made and the calibration results of each resident model component will be discussed in the following chapters.

CHAPTER 3
Population Synthesizer

CHAPTER 3 – POPULATION SYNTHESIZER

3.1 Introduction

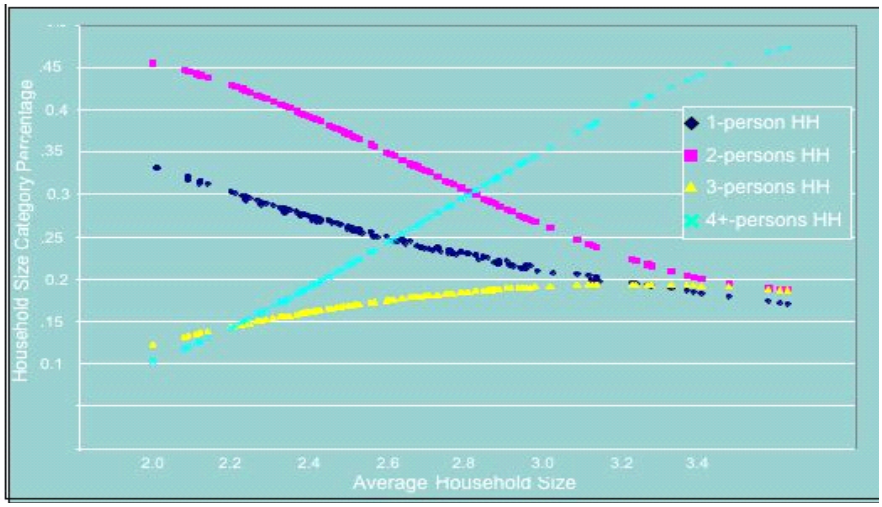
The population synthesis procedure is designed to create a list of households in each TAZ with all necessary details regarding the household and person variables used in the travel models and according to specific zonal characteristics; namely, average number of workers in a household per zone, average household size and number of households per income group. These characteristics are chosen because they have the most relevance in terms of travel choices. Given that population per zone is not explicitly controlled, it is possible to have a total population that is slightly larger (or smaller) than the population forecasted by TRPA; however, the population is not meant to exactly replicate reality but rather to generate the appropriate amount of demand on the network.

The basic idea is to set up a 3-dimensional table for each zone with dimension one being number of household by size (1, 2, 3, 4+), dimension two being number of households by number of workers (1, 2, 3+) and the third dimension number of households by income category (low, med and high). In each dimension the marginal distributions can be calculated. The cells in the table are given "seed" values based on what is given by the Census Transportation Planning Package (CTPP) data for the census tract that contains the zone. A procedure called iterative proportional fitting (IPV) or matrix-balancing is then used to adjust the seed values to match the marginal distributions in all dimensions. Once the table has been balanced, each cell is multiplied by the total number of households to give the total number of households per category (size, worker, income combination). Household records from the Public Use Micro-Sample Area (PUMA) that encompasses the zone are randomly drawn that match the given category until all of the households in the table have been accounted for. In addition to the number of workers, size and income, the PUMS household record also indicates the number of children, the age of the persons, and number of non-working adults. When the procedure is done for every zone, then the synthetic household and person files is written and saved for later use.

3.2 Calculation of the Marginal Totals

The socio-economic file that is described in **Appendix I** contains the number of occupied residences as well as the total population of each zone. From that information an average person per occupied household is calculated. For the IPV procedure it is necessary to know the percentage of households in each size category (i.e. for zone 9, what percentage of households have 1 person, 2 people, 3 people or 4 or more people). These are the marginal distributions for the first dimension as described above. Percentage-curves are created based on the observed regional distribution of average household size to actual persons per household and are used to define the distributions.

Figure 3.1 Percentage-curve for household size based on average household size



From these curves the HH Size marginal distributions can be obtained given the average household size in each zone.

Similar curves were produced for the number of workers in the household based on the average number of workers per household. Currently, however, TRPA does not forecast the average number of workers per household for each zone so a labor force model was created to forecast the total number of workers in each zone (**see Appendix I, Labor Force Model**). With the results of the labor force model added to the socio-economic file, the average number of workers per occupied households is calculated. Given this and the workers per household percentage curves, the workers per household marginal distributions are obtained.

The marginal distributions for the households by income category can be calculated directly from the socio-economic file since TRPA does forecast households by income level (low, medium, high) for each zone.

3.3 Synthetic Population Results

The synthetic population procedure was run multiple times to determine the amount of variation in population size given the randomness of the procedure. The following figures show that the variation is minimal.

Figure 3.2: Number of persons by type for 10 different synthetic population runs

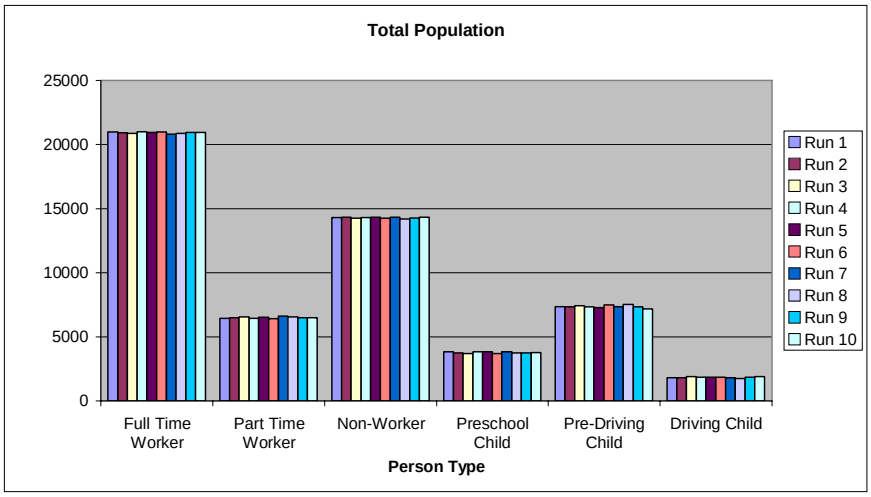
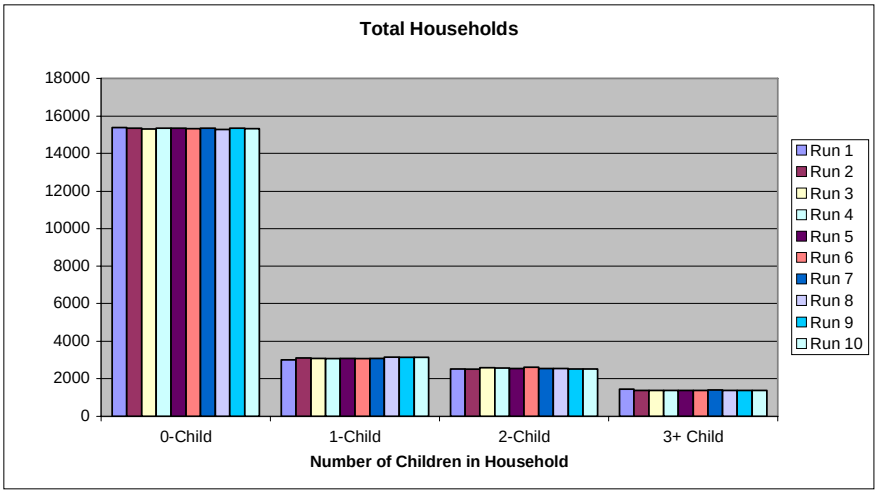


Figure 3.3: Households with children for 10 different synthetic population runs



In the 2000 base scenario, the average total population for 10 runs was 54725, with a minimum of 54644 and a maximum of 54811. This is within 2% of the actual population of 55,395 as specified in the socio-economic data file.

CHAPTER 4
Auto-Ownership Model

CHAPTER 4 – AUTO-OWNERSHIP MODEL

4.1 Introduction

The number of autos available to a household is an important variable for explaining household travel behavior. It is included in such subsequent models as tour generation, mode choice, destination choice, and stop frequency/location choice. In the current model system developed for TRPA, auto ownership is considered a household-attribute variable (as in the most conventional models); thus, the auto-ownership choice model employs only household and zonal characteristics and is applied before any travel-related model.

4.2 Modeled Behavorial Unit and Set of Observations

The household auto-ownership model is formulated and estimated using the 1,220 surveyed households. **Table 4.1** below summarizes the auto-ownership characteristics of the surveyed households, as well as the corresponding region-wide values obtained from the CTPP (U.S. Census).

Table 4.1: Household distribution of auto-ownership by data source

Autos Owned	Surveyed		Expanded	
	Number	%	Number	%
0	34	2.79%	1462	6.54%
1	342	28.03%	5937	26.56%
2	550	45.08%	9067	40.55%
3	196	16.07%	4166	18.63%
4+	98	8.03%	1729	7.73%
Total	1220	100.00%	22361	100.00%

4.3 Set of Choice Alternative and Availability Rules

There are five naturally ordered alternatives; no autos, one auto, two autos, three autos, four or more autos. All alternatives are assumed available for each household. However, the integration of the relative auto-sufficiency indices (explained in the next section below) into the utility functions excludes improbable combinations (like single-person household having four autos) because they give those choices highly negative utility values.

4.4 Auto Sufficiency

Relative auto sufficiency is calculated as the number of autos minus number of workers (or drivers) according to Table 4.2 below. By definition, auto sufficiency is a differential variable across choice alternatives for the same household.

Table 4.2: Relative auto sufficiency

No. of workers or drivers	Auto-ownership alternatives				
	0	1	2	3	4
0	0	1	2	3	4
1	-1	0	1	2	3
2	-2	-1	0	1	2
3	-3	-2	-1	0	1
4	-4	-3	-2	-1	0

Auto sufficiency coefficients are applied to each alternative in the corresponding utility and are weighted by the relative auto sufficiency of the household. For example, a household with 2 workers would see a 0-auto utility that included a (-2) times the auto sufficiency penalty coefficient. It is assumed that alternatives with negative auto sufficiency (i.e. not sufficient a number of autos versus the number of workers or drivers) should be less frequently observed, all else being equal. On the other hand, alternatives with a large positive auto sufficiency should also be discouraged because households with many surplus autos are also rare. The coefficients that penalize for auto shortage may be different from those for auto surplus. Auto sufficiency variables can be applied for one of the modifications (either relative to workers or relative to drivers) but not for both simultaneously. Based on the observed data that is shown below in **Table 4.3**, auto-sufficiency for the Tahoe model was calculated based on the number of drivers vs. the number of autos.

The observed auto-sufficiency data also shows that auto-surplus cases are more frequent than auto-shortage cases. Thus, one can expect that all else being equal the auto-shortage penalizing coefficients should be larger than the auto-surplus penalizing coefficient.

Table 4.3: Observed distribution of households by auto-sufficiency category

Number of Workers or Drivers	Number of Autos					Total
	0	1	2	3	4	
Workers						
0	18	108	104	22	8	260
1	12	198	197	48	24	479
2	3	32	239	100	46	420
3	1	4	10	26	20	61
Drivers						
1	22	236	81	17	3	359
2	10	92	421	110	56	689
3	0	11	41	61	14	127
4+	2	3	7	8	25	45

4.5 Estimation Results

The final model structure and results of the coefficient estimation are summarized in **Table 4.4** below. Alternative-specific constants were not estimated at this stage because of multi-colinearity with the auto-sufficiency variables. Alternative-specific-constants are included in the final model and their estimation and values are reported below in the discussion of the validation stage of the model.

Table 4.4 Estimation results for the household auto-ownership model (parenthetic values indicate t-statistics)

Variable	Number of autos owned by household				
	0	1	2	3	4+
Auto Sufficiency Measures:					
Auto Surplus (# of autos more than drivers)	-1.2635 (-11.3534)				
Auto Shortage (# of drivers less than autos)	-3.159 (-7.1911)				

Table 4.4 continued

Variable	Number of autos owned by household				
	0	1	2	3	4+
Household characteristics:					
Medium Income	—	1.2741 (1.7122)	1.9391 (2.5869)	2.1822 (2.8176)	
High Income	×		1.3462 (6.5432)	2.2051 (8.0864)	
Presence of a Retired Person in Household	—	2.2701 (2.957)	2.2653 (2.9421)	1.1047 (1.3914)	
Presence of 4+ Persons in Household	—	5.348 (3.9969)	6.4645 (4.8571)	7.0311 (5.263)	
Presence of a Driving Age Child	—	0.2899 (0.2028)	0.9344 (0.6695)	2.1951 (1.5651)	
0 Worker Household with no Retired Persons	—	0.7008 (0.9407)	0.7049 (0.9252)	-0.5841 (-0.7156)	
1 Worker Household	—	1.5801 (2.5052)	1.3794 (2.1725)	-0.1753 (-0.2658)	
2 Worker Household	—	3.3694 (3.1152)	4.9029 (4.5878)	3.7044 (3.4305)	
Zonal Characteristics					
Rural Area	—	3.4095 (2.6118)	3.2523 (2.488)	2.0952 (1.577)	
Medium Urban Area	—	2.4496 (4.0291)	1.9859 (3.2338)	1.0798 (1.6689)	
Total Employment Accessibility by Non-Auto Mode in 30 minutes	—	-4.4095 (-1.2663)	-11.621 (-2.886)	-20.5825 (-4.1749)	
Statistics					
Log Likelihood Initial/with 0	-1963.5142				
Log Likelihood with Constants	-1600.3656				
Log Likelihood Final	-1268.3375				
R^2 with respect to 0	0.354				
R^2 with respect to constants	0.2075				
No. of Observations	1220				

Zero-auto utility has been chosen as the reference alternative with all zero constants and coefficients except for the auto-sufficiency variable.

Due to the relatively few observations of "4+ auto" households, the "3-auto" and "4+ auto" alternatives were collapsed for estimation purposes and therefore share the same coefficients. The distinction between them is made by means of the auto-sufficiency variables that refer to the number of autos. Thus, all else being equal, the same household will have a higher auto surplus and/or lower auto shortage for the "4+ autos" alternative versus "3 autos" alternative.

Negative signs for auto shortage and surplus indicate that the most probable auto-ownership state is when the number of autos owned by a household is equal to the number of drivers.

Higher income, as expected, works strongly in favor of additional autos. The coefficients for medium-income and high-income dummies are logically aligned across auto-ownership alternatives. Having one or two autos is

favored by medium income more than by high income. However, the "3-auto" and "4+-auto" alternatives are favored by high-income households relative to medium income households.

The presence of a retired person in the household has a significant positive impact on car ownership, especially on the "1-auto" or "2-auto" alternative. Intuitively this makes sense as one would expect a household with a retiree to have less need for a higher number of cars (kids have moved out; no job to drive to); on the other hand, it would also be expected that the retiree would have enough earning power and desire for independence to own at least one car.

Also as expected, if a household has four or more persons in it, there is a preference for it to own a larger number of autos. In addition the presence of driving-age children has a significant positive impact on car-ownership, especially on having the 3rd and 4th car.
If a household has no workers, then the data shows a preference to own fewer autos . If a household has one or two workers, then there is both a preference to own more cars as well as a desire to have the number of autos match the number of workers. This last point reflects the results show in Table 4.3 concerning the worker auto-sufficiency variable.

The land type is associated with auto-ownership in a logical manner: the more "urban" a household's location, the lesser the preference for owning autos. This makes sense as one would expect a household in a less urban setting to be more dependent on autos to make both work- and non-work-based trips.

Accessibility to jobs by non-auto modes (transit and walk) proved to have a significant negative impact on high car-ownership alternatives that is gradually growing from the "1 car" alternative through "3 cars" and "4+ cars alternatives". It means that improvement of transit and pedestrian environments reduces the need for cars that is finally expressed not only in less car use but also in lower car ownership. The high absolute value of the coefficients on this variable seem to imply that they have a greater impact on the model than the other reported results; this is untrue, however, because the relative size of the accessibility variable is generally smaller than the other variables by a factor of 10.

4.6 Estimation of Constants and Model Validation

In order to verify the validity of the estimated model to accurately reflect the observed data at the individual household level the model was applied to the surveyed population. This application consisted of two stages: First, alternative specific constants were estimated to match the model output to known regional data (**Table 4.1**); and second, the model was validated through its actual application and an investigation of its variability.

The values of the alternative specific constants are reported in **Table 4.5**. It is noted that the added constants do not change the basic model sensitivities but instead reflect limited sample size for the extreme alternatives (in particular the "0-auto" alternative).

Table 4.5: Estimated alternative-specific constants for auto-ownership model

	Number of autos owned by household				
	0	1	2	3	4+
Alternative-Specific Constants	0	-5.6401	-7.1694	-5.506	-5.8091

Table 4.6: Model application for surveyed population of households

Observed Auto Ownership	Modeled Auto Ownership					Total
	0	1	2	3	4+	
Core Probabilistic Model						
0	215	226	82	0	0	523
1	774	3890	1319	361	53	6397
2	387	1580	6858	2338	988	12151
3	0	191	692	1296	247	2426
4+	86	52	115	170	441	864
Total	1462	5939	9066	4165	1729	22361
Monte Carlo simulation 1						
0	301	816	280	85	18	1500
1	645	3299	1500	404	53	5901
2	344	1320	4978	1679	723	9044
3	86	365	1681	1466	459	4057
4+	86	139	626	531	476	1858
Total	1462	5939	9065	4165	1729	22360
Monte Carlo simulation 2						
0	387	747	214	64	0	1412
1	559	3369	1599	361	141	6029
2	344	1354	4764	1509	758	8729
3	86	313	1978	1722	300	4399
4+	86	156	511	510	529	1792
Total	1462	5939	9066	4166	1728	22361
Monte Carlo simulation 3						
0	258	677	264	43	0	1242
1	774	3386	1500	446	106	6212
2	215	1320	5259	1488	723	9005
3	129	365	1665	1700	370	4229
4+	86	191	379	489	529	1674
Total	1462	5939	9067	4166	1728	22362
Monte Carlo simulation 4						
0	473	781	313	21	18	1606
1	516	3126	1418	425	106	5591
2	301	1511	4978	1509	723	9022
3	86	382	1978	1700	388	4534
4+	86	139	379	510	494	1608
Total	1462	5939	9066	4165	1729	22361
Monte Carlo simulation 5						
0	387	677	429	85	0	1578
1	645	3473	1368	361	106	5953
2	301	1215	4830	1530	670	8546
3	0	434	1797	1637	476	4344
4+	129	139	643	553	476	1940
Total	1462	5938	9067	4166	1728	22361

The results of the model applications are shown in **Table 4. 6** above. For the core probabilistic model the fractional probabilities were summed, while for the Monte-Carlo runs the resulting discrete realizations (number of autos for each household) were totaled. The results include expansion factors for the 1,220 surveyed households to represent the entire population of 22,361 households in the Tahoe basin for the base year of 2000. The same expansion factors were used in the model estimation.

Table 4.6 cells can be broken into three categories:

1. Diagonal that corresponds to exact replication of the observed auto ownership for each household (shaded in dark gray).
2. Adjacent-to-diagonal cells that correspond to a minor deviation (one auto) between the observed and modeled auto ownership (shaded in light gray).
3. Other cells that correspond to a significant deviation (two autos or more) between the observed and modeled auto ownership (not shaded).

The actual auto ownership has been replicated for the majority of households with a high degree of accuracy Summary statistics for the three categories (exact replication, minor discrepancy, and major discrepancy) mentioned above are presented in **Table 4.7** below. Overall, over 50% of the households were modeled exactly, just over 30% of the households were modeled with a minor deviation, and only 10% of the households were modeled with significant discrepancy between the actual and predicted number of autos.

Table 4.7: Summary of the auto-ownership prediction accuracy

Model	Number of Households		
	Exact Prediction	Minor Discrepancy (1 auto)	Major Discrepancy (2 autos or more)
Core Probabilistic Model	12700 (56.8%)	7346 (32.85%)	2315 (10.35%)
Monte Carlo simulation 1	10520 (47.05%)	8631 (38.6%)	3209 (14.35%)
Monte Carlo simulation 2	10771 (48.17%)	8556 (38.26%)	3034 (13.57%)
Monte Carlo simulation 3	11132 (49.78%)	8283 (37.04%)	2947 (13.18%)
Monte Carlo simulation 4	10771 (48.17%)	8611 (38.51%)	2979 (13.32%)
Monte Carlo simulation 5	10803 (48.31%)	8261 (36.94%)	3297 (14.74%)

It should be noted from Tables 4.6 - 4.7 above that despite differences between the micro-simulation runs themselves, they all approximate the core model reasonably well and reflect the observed auto-ownership choices. Table 4.7 shows that even though the level of exact prediction falls from the core-probabilistic model to the Monte Carlo simulations, the level of major discrepancy remains under 15%. The limited variability is important to the model's performance as the small region-wide population (22,361) limits the potential variance reduction in Monte Carlo simulations (whose error is inversely proportional to the square-root of the sample size used to apply the auto-ownership model to the synthetic population.

4.7 Model Application for Synthetic Population

The auto ownership model is the first model applied to the synthetic population.

In order to investigate the variability of the auto-ownership model when applied to the synthetic population, the model was run multiple times under various conditions. First, to investigate the overall variability of the auto-ownership model as it relates to variations in the synthetic population, a series of five different synthetic populations were generated (using different random seeds). For each of these populations, the auto-ownership model was run five times (each Monte Carlo selection process using a different random seed). The results are summarized in **Table 4.8**.

Table 4.8: Summary of auto-ownership results on five different synthetic populations

	Auto-Ownership Alternative				
	0	1	2	3	4+
Region Summary					
Actual Percentage of Households	6.50%	26.60%	40.50%	18.60%	7.70%
Synthesized Population 1					
Average Percentage of Households	6.20%	24.00%	40.00%	21.30%	8.50%
Bounds on Percentages	[6.00%, 6.30%]	[23.70%, 24.20%]	[39.90%, 40.10%]	[20.90%, 21.70%]	[8.30%, 8.70%]
Synthesized Population 2					
Average Percentage of Households	6.00%	24.70%	39.40%	21.40%	8.50%
Bounds on Percentages	[5.90%, 6.30%]	[24.40%, 25.10%]	[39.20%, 39.50%]	[21.20%, 21.60%]	[8.30%, 8.70%]
Synthesized Population 3					
Average Percentage of Households	5.90%	24.60%	40.00%	21.20%	8.40%
Bounds on Percentages	[5.70%, 6.10%]	[24.30%, 24.70%]	[39.80%, 40.30%]	[20.90%, 21.50%]	[8.30%, 8.40%]
Synthesized Population 4					
Average Percentage of Households	6.00%	24.30%	39.50%	21.40%	8.80%
Bounds on Percentages	[5.70%, 6.30%]	[24.20%, 24.50%]	[39.00%, 39.80%]	[21.00%, 21.70%]	[8.60%, 9.00%]
Synthesized Population 5					
Average Percentage of Households	6.00%	24.40%	39.50%	21.40%	8.60%
Bounds on Percentages	[5.90%, 6.10%]	[24.30%, 24.60%]	[39.00%, 40.30%]	[20.70%, 21.70%]	[8.50%, 8.70%]

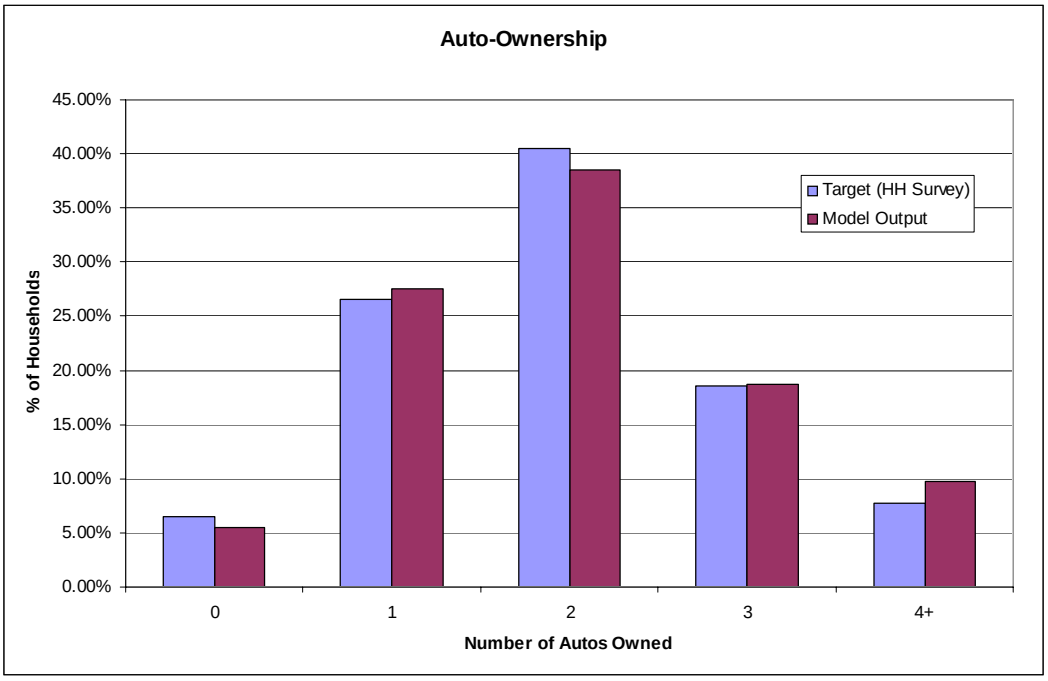
The results presented in Table 4.8 show that the variability of the auto-ownership model across both runs on the same synthetic population and runs on different synthetic populations is small. Also, the results of the various runs are seen to be close to the actual proportions of households in the auto-ownership categories calculated from the CTPP.

In the actual model implementation, a single (fixed) random seed is used so that the same synthesized population, including its auto-ownership characteristics, is generated each time the model is run. **Table 4.9** and **Figure 4.1** summarize the auto-ownership characteristics of the population from the final model implementation, and compares them to the actual regional totals generated from the CTPP.

Table 4.9: Comparison of actual auto-ownership model implementation to regional characteristics

Cars Owned	CTPP Totals		Model Results	
	Number	%	Number	%
0	1462	6.54%	1232	5.51%
1	5937	26.56%	6170	27.59%
2	9067	40.55%	8608	38.50%
3	4166	18.63%	4187	18.72%
4+	1729	7.73%	2164	9.68%
Total	22361	100.00%	22361	100.00%

Figure 4.1: Comparison of auto-ownerships model to regional characteristics



CHAPTER 5
Daily Activity Pattern Model

CHAPTER 5 – DAILY ACTIVITY PATTERN MODEL

5.1 Model Structure

A person's daily activity pattern (DAP) is classified by three main categories:

- **Mandatory pattern** that includes at least one of the two mandatory activities – work or school. This constitutes either a workday or school day, and may include additional non-mandatory activities such as separate home-based tours or intermediate stops on the mandatory tours.
- **Non-mandatory pattern** that includes only maintenance and discretionary tours. By virtue of the tour primary purpose definition, maintenance and discretionary tours cannot include travel for mandatory activities.
- **At-home pattern** that includes only in-home activities. It should be noted that for simplicity, cases with complete absence from town (business travel) were combined with this category.

The important feature of the DAP model is a linkage across household members. Consider the following scenario: a preschool age child is sick. It is likely that an adult in the household will choose an at-home pattern to take care of the child. In this case, the adult's choice is "dependent" on the child's choice.

If there are several household members of the same person category, they all have the same utility, and in the model application they are processed sequentially according to the initially assigned order.

Most intra-household impacts relate to the sharing of non-mandatory activities. In this context, it is important to make a distinction between in-home activities and out-of-home activities. It is also important to distinguish the impact of children on adults (stemming from the child care function) from the cross-impact across adults themselves. Thus, the following four basic intra-household impacts will be analyzed:

- **Childcare at home.** If at least one of the preschool or school children stays at home, then at least one of the household adults might also stay at home to take care of the child.
- **Escorting child for non-mandatory activity.** It is assumed that if a non-mandatory pattern has been chosen for a child on a regular workday, it is most frequently associated with visiting the doctor, out-of-home family event, sports event, etc; thus it may require escorting by an adult family member. Thus, in order to take into account a probable time conflict with the mandatory activity, these adults should also have a non-mandatory DAP.
- **Sharing in-home non-mandatory activity by adults.** If at least one of the household adult members stays at home (or is absent, travels out of town, has a vacation) there is a possibility that the other adult household members will join him/her. Thus, the at-home or absent utility for each subsequently modeled adult person category includes an indicator that a previously model adult stayed at home.
- **Sharing out-of-home non-mandatory activity by workers and students.** If at least one of the household adult workers has chosen a non-mandatory DAP (day-off for major shopping, vacation, family event) there is a possibility that another adult household members will join him/her. Thus, the non-mandatory utilities for each subsequently modeled adult person includes an indicator of a non-mandatory DAP for the previously modeled adults. Non-working adults may be excluded from impacting other household members because they predominantly have a non-mandatory DAP.

Below is the structure of the daily activity pattern type choice model.

Choice alternatives:

- Work day
  - 1 work tour (not available for preschool children)
  - 2 work tours (not available for children)
  - Work and school tours (available for workers only)
- School day
  - 1 school tour (available for children only)
  - 2 school tours (available for school children only)
  - School and secondary work tours (available for school children only)
- Non-mandatory out-of-home activity
- Full day at home / absent

Main explanatory variables in the utility equation:

- Household size and composition
  - Number/presence of full-time workers
  - Number/presence of part-time workers
  - Number/presence of non-working adults
  - Presence of a preschool child,
  - Presence of a school pre-driving-age child
  - Presence of a school driving-age child
- Household income
- Car ownership/sufficiency
- Residential area type
- Accessibility indices:
  - Auto accessibility to jobs
  - Walk accessibility to jobs
  - Walk accessibility to retail attractions
- Activity patterns chosen by the other household members (modeled prior to the person):
  - Preschool child at home / with non-mandatory pattern
  - School pre-driving-age child at home / with non-mandatory pattern
  - School driving-age child at home / with non-mandatory pattern
  - Full-time worker at home / with non-mandatory pattern
  - Part-time worker at home / with non-mandatory pattern
  - Non-working adult at home / with non-mandatory pattern

5.2 Estimation Results

The daily activity pattern model was estimated using the Tahoe residential survey as the source data. The estimation is stratified by person type since each had a different set of available patterns. The results are presented in **Tables 5.1 through 5.6**. The accessibilities mentioned in the estimation are discussed in **Appendix I**.

Table 5.1: Daily activity pattern estimation results for pre-school children

	School	Non-Mandatory	At-Home
Alternative-specific constant	3.1033	1.3536	
Non-worker in household	-2.8805	0.0379	
Part-time worker in household	-0.4365	0.7204	
Full-time worker in household	-3.0416	-0.9645	
Another child in household	0.7078	0.1865	
Medium income	-2.1003	-0.7333	
High income	1.0665	0.7236	
One car in household	1.1183	0.6500	
Two cars in household	0.8971	0.5497	

Table 5.2 Daily activity pattern estimation results for non-driving children

	School	School School	Non-Mandatory	At-Home
Alternative-specific constant	1.1306	-1.6674	0.3564	
Non-worker in household	-0.7568	-1.3433	-0.0316	
Part-time worker in household	-0.0967		0.4509	
Full-time worker in household	-2.0338	-2.1438	-0.6411	
Preschool child in household			-0.6050	
Medium income	0.4749	1.2982	0.7334	
High income	1.3009		1.6745	
One car in household	1.0266		0.2568	
Two cars in household	-0.0726	0.7736	0.5579	
School day	2.8481	1.5478	0.0458	
Live in suburban area	0.2026			
Live in urban area	1.2817			

Table 5.3 Daily activity pattern estimation results for driving children

	Work	Work-Work	School	School-School	School Work	Non-Mandatory	At-Home
Alternative-specific constant	-1.6834	-0.3575	-1.6834	-0.3575	2.2705	2.5968	
Non-worker in household	0.1574	-1.5132	0.1574	-1.5132	-0.8462	0.0127	
Part-time worker in household	0.5388	0.2817	0.5388	0.2817	-0.7776	-0.9249	
Full-time worker in household					-0.3208	-1.1139	
Preschool child in household	1.6711		1.6711				
Medium income	3.2684	-0.2949	3.2684	-0.2949	2.1704	1.8723	
High income	0.9955	-1.3051	0.9955	-1.3051	0.2397	0.6335	
Live in suburban area	-2.1162	-1.6497	-2.1162	-1.6497	-3.0069	-2.6544	
Zero cars in household	4.6871		4.6871				
One car in household	1.2765		1.2765		0.2480	0.7957	
Two cars in household	-2.2721	1.3468	-2.2721	1.3468	-1.9222	-1.1850	
Child with at home pattern							-0.6949
Accessibility to total employment by walk (20 minutes)	107.6514	33.9161	107.6514	33.9161	94.6874	97.7030	
School day	3.5795		3.5795		0.5950	-0.2798	

Table 5.4 Daily activity pattern estimation results for full-time workers

	Work	Work-Work	School-Work	Non-Mandatory	At-Home
Alternative-specific constant	2.7468	0.6545	-0.6089	0.8744	
Non-worker in household	-0.1832	-0.2535	0.0044	-0.1004	
Part-time worker in household	-0.2415	0.1031	-0.3077	-0.1425	
Preschool child in household	0.5896	0.5274	0.0753	0.4430	
Non-preschool child in household	-0.0147	0.0318	0.3764	0.0433	
Medium income	-0.0382	-0.1667	-0.0964	0.1675	
High income	-0.5011	-0.8824	-0.3479	-0.5340	
Zero cars in household		-0.8686	0.0611	-0.5539	
Less cars than workers in household	-1.0250	-1.0873	-0.7965	-1.2174	
More cars than workers in household	-0.2430	0.1421	-0.6368	-0.1067	
Live in urban area	-1.0205	-0.2021	-0.4663	0.2349	
Auto accessibility to total employment (30 minutes)	-0.3013	0.3981	2.9235	0.8771	
Preschool child with at home pattern					1.9232
Pre-driving child with at home pattern					0.5374
Driving child with at home pattern					-0.2160
Child with non-mandatory pattern				0.2028	
Driving child with non-mandatory pattern				-0.1357	
School day			0.4851		

Table 5.5 Daily activity pattern estimation results for part-time workers

	Work	Work-Work	School Work	Non-Mandatory	At Home
Alternative-specific constant	1.2481	-2.8510	-1.0314	1.0506	
Non-worker in household	0.4901		2.0082	0.2240	
Full-time worker in household	-0.8210	-0.4981	0.1947	-1.1996	
Preschool child in household	0.0055	0.4412	-1.3963	-0.5531	
Non-preschool child in household	-0.1603	-0.3922	-0.4459	-0.8817	
Medium income	0.9122	1.6303	0.0240	0.7831	
High income	0.3584	2.0599	-0.8139	0.7849	
One car in household	0.1764	1.3276	0.9259	-0.1104	
Two cars in household	0.3986	2.0136	1.5642	1.0022	
Live in urban area			4.8523	3.1789	
Accessibility to retail employment by walk (20 minutes)	-2.1591	-15.6027	-18.5285	-11.9813	
Other adult with at-home pattern					0.6025
Child with at home pattern					2.2354
Child with non-mandatory pattern				0.6945	
Other adult with non-mandatory pattern				0.6217	
Household size > 3	1.7001			2.1855	
School day			0.5907		

Table 5.6 Daily activity pattern estimation results for non-workers

	Work	Work-Work	School-Work	Non-Mandatory	At-Home
Alternative-specific constant	-1.7943	-4.4925	-6.8329	1.7909	
Another non-worker in household	-1.5079			-0.9522	
Part-time worker in household		1.4855			
Full-time worker in household	-1.2499	-1.0314	-0.6142	-1.3054	
Preschool child in household				2.4610	
Non-preschool child in household				0.9845	
Medium income	0.9593	1.9694	1.2093	0.3343	
High income	1.1713	1.8817	1.4219	0.4879	
Live in suburban area	0.9755		0.8673		
Live in urban area		2.9681			
Auto accessibility total employment (30 minutes)			5.2105		
Other adult with at-home pattern					-0.4449
Preschool child with at home pattern					5.6332
Other adult with non-mandatory pattern				0.2088	
School day	0.4385				

5.3 Estimation and Model Results

Tables 5.7 and 5.8 show the daily activity patterns that were observed in the household survey and the results after the model was applied to the synthetic residential population in the base year scenario.

Table 5.7: Observed Daily activity patterns (household survey)

Person Type	Activity Type							
	Non-Mandatory	*At-Home*	*1 Work Tour*	*2 Work Tours*	*1 School Tour*	*2 School Tours*	*1 School/ 1 Work Tour*	Total
Pre-School Child	57.8%	20.2%			22.0%			100.0%
Pre-Driving Child	43.3%	17.6%			37.7%	1.4%		100.0%
Driving Child	32.3%	18.5%			25.4%	3.1%	20.8%	100.0%
Full-Time Worker	18.8%	7.3%	50.8%	9.2%			13.9%	100.0%
Part-Time Worker	36.0%	12.0%	38.8%	4.7%			8.5%	100.0%
Non-Worker	73.3%	18.1%	4.9%	1.1%			2.6%	100.0%

Table 5.8: Estimated Daily activity patterns (model results)

Person Type	Activity Type							
	Non-Mandatory	*At-Home*	*1 Work Tour*	*2 Work Tours*	*1 School Tour*	*2 School Tours*	*1 School/ 1 Work Tour*	Total
Pre-School Child	55.8%	20.7%			23.5%			100.0%
Pre-Driving Child	51.7%	21.8%			25.2%	1.3%		100.0%
Driving Child	34.7%	17.9%			10.5%	3.2%	19.2%	100.0%
Full-Time Worker	15.3%	8.7%	63.4%	9.1%			3.6%	100.0%
Part-Time Worker	36.7%	11.3%	42.8%	2.4%			6.7%	100.0%
Non-Worker	31.1%	7.0%	42.6%	2.0%			17.3%	100.0%

CHAPTER 6
Mandatory Tour Destination, Time-of-Day, and Mode Choice Model

CHAPTER 6 – MANDATORY TOUR DESTINATION, TIME-OF-DAY, AND MODE CHOICE MODEL

6.1 Introduction

If a person in a household chooses a daily activity pattern with a work or school component, then that person is said to be making a 'mandatory tour.' The mandatory tour destination, time-of-day, and mode choice model (DTM) determines where that tour will go (the destination), when the tour will happen (the time-of-day), and what mode the person will use to travel during the tour (car, bus, etc). If the daily activity pattern chosen by the individual includes both school and work, then the school tour is processed first, followed by the work tour.

6.2 Destination Choice Sub-model

The destination choice model is a multinomial logit model in which each potential destination zone is an alternative. The probability of each zone being chosen is calculated from a utility function, where the utility consists of variables such as distance, income level, and area type. To provide a measure of a zone's attractiveness based on tour-specific characteristics, a size term is included in the utility expression. For work tours, this size term is the natural logarithm of the total employment in the zone. For school tours, the size term is the natural logarithm of school enrollment, stratified by person type:

Table 6.1: School tour destination choice size term specification

	Size Term Coefficient on Enrollment			
Person Type	Elementary	Middle School	High School	College
Full-Time Worker	0	0	0	1
Part-Time Worker	0	0	0	1
Non-worker	0	0	0	1
Pre-School Child	1	0	0	0
Pre-Driving Child	1	1	1	0
Driving Child	0	0	1	0

Also included in the utility expression is the logsum from the mode choice model, which provides accessibility indices for a destination zone - the higher the logsum, the more "accessible" (by auto, transit, walking) a zone is. Because the mode-choice model uses time-of-day specific skims, a time-of-day choice must be made before its utility can be evaluated. Because the actual time-of-day model occurs after the destination choice model, pre-selected time-of-day choices are used to evaluate the mode choice logsums used in the model. These pre-selected choices are based on the expected time-of-day for a given purpose. For the work purpose, the time-of-day choice used for the logsum calculation is AM peak start, PM peak end. For the school purpose, if only one school tour is being made, the AM peak start, midday end time-of-day choice is chosen; otherwise the choice is midday start, midday end.

In the Tahoe region, a number of residents actually travel outside of the region to go to work or school. To capture this effect, size terms were assigned to external zones. These size terms are discussed in **Appendix I**. In addition to the size terms, each external zone has an alternative specific constant that allowed for further refinement in the calibration phase of model development. Because there are very different characteristics in the resident worker flows to external zones between seasons, different constants were calibrated for the summer and winter models.

The mandatory tour destination choice model specifications are presented in the following tables.

Table 6.2 Mandatory work destination choice model specification

Variable	Coefficient
Distance (miles) - Low Income	-0.0640
Distance (miles) - Medium Income	-0.1680
Distance (miles) - High Income	-0.1700
Mode Choice Logsum - Full or Part Time Worker & Low Income	0.7894
Mode Choice Logsum - Full or Part Time Worker & Medium or High Income	0.2418
Mode Choice Logsum - Non-worker or Driving Child	1.0000
Size Term	1.0000
Urban Origin, Suburban Destination	0.1363
Suburban Origin, Suburban Destination	0.1665
Suburban Origin, Rural Destination	0.5142
Rural Origin, Suburban Destination	0.3998
Rural Origin, Rural Destination	0.6216
No Cars in Household and Transit Within ¼ Mile at Both Origin and Destination	2.8530
Workers Minus Cars in Household (if positive) and Transit Within ¼ Mile at Both Origin and Destination	1.4090
Variable	Coefficient
Alternative Specific Constant for External Zone (Summer)	4.6500
Alternative Specific Constant for External Zone 1 (Summer)	-0.1600
Alternative Specific Constant for External Zone 2 (Summer)	-0.5500
Alternative Specific Constant for External Zone 3 (Summer)	-1.430
Alternative Specific Constant for External Zone 4 (Summer)	0.2850
Alternative Specific Constant for External Zone 5 (Summer)	3.4000
Alternative Specific Constant for External Zone 6 (Summer)	-0.6050
Alternative Specific Constant for External Zone 7 (Summer)	-1.0000
Alternative Specific Constant for External Zone (Winter)	
Alternative Specific Constant for External Zone 1 (Winter)	-0.1186
Alternative Specific Constant for External Zone 2 (Winter)	-0.3186
Alternative Specific Constant for External Zone 3 (Winter)	-1.1086
Alternative Specific Constant for External Zone 4 (Winter)	0.6014
Alternative Specific Constant for External Zone 5 (Winter)	3.5314
Alternative Specific Constant for External Zone 6 (Winter)	-0.4086
Alternative Specific Constant for External Zone 7 (Winter)	-0.9286
No Employment in Zone	Alternative Unavailable

Table 6.3 School destination choice model specification

Variable	Coefficient
Distance (miles)	-0.7500
Mode Choice Logsum	1.0000
Size Term	1.0000
Origin and Destination the Same Zone	1.4950
Drivers Minus Cars in Household (if positive) and Transit Within ¼ Mile at Both Origin and Destination	0.5167
Urban Origin, Rural Destination	-0.7322
Urban Origin, Suburban Destination	-0.6987
Alternative Specific Constant for External Zone	12.0000
Alternative Specific Constant for External Zone 1	5.5000
No (Applicable) Enrollment in Zone	Alternative Unavailable

6.3 Destination Choice Sub-model Calibration

To calibrate the destination choice sub-model, three primary aspects were examined:

- County to county flows
- Tour distance
- Internal to external flows

To perform the calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Table 6.4a: County to county flows for high income mandatory work trips – household travel survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	14.92%	0.00%	0.00%	0.00%	0.24%	3.35%	18.50%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.25%	0.00%	8.16%	1.67%	0.12%	1.99%	12.19%
El Dorado	0.17%	0.00%	6.60%	29.28%	2.77%	1.89%	40.71%
Placer	2.35%	0.00%	0.00%	0.24%	19.87%	6.15%	28.60%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	17.68%	0.00%	14.76%	31.18%	23.00%	13.38%	100.00%

Table 6.4b: County to county flows for high income mandatory work trips – model

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	15.28%	0.00%	0.31%	0.06%	1.96%	5.26%	22.88%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.16%	0.00%	10.44%	3.74%	0.06%	2.37%	16.76%
El Dorado	0.21%	0.00%	17.82%	18.25%	0.45%	2.20%	38.92%
Placer	4.46%	0.00%	0.05%	0.17%	11.93%	4.82%	21.43%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	20.10%	0.00%	28.62%	22.22%	14.41%	14.65%	100.00%

Table 6.5a: County to county flows for medium income mandatory work trips – household travel survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	7.52%	0.00%	0.00%	0.00%	1.12%	1.04%	9.68%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.15%	0.00%	3.22%	1.20%	0.31%	1.39%	6.27%
El Dorado	0.31%	0.00%	10.14%	35.51%	1.98%	3.11%	51.04%
Placer	2.18%	0.00%	0.00%	0.35%	22.46%	8.02%	33.00%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	10.16%	0.00%	13.36%	37.06%	25.87%	13.55%	100.00%

Table 6.5b: County to county flows for medium income mandatory work trips – model

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	7.34%	0.00%	0.10%	0.04%	1.19%	2.73%	11.40%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.13%	0.00%	4.57%	1.65%	0.00%	0.99%	7.34%
El Dorado	0.22%	0.00%	29.95%	31.02%	1.92%	4.47%	67.58%
Placer	3.22%	0.00%	0.04%	0.10%	7.11%	3.21%	13.68%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	10.91%	0.00%	34.66%	32.80%	10.23%	11.40%	100.00%

Table 6.6a: County to county flows for low income mandatory work trips – household travel survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	9.52%	0.00%	0.00%	0.00%	0.00%	0.00%	9.52%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	5.79%	0.82%	0.00%	0.70%	7.31%
El Dorado	0.70%	0.00%	12.95%	36.52%	4.20%	4.58%	58.95%
Placer	1.32%	0.00%	0.00%	0.00%	15.20%	7.70%	24.22%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	11.53%	0.00%	18.74%	37.34%	19.40%	12.98%	100.00%

Table 6.6b: County to county flows for low income mandatory work trips – model

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	5.18%	0.00%	0.16%	0.09%	0.71%	3.54%	9.68%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.23%	0.00%	4.56%	1.21%	0.07%	1.84%	7.91%
El Dorado	0.50%	0.00%	25.47%	30.54%	0.94%	9.69%	67.14%
Placer	3.47%	0.00%	0.29%	0.33%	6.05%	5.13%	15.28%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	9.38%	0.00%	30.48%	32.17%	7.77%	20.20%	100.00%

Table 6.7a: County to county flows for child mandatory school trips – household travel survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	19.93%	0.00%	0.00%	0.00%	0.00%	0.00%	19.93%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	5.25%	0.35%	0.39%	0.00%	5.98%
El Dorado	0.00%	0.00%	0.00%	44.17%	3.37%	0.00%	47.55%
Placer	0.00%	0.00%	0.00%	0.00%	25.86%	0.69%	26.55%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	19.93%	0.00%	5.25%	44.52%	29.62%	0.69%	100.00%

Table 6.7b: County to county flows for child mandatory school trips – model

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	13.47%	0.00%	0.00%	0.00%	0.42%	0.00%	13.89%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	4.81%	4.20%	0.00%	0.00%	9.01%
El Dorado	0.00%	0.00%	0.47%	58.32%	1.21%	0.00%	60.01%
Placer	1.37%	0.00%	0.00%	0.00%	15.73%	0.00%	17.10%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	14.84%	0.00%	5.28%	62.53%	17.36%	0.00%	100.00%

Table 6.8a: County to county flows for adult mandatory school trips – household travel survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	0.00%	10.20%	0.00%	3.18%	13.38%
El Dorado	0.00%	0.00%	0.00%	76.97%	0.00%	5.20%	82.17%
Placer	0.00%	0.00%	0.00%	0.00%	0.00%	4.44%	4.44%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	0.00%	0.00%	0.00%	87.17%	0.00%	12.83%	100.00%

Table 6.8b: County to county flows for adult mandatory school trips – model

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	3.40%	0.00%	0.00%	0.00%	0.00%	4.00%	7.40%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	0.00%	13.37%	0.00%	2.60%	15.96%
El Dorado	0.03%	0.00%	0.00%	67.39%	0.00%	0.03%	67.45%
Placer	3.10%	0.00%	0.00%	0.18%	0.00%	5.91%	9.19%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	6.53%	0.00%	0.00%	80.94%	0.00%	12.53%	100.00%

Figure 6.1: Distance distribution comparison for high income work tours

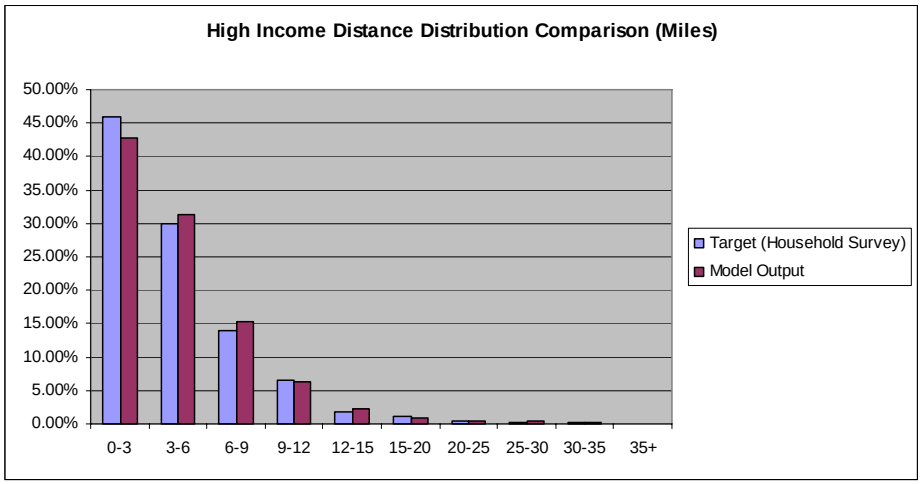


Figure 6.2: Distance distribution comparison for medium income work tours

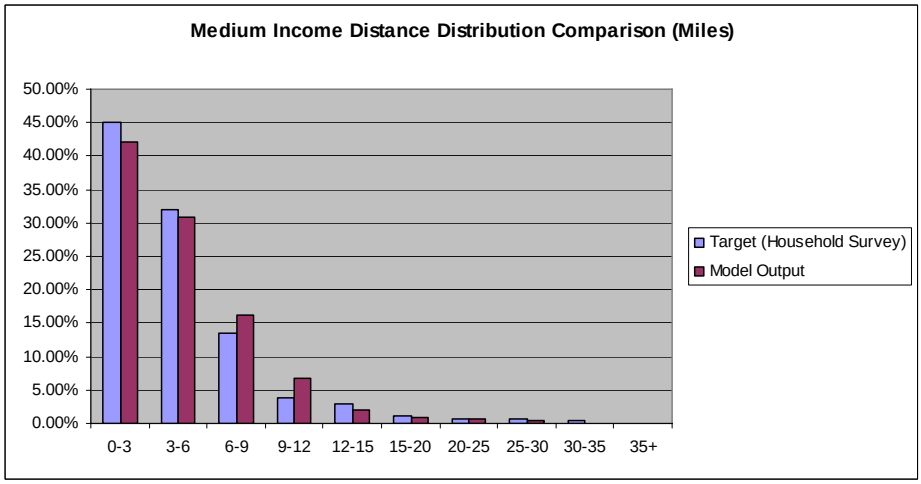


Figure 6.3: Distance distribution comparison for low-income work tours

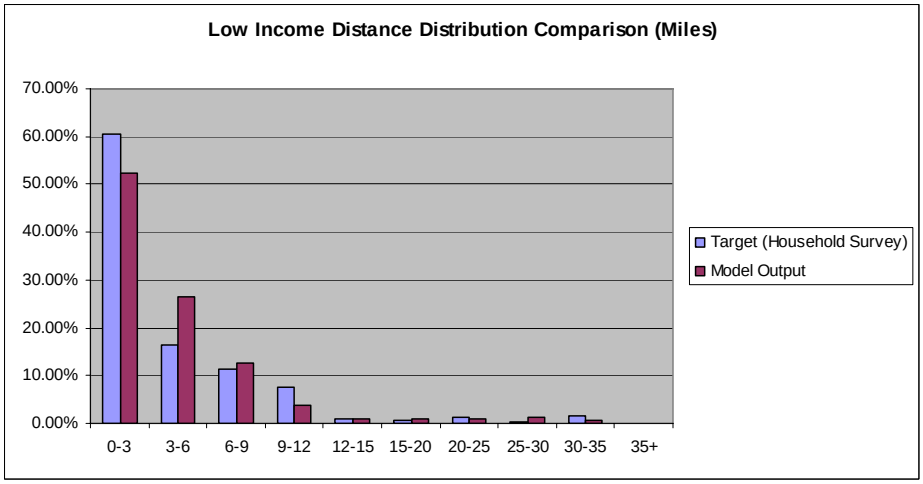


Figure 6.4: Distance distribution comparison for child school tours

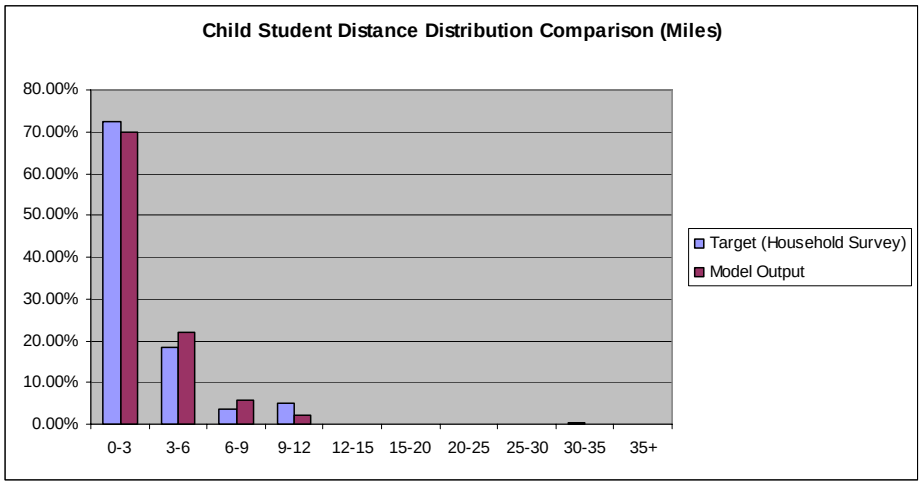


Figure 6.5: Distance distribution comparison for adult school tours

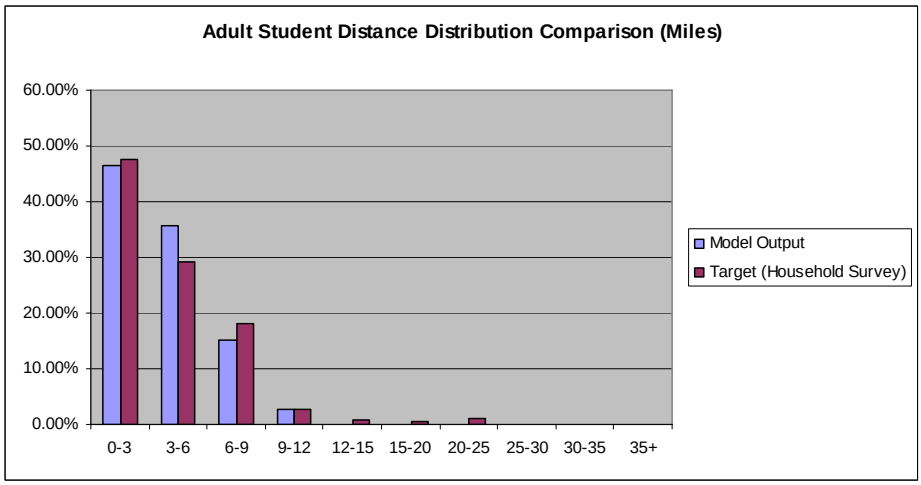


Table 6.9: Mandatory tour destination choice distance and travel time comparison

	Household Travel Survey				Model			
	Distance		Travel Time		Distance		Travel Time	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
Work - high income	4.467	3.839	8.460	6.166	4.602	4.021	8.470	6.159
Work - medium income	4.557	4.378	8.703	6.969	4.625	3.910	8.579	6.038
Work - low income	4.087	5.332	7.861	8.266	4.206	5.021	7.915	7.496
School - Child	2.769	3.141	5.559	5.083	2.658	2.217	5.383	3.747
School - Adult	3.554	2.290	7.098	3.724	4.172	3.243	7.583	4.955

Figure 6.6: Internal-External destination zone comparison for summer work tours

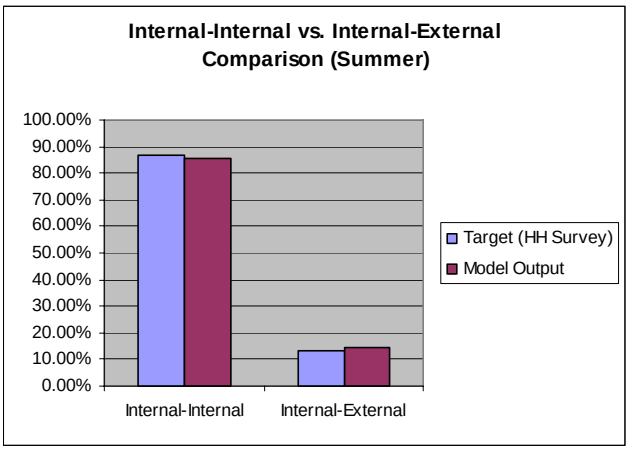


Figure 6.7: External station distributions for summer work tours

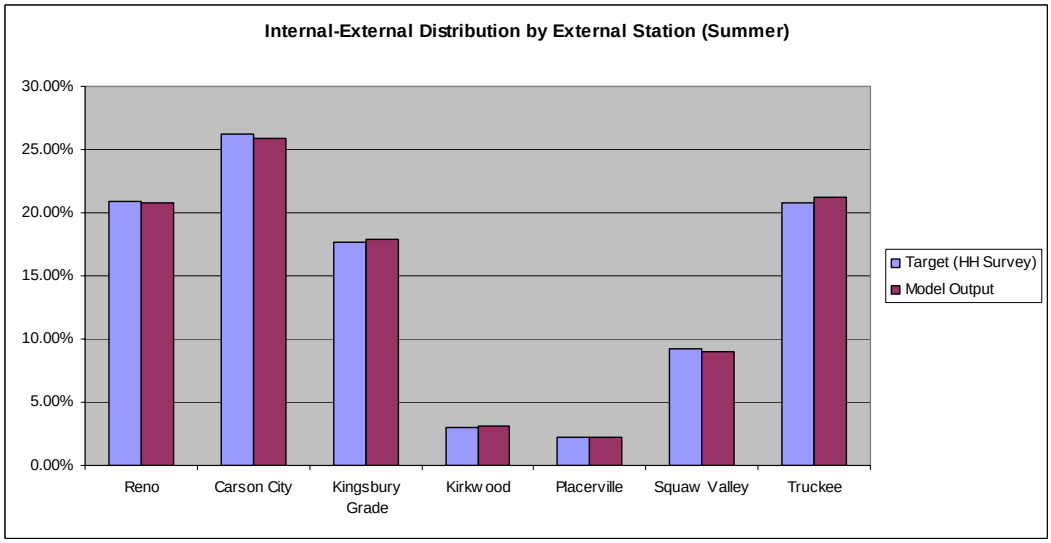


Figure 6.8: Internal-External destination zone comparison for winter work tours

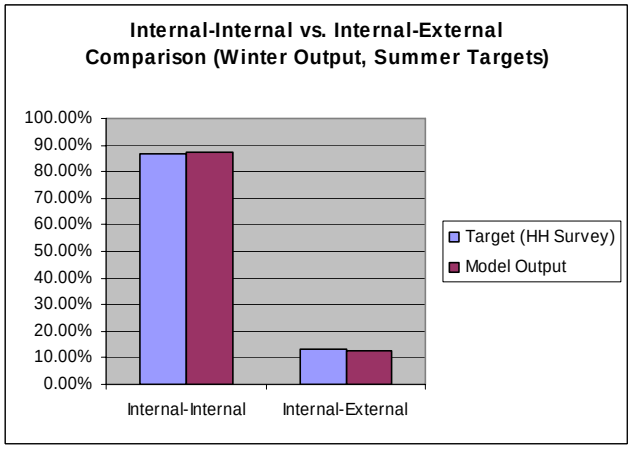


Figure 6.9: External station distributions for winter work tours

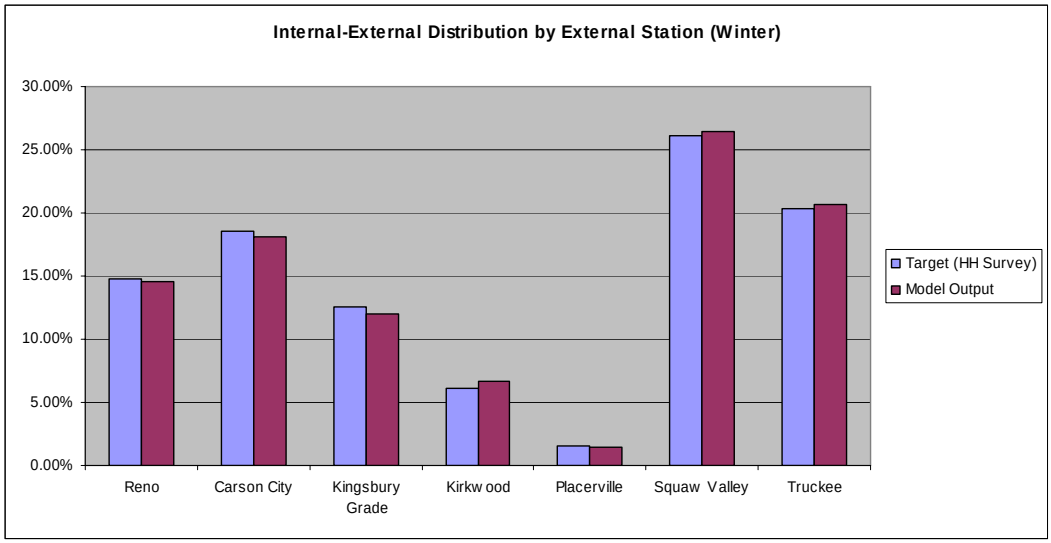


Figure 6.10: Internal-External destination zone comparison for adult school tours

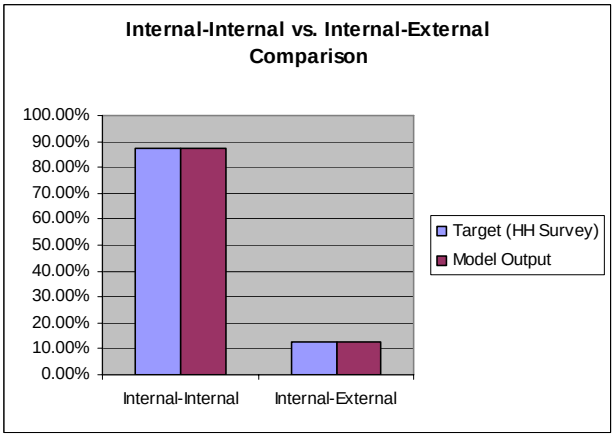
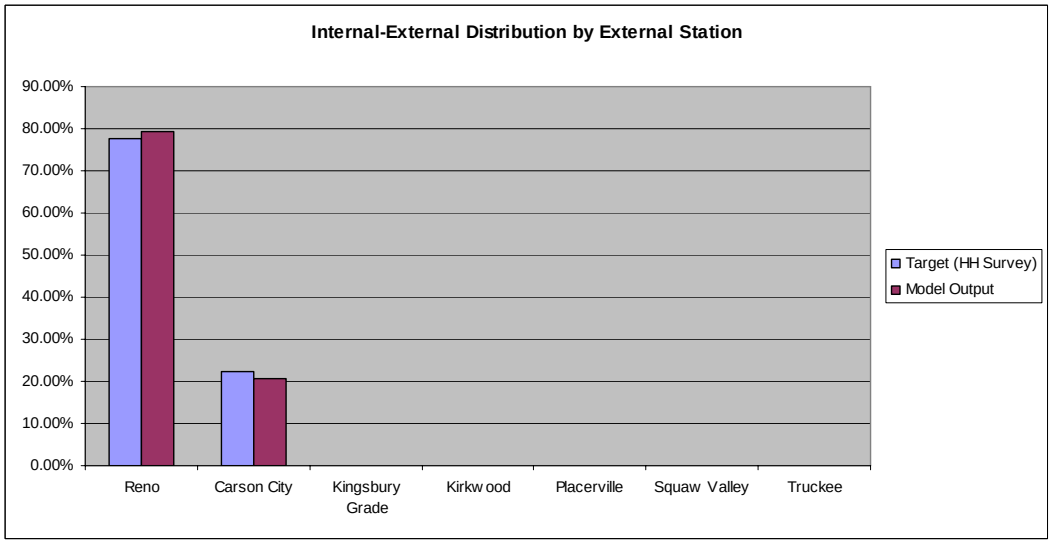


Figure 6.11: External station distribution for adult school tours



6.4 Demand Constraints and Shadow Pricing

In the mandatory work destination choice model, the size term (attractiveness measure) of a zone is based on the employment in that zone. However, the destination choice model places no constraints on how many people choose a given zone for their work destination. Thus, it is possible that more people choose the zone as their work destination then there are employment spots. This overfilling of employment is unrealistic and, especially since the target employment distribution among zones is known, should be addressed.

The solution for the overfilling of zonal employment in the model is to use shadow pricing. In this scheme, the mandatory work destination choice model is run several times. If the number of work tours choosing a zone as the destination exceeds the employment in that zone, then a negative penalty ("shadow price") is added to the utility of that zone. Conversely, if a zone's employment is under-filled, a positive shadow price is added to the utility. After a number of iterations, the result is that the work destination choice distribution among zones more closely matches that of the actual employment distribution.

The actual shadow price is calculated using the following formula:

$$P_{z,i} = P_{z,i-1}\left(\min\left\{\frac{E_z+1}{D_z+1}, \exp\left(\tfrac{1}{4}\right)\right\}\right)$$

where

z is a zone
i is the shadow price iteration
$P_{z,i}$ is the price in zone z at iteration i
E_z is the employment in zone z
D_z is the number of mandatory work tours that chose zone z as a destination

The shadow price in zone z at iteration i is calculated as $\ln\left(P_{z,i}\right)$. If a zone's employment is over-filled, the shadow price will tend towards the negative, and if the employment is under-filled, the shadow price will tend to be positive. The reason the "min" construct is used in the price formula is that for zones with very low employment (<10) the shadow price can swing wildly for small changes in D_z; the effect of the minimum calculation is to dampen these swings.

For the first iteration, $P_{z,i}$ can be initialized to 1. Instead, the model uses a $P_{z,i}$ determined during calibration that essentially was the last price calculated before shadow price iterations stopped. Thus, at least for the base scenario, no shadow price iterations are needed when running the mandatory work destination choice model. Furthermore, as long as relative employment among zones remains close to that in the base scenario, the necessity of doing shadow price iterations in other scenarios is diminished.

The determination of when the shadow price iterations should stop uses a two-tiered measure. The first is that

$$\frac{D_z - E_z}{E_z} < \varepsilon,\ E_z\varepsilon \geq 1,$$

$$\frac{D_z - E_z - 1}{E_z} < 2\varepsilon,\ E_z\varepsilon < 1$$

where ε is a small constant. These formulas ensure that the employment is not over-filled beyond a small, allowable percentage. The second formula is a special case for zones with small employment; it allows a slightly greater overfilling of the zonal employment.

The second measure for determining if shadow price iterations can stop is based on the number of zones with over-filled employment. As noted above, the first measure allows employment to be over-filled slightly. The second measure puts a constraint on the number of these over-filled zones:

$$\frac{1}{Z}\sum_z O_z < \varepsilon$$

where

$$O_z = \begin{cases} 1 \text{ if } z \text{ is overfilled} \\ 0 \text{ otherwise} \end{cases}$$

Z is the total number of zones

6.5 Time-of-Day Sub-model

The time-of-day sub-model is a multinomial logit model in which start/stop hour pairs make up the alternatives. The earliest allowed start/stop time is 5:00 am (corresponding to the 5:00-6:00 hour), and the latest allowed is midnight (corresponding to the 12:00am-1:00am hour). As far as skim periods are concerned, the following definitions are used:

Table 6.10: Skim period definitions

Skim Period	Start Time	End Time	Duration
AM Peak (AM)	7:00 AM	10:00 AM	3 hours
Midday (MD)	10:00 AM	4:00 PM	6 hours
PM Peak (PM)	4:00 PM	7:00 PM	3 hours
Late Night (LN)	7:00 PM	7:00 AM	12 hours

The time-of-day choice model estimation results are presented in the following tables.

Table 6.11: Time-of-day estimation results for mandatory work tours

Variable	Coefficient
Early start at 5	-1.1509
Early start at 6	-0.6509
AM peak start at 7	-0.0175
AM peak start at 8	0.0000
AM peak start at 9	-0.7635
Midday start at 10/11/12	-1.3180
Midday start at 13/14/15	-1.6780
PM peak start at 16/17/18	-1.8470
Evening start at 19/20/21	-1.5850
Late start at 22/23	-0.1774

Variable	Coefficient
Early end at 5/6	-1.2360
AM peak end	-1.5960
Midday end at 10/11/12	-1.3760
Midday end at 13/14/15	-0.8211
PM peak end at 17	0.2900
PM peak end at 18	0.1559
Evening end at 19/20/21	-2.0000
Late end at 22/23	-2.3000
Duration of 0 hours	-1.6329
Duration of 1 hour	-0.6329
Duration of 2 hours	-0.6329
Duration of 3 to 4 hours	0.1479
Duration of 5 to 6 hours	0.0888
Duration of 7 or 8 hours	0.2339
Duration of 9 hours	-0.1351
Duration of 11 hours	-0.2694
Duration of 12 to 13 hours	-1.1200
Duration of 14 to 18 hours	-2.0390
Start time multiplied times tour travel time (by auto)	-0.0006
Duration multiplied times tour travel time (by auto)	0.0016
Mode choice logsum - Pre-AM start, MD/PM end	0.2372
Mode choice logsum for LN end	0.2372
Mode choice logsum for AM/MD/PM start, AM/MD/PM end	0.4744
Start time - Part-time worker	0.0520
Duration - Part-time worker	-0.0101
Start time - Non-worker	0.0298
Duration – Non-worker	-0.1513
Start time - Driving child	0.1844
Duration - Driving child	0.1214
Start time - Pre-driving child	-0.0817
Duration - Pre-driving child	-0.2518
Start time - Medium income	-0.0082
Duration - Medium income	0.0292
Start time - High income	-0.0205
Duration - High income	0.0729
Start time - Urban destination	0.0694
Duration - Urban destination	0.1330
Start time - First tour of Work-Work pattern for adult	-0.3364
Duration - First tour of Work-Work pattern for adult	-0.2894
Start time - Second tour of Work-Work pattern for adult	-0.0923
Duration - Second tour of Work-Work pattern for adult	-0.0818
Start time - Work tour of Work-School pattern for child	-0.0632
Duration - Work tour of Work-School pattern for child	0.3052
Start at 5/6 - High income	-0.7047
End at 22/23 - High income	-0.6194

Variable	Coefficient
Start at 5/6 - Urban destination	-0.2515
End at 22/23 - Urban destination	-0.8595
Start at 5/6 - Rural destination	0.3077
End at 5/6 - Rural destination	-0.1501
Duration 0-8 - Full time worker	-1.4310
Start at 10/11/12 - Full time worker	-0.7841
End at 13/14/15 - Part time worker	0.6131
Duration < 8 - First tour of Work-Work pattern for adult	1.8670
Duration < 8 - Second tour of Work-Work pattern for adult	2.0550
Duration < 8- Work tour of Work-School pattern for child	1.7810
Start at 8 - Part time worker	0.4000
Duration < 5 - Full time worker	-0.3500
Start at 9 - Child	2.1000
End > 15 – Non-worker	-0.2300
End 22/23 - Child	-0.9900
Start > 21 - Child	-1.4000

Table 6.12: Time-of-day estimation results for mandatory school tours

Variable	Coefficient
Early start at 5/6	-5.1260
AM peak start at 7	-0.8758
AM peak start at 9	-0.1030
Midday start at 10/11/12	-1.9860
Midday start at 13/14/15	-0.9985
PM peak start at 16/17/18	-0.4682
Evening start at 19/20/21	Alternative Unavailable
Late start at 22/23	Alternative Unavailable
Early end at 5/6	Alternative Unavailable
AM peak end	Alternative Unavailable
Midday end at 10/11/12	1.3780
Midday end at 13/14/15	1.7350
PM peak end at 17	-0.5839
PM peak end at 18	-1.1560
Evening end at 19/20/21	-3.2470
Late end at 22/23	-4.6300
Duration of 0 to 2 hours	-4.8690
Duration of 3 to 4 hours	-3.0750
Duration of 5 to 6 hours	-2.8550
Duration of 7 hours	-0.4155
Duration of 9 hours	-0.2334
Duration of 10 hours	0.4098
Duration of 11 hours	0.4098
Duration of 12 to 13 hours	0.5036
Duration of 14 to 18 hours	0.8472

Variable	Coefficient
Start time multiplied times tour travel time (by auto)	-0.0040
Duration multiplied times tour travel time (by auto)	0.0045
Start time - Driving child	-0.5271
Duration - Driving child	0.0503
Start time - All adults are full-time workers	-0.0953
Duration - All adults are full-time workers	0.1338
Start time - Medium income	0.0699
Duration - Medium income	0.0515
Start time - High income	0.1748
Duration - High income	0.1289
Start time - First tour of School-School pattern	-0.4075
Duration - First tour of School-School pattern	-0.5517
Start time - Second tour of School-School pattern	-0.6021
Duration - Second tour of School-School pattern	-0.1084
Start time - School tour of Work-School pattern for child	-0.5424
Duration - School tour of Work-School pattern for child	-0.3600
Start at 5/6 - High income	-0.7059
End at 22/23 - High income	-0.8919
Duration 0-6 - Driving child	1.0530
End at 16 - Pre-driving child	1.4350
Duration of 7 - adults	-0.7000
Duration of 8 - adults	0.1000
Duration of 9 - adults	0.8800

6.6 Time-of-Day Choice Sub-model Calibration

To calibrate the time-of-day choice sub-model, three primary aspects were examined:

- Start time
- End time
- Duration

To perform the calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Figure 6.12a: Time of day departure time comparison for full-time mandatory work tours (Coincidence ratio: 0.74)

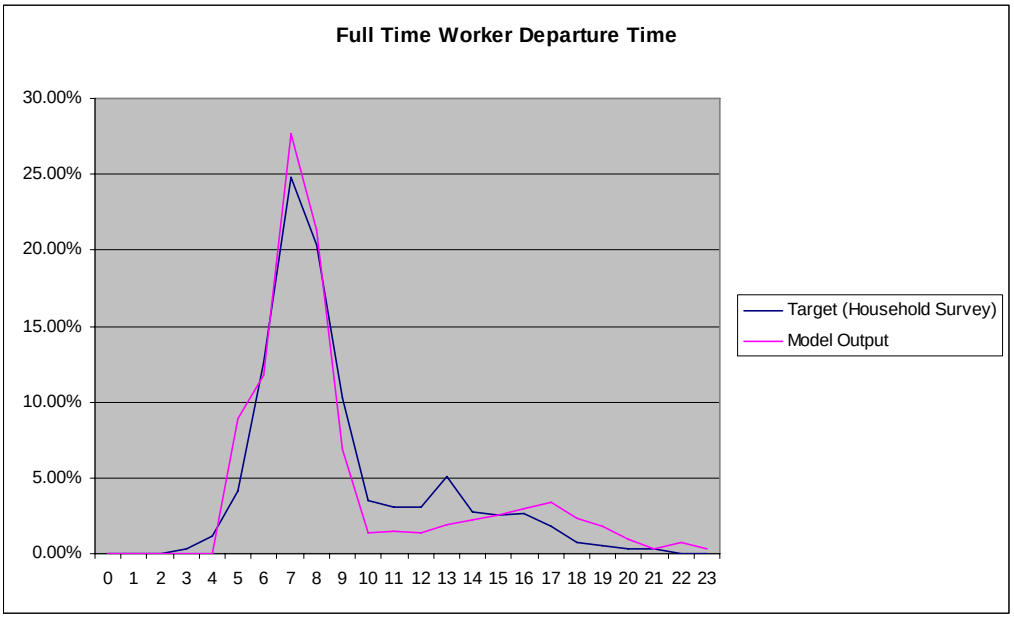


Figure 6.12b: Time of day arrival time comparison for full-time mandatory work tours (Coincidence ratio: 0.67)

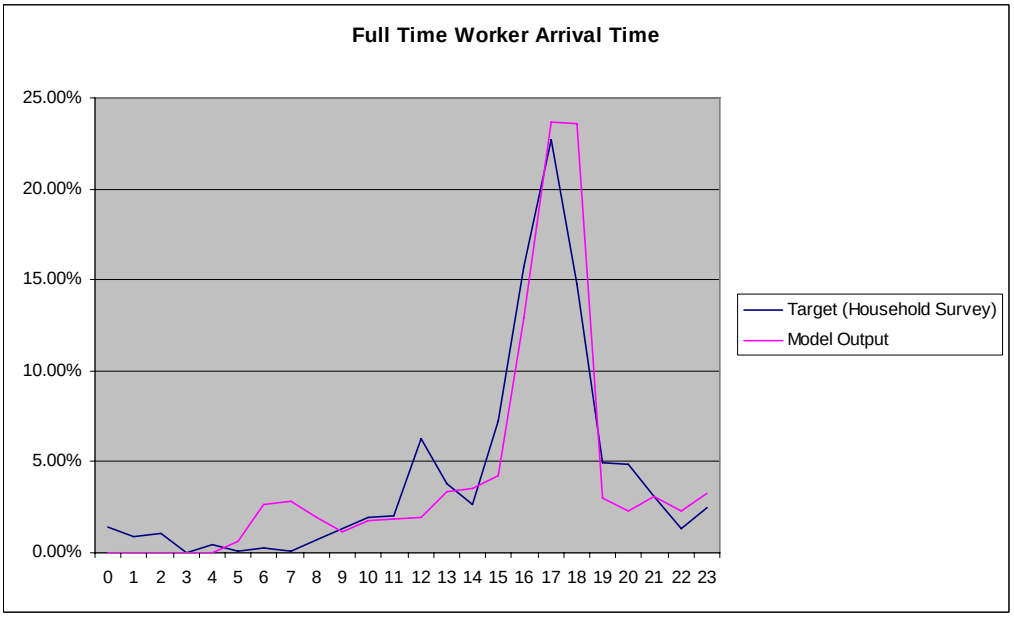


Figure 6.12c: Time of day duration comparison for full-time mandatory work tours (Coincidence ratio: 0.72)

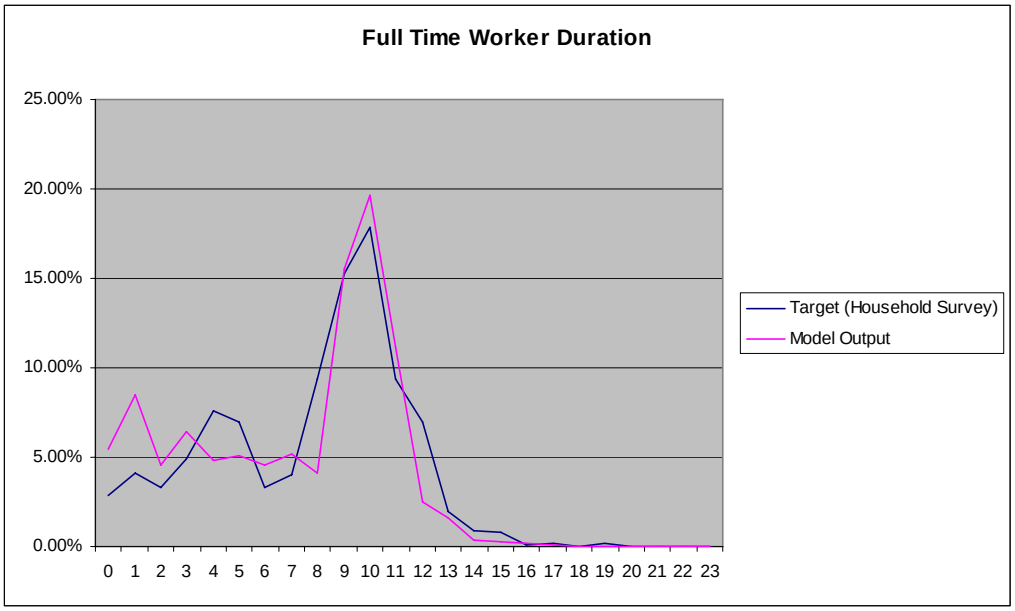


Figure 6.13a: Time of day departure time comparison for part-time mandatory work tours (Coincidence ratio: 0.71)

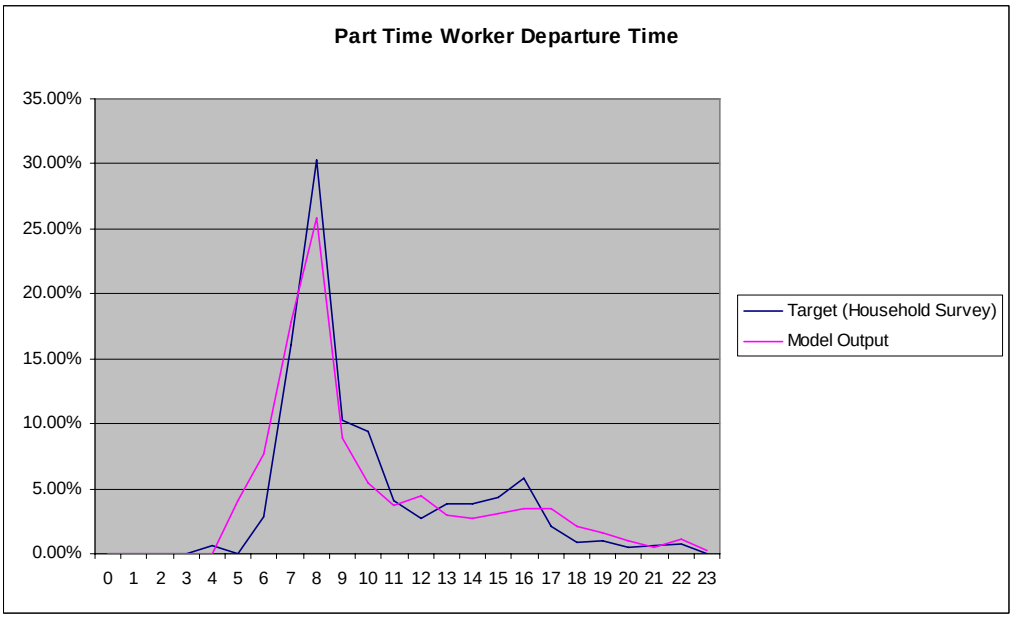


Figure 6.13b: Time of day arrival time comparison for part-time mandatory work tours (Coincidence ratio: 0.65)

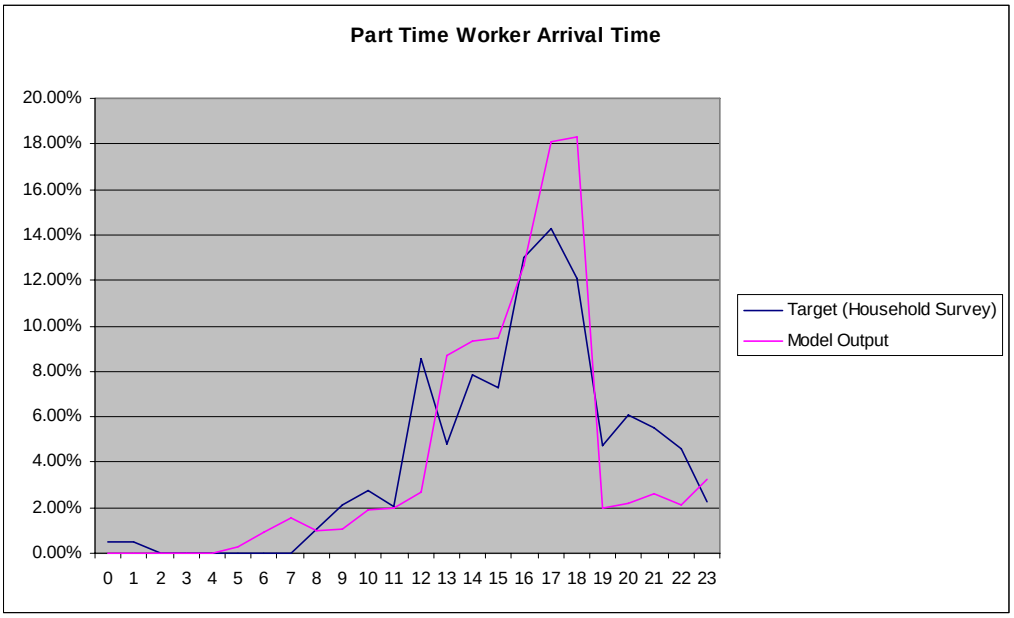


Figure 6.13c: Time of day duration comparison for part-time mandatory work tours (Coincidence ratio: 0.74)

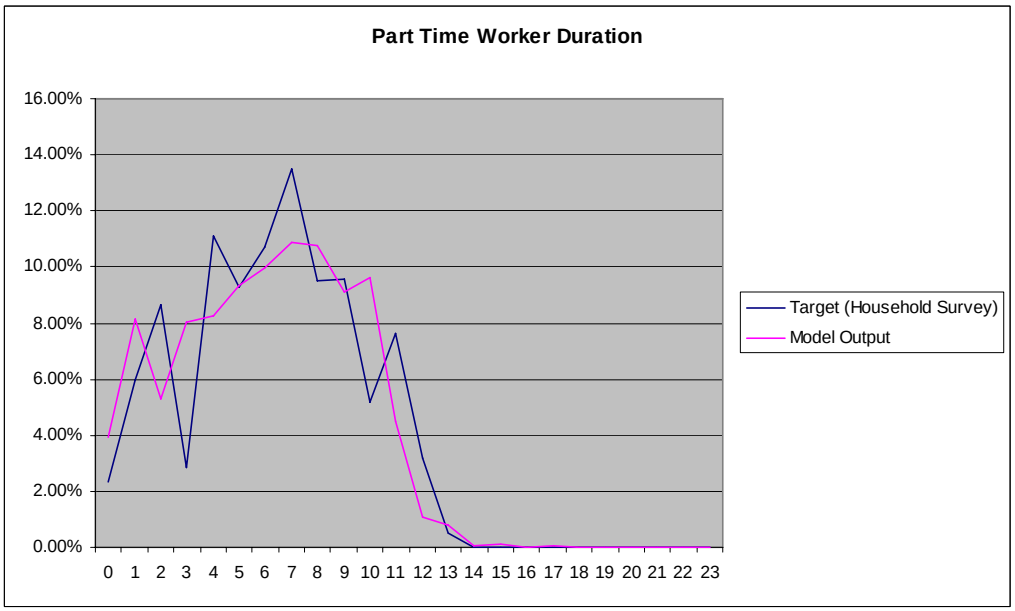


Figure 6.14a: Time of day departure time comparison for non-worker mandatory work tours (Coincidence ratio: 0.61)

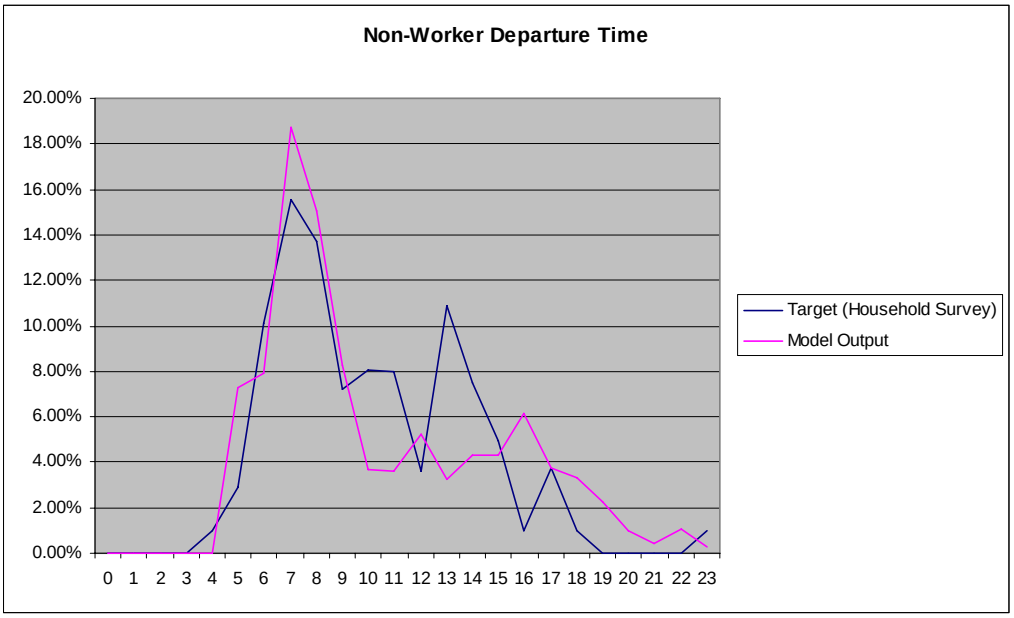


Figure 6.14b: Time of day arrival time comparison for non-worker mandatory work tours (Coincidence ratio: 0.66)

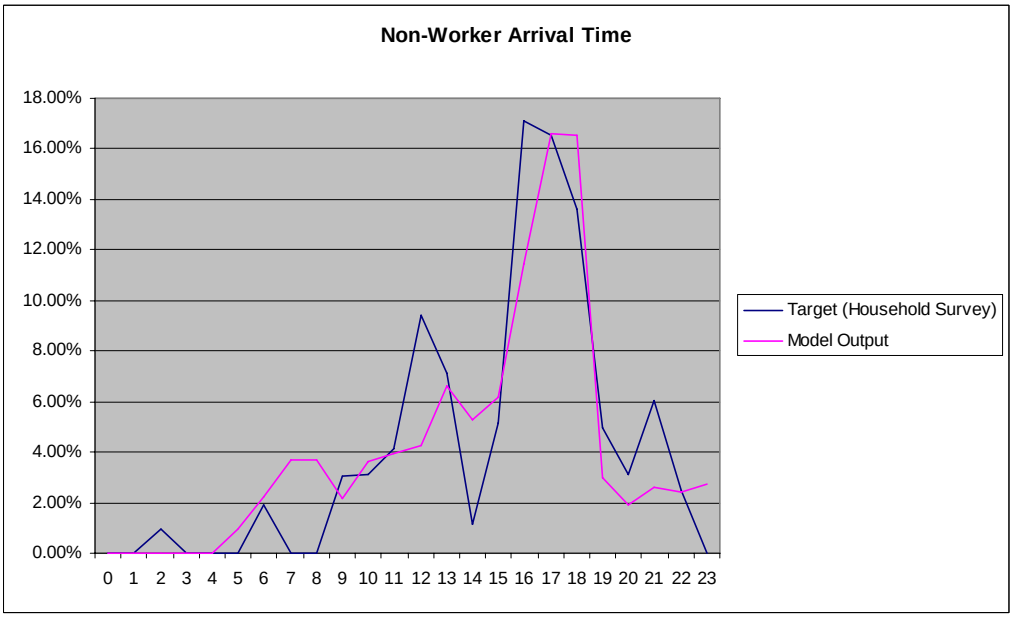


Figure 6.14c: Time of day duration comparison for non-worker mandatory work tours (Coincidence ratio: 0.60)

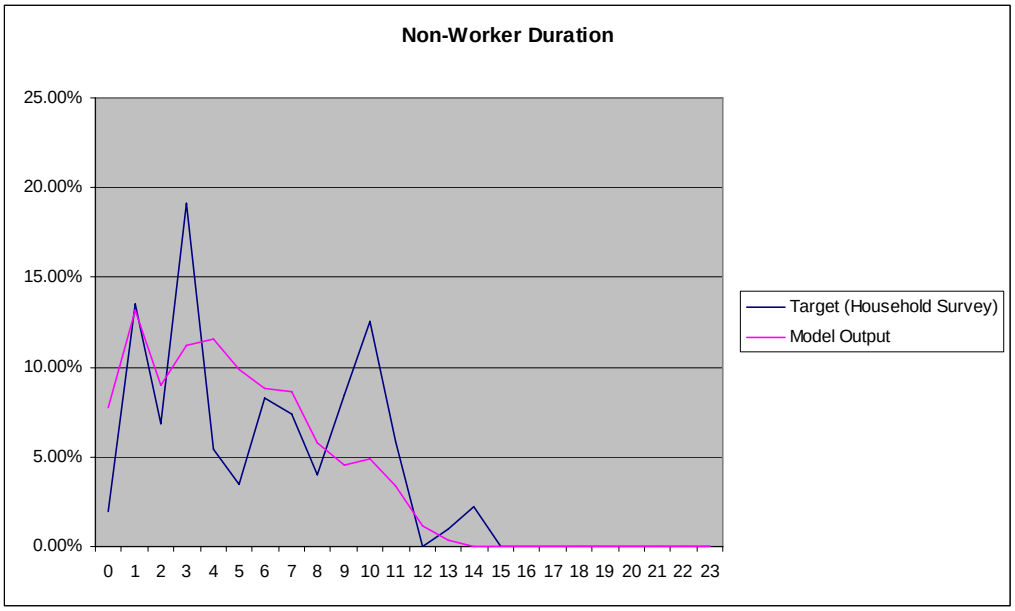


Figure 6.15a: Time of day departure time comparison for child mandatory work tours (Coincidence ratio: 0.31)

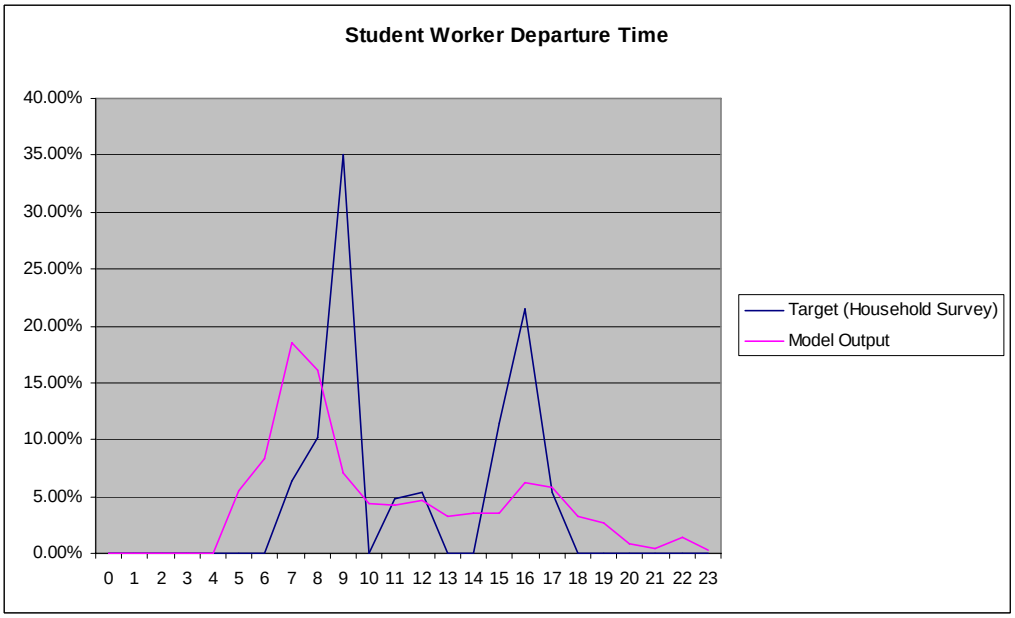


Figure 6.15b: Time of day arrival time comparison for child mandatory work tours (Coincidence ratio: 0.36)

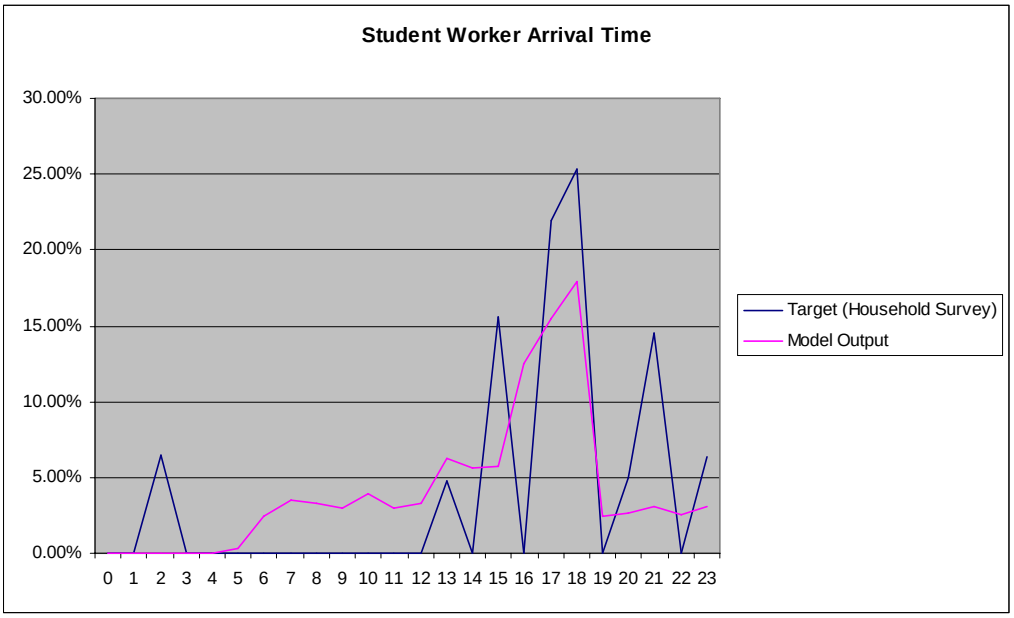


Figure 6.15c: Time of day duration comparison for child mandatory work tours (Coincidence ratio: 0.30)

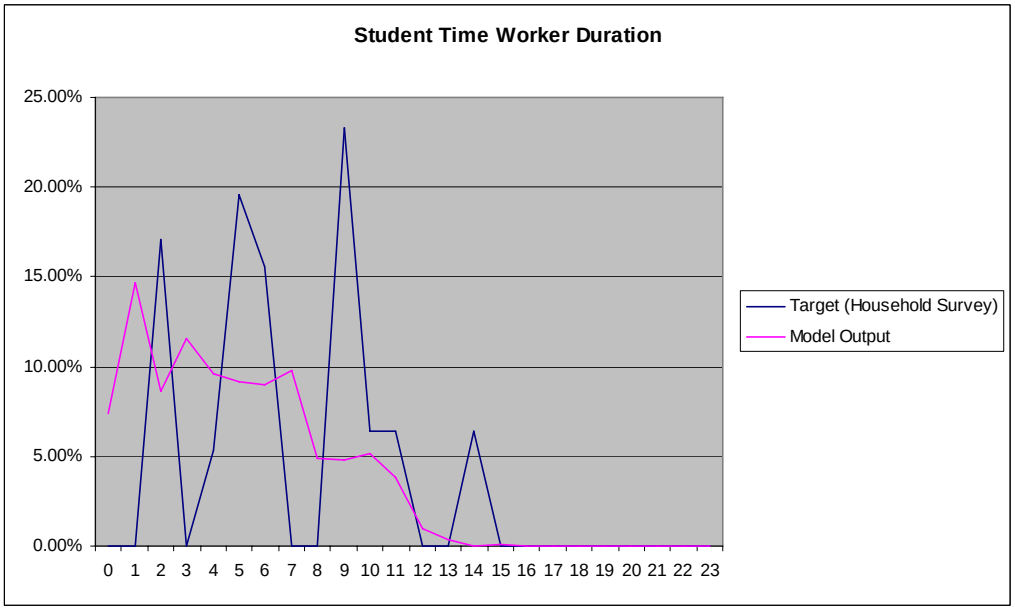


Figure 6.16a: Time of day departure time comparison for child mandatory school tours (Coincidence ratio: 0.81)

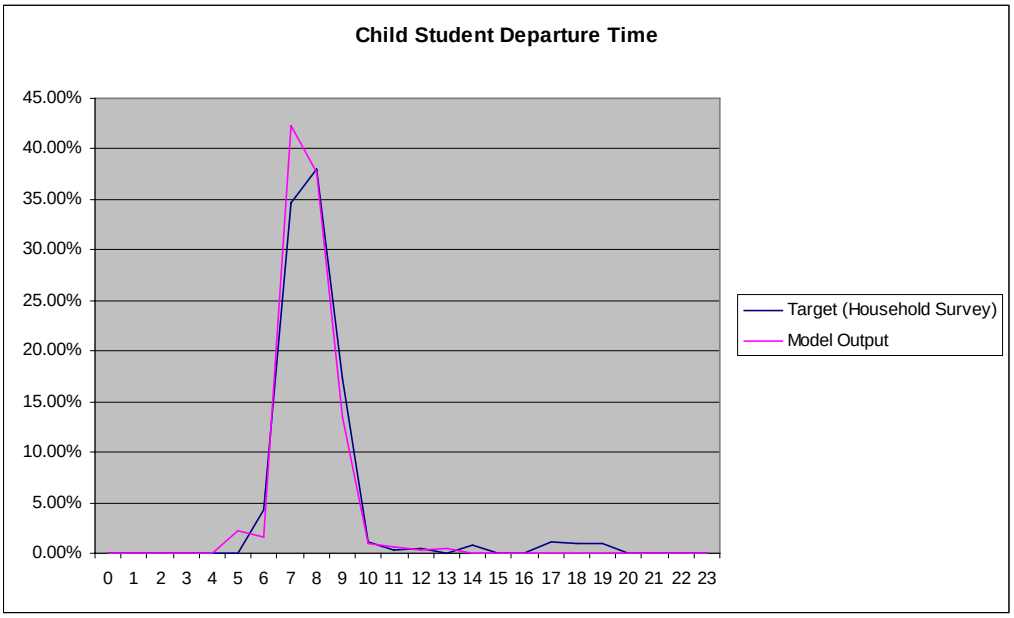


Figure 6.16b: Time of day arrival time comparison for child mandatory school tours (Coincidence ratio: 0.77)

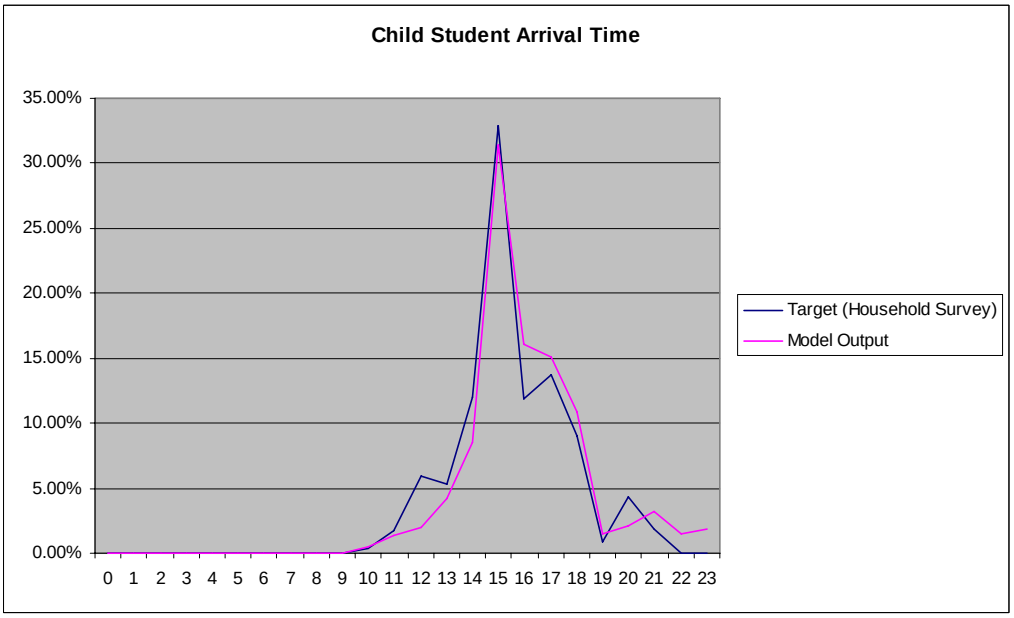


Figure 6.16c: Time of day duration comparison for child mandatory school tours (Coincidence ratio: 0.59)

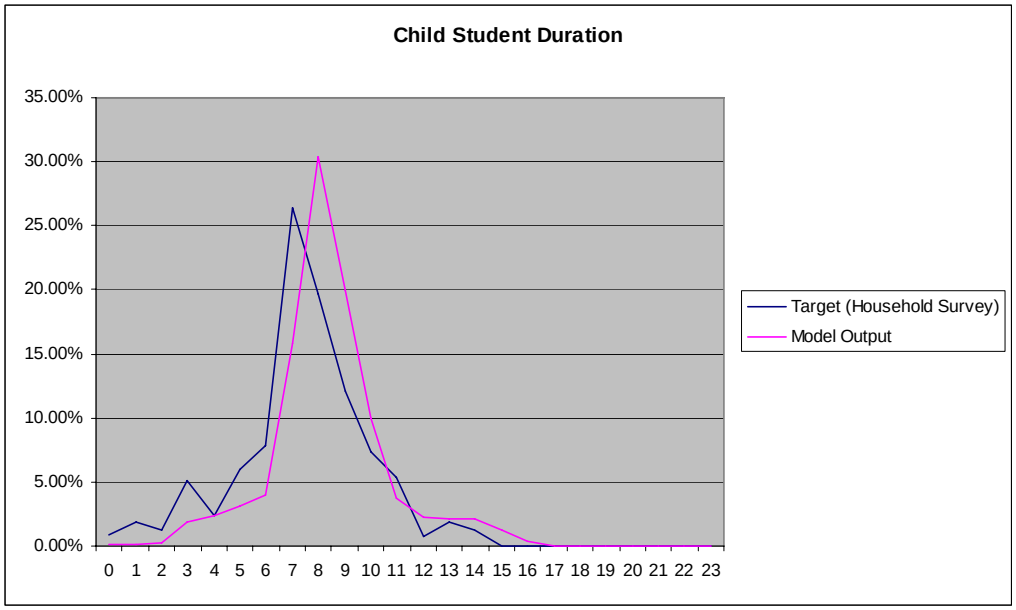


Figure 6.17a: Time of day departure time comparison for adult mandatory school tours (Coincidence ratio: 0.83)

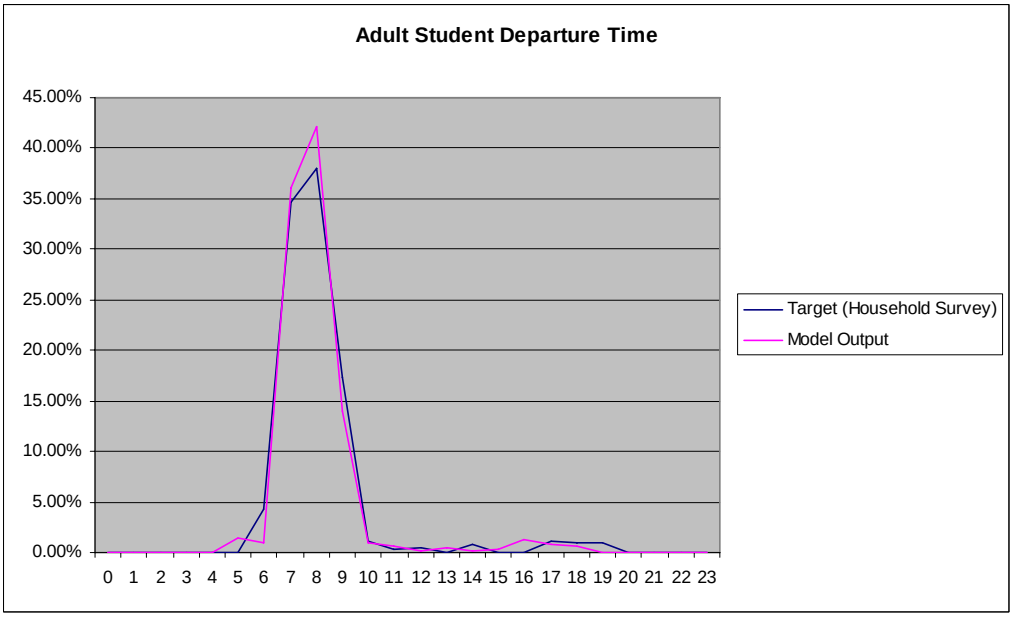


Figure 6.17b: Time of day arrival time comparison for adult mandatory school tours (Coincidence ratio: 0.75)

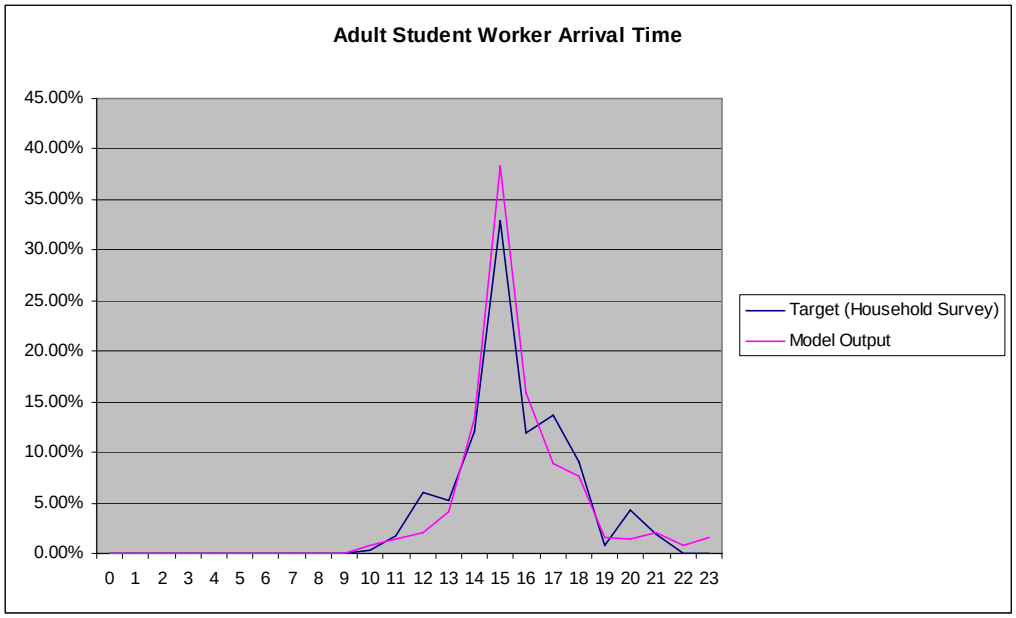
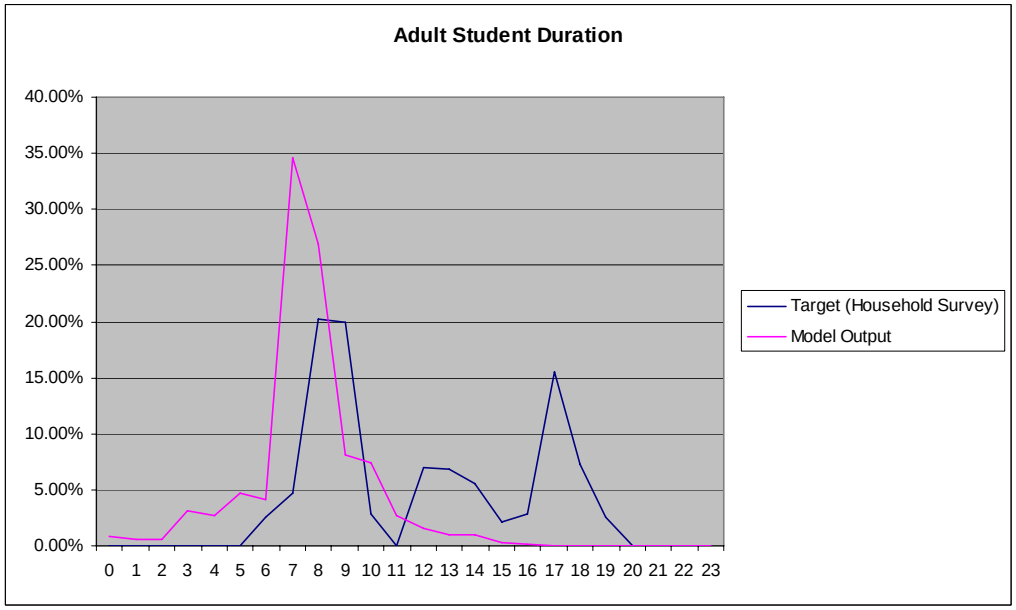


Figure 6.17c: Time of day duration comparison for adult mandatory school tours (Coincidence ratio: 0.27)



6.7 Mode Choice Sub-model

The mode choice model is a multinomial logit model in which each mode is an alternative. For the mandatory tours, the following alternatives are available:

- Drive alone
- Shared auto
- Walk to transit
- Drive to transit
- Non-motorized
- School bus (school trips made by a child only)

The primary component of the model is travel time, which uses the same coefficient across all modes. For the modes that have costs associated with them (transit has fares, auto modes have operating costs), a value of time factor was estimated; this factor can transfer dollar costs into time, for which a utility can be calculated using the travel time coefficient.

The mode choice model estimation results are presented in the following tables.

Table 6.13: Mode choice estimation results for mandatory work tours

Variable	Drive Alone	Shared Auto	Walk to Transit	Drive to Transit	Non Motorized
Low Income	1.3000	-1.8000	1.6000	-1.5000	3.5600
Medium Income	1.5700	-0.0900		-1.5000	2.8500
High Income	1.9000	-0.3000	-1.5000	-1.5000	2.8000
Time (minutes)	-0.0213				
Value of Time ($/hour) – Worker	8.0300				
Value of Time ($/hour) – Non-worker/Child	4.0150				
At least one auto in household		-1.4160		-0.7176	0.6831
No autos in household	Not Available		2.3480		2.3090
Pre-Driving Child	Not Available				
Urban origin			0.5720	0.5720	
Urban destination			0.7718	0.7718	0.8453
Start in AM Peak				0.8498	
End in PM Peak			0.6257		
Natural Log of tour distance		-0.3148			

Table 6.14: Mode choice estimation results for mandatory school tours

Variable	Drive Alone	Shared Auto	Walk to Transit	Drive to Transit	Non Motorized	School Bus
Child	1.3350	0.7000	-1.5000	-533.4667	1.4600	0.0900
Adult	1.8000	-0.8500	-5.4505	-533.4667	1.1500	Not Available
Time (minutes)	-0.0092					
Value of Time ($/hour) – Worker	2.2400					
Value of Time ($/hour) – Non-worker/Child	1.1200					
Driving Child						-1.2517
Low Income	-0.3831		1.0639		0.1769	
High Income					-0.6848	
Drivers Minus Autos in Household (if positive)	-1.9801		2.2255			0.8314
No autos in household	Not Available		3.6531		2.5646	1.0943
Pre-Driving Child	Not Available					
Home and school in same zone					0.5370	0.1146
Natural Log of tourdistance		-0.3867				0.3816

6.8 Mode Choice Sub-model Calibration

To calibrate the mode choice sub-model, the mode choice shares were examined. To perform this analysis, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Figure 6.18: Mode choice share comparisons for high income mandatory work tours

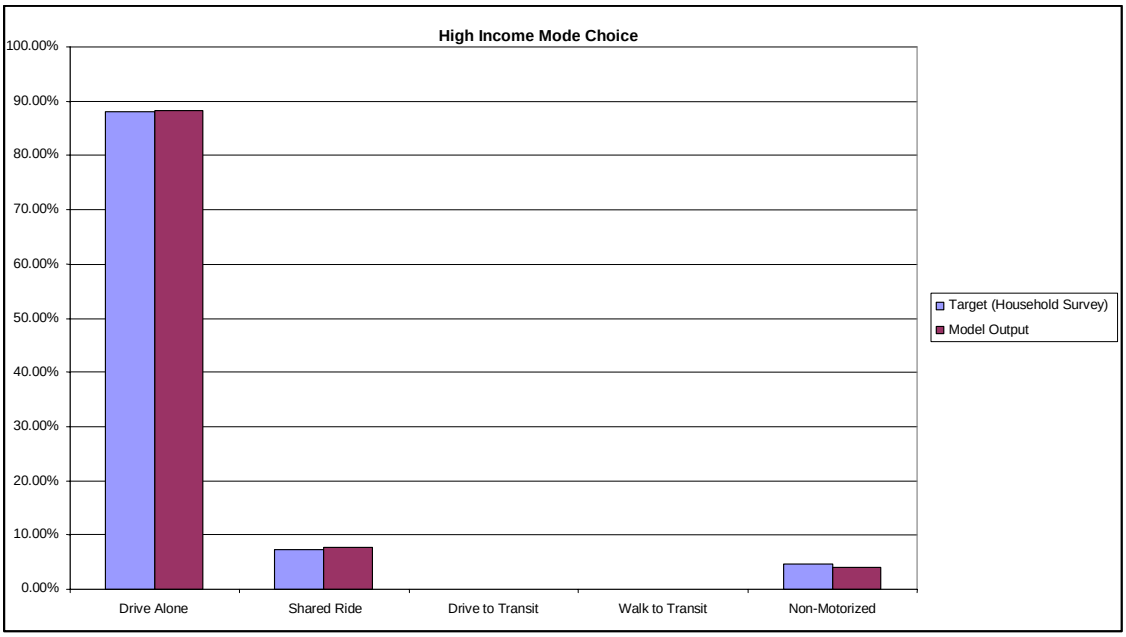


Figure 6.19: Mode choice share comparisons for medium income mandatory work tours.

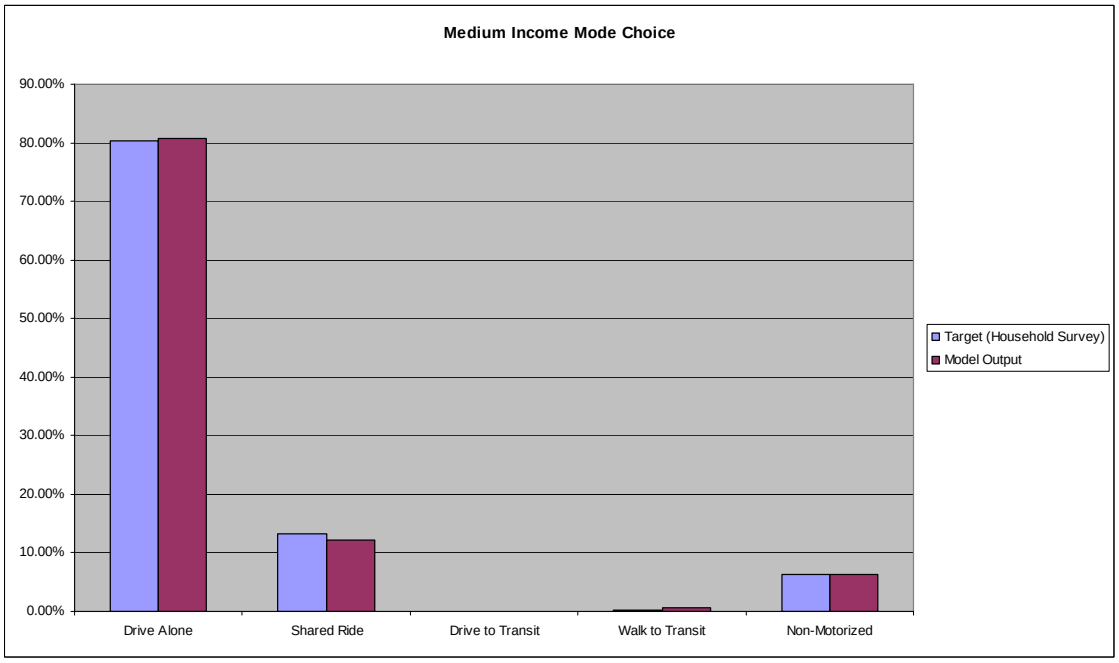


Figure 6.20: Mode choice share comparisons for low income mandatory work tours

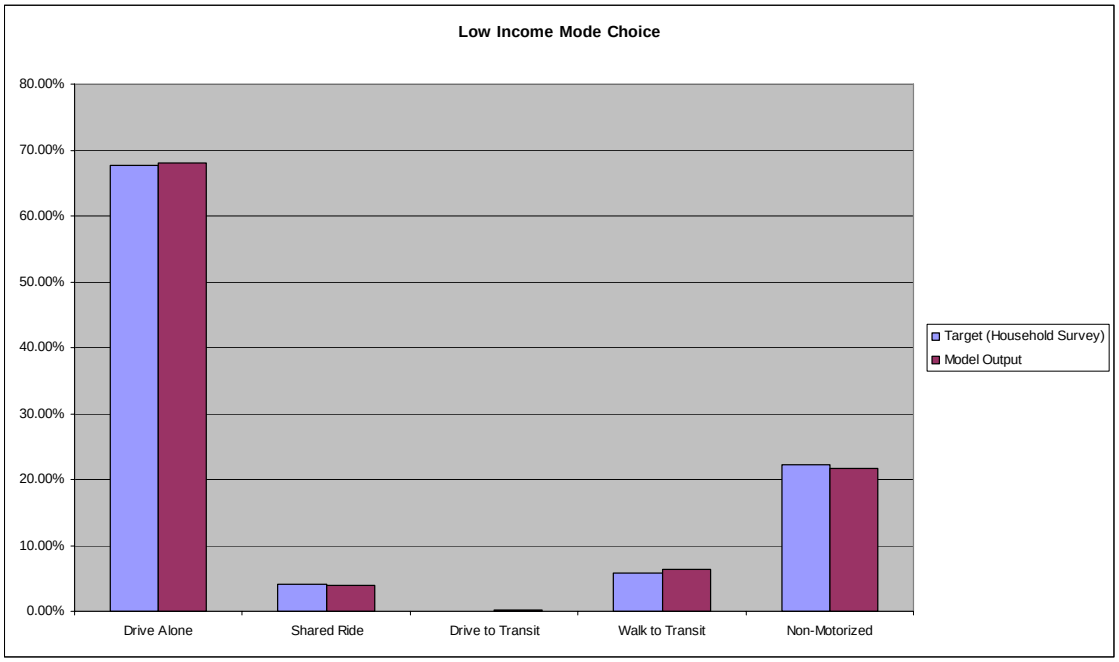


Figure 6.21: Mode choice share comparisons for child mandatory school tours

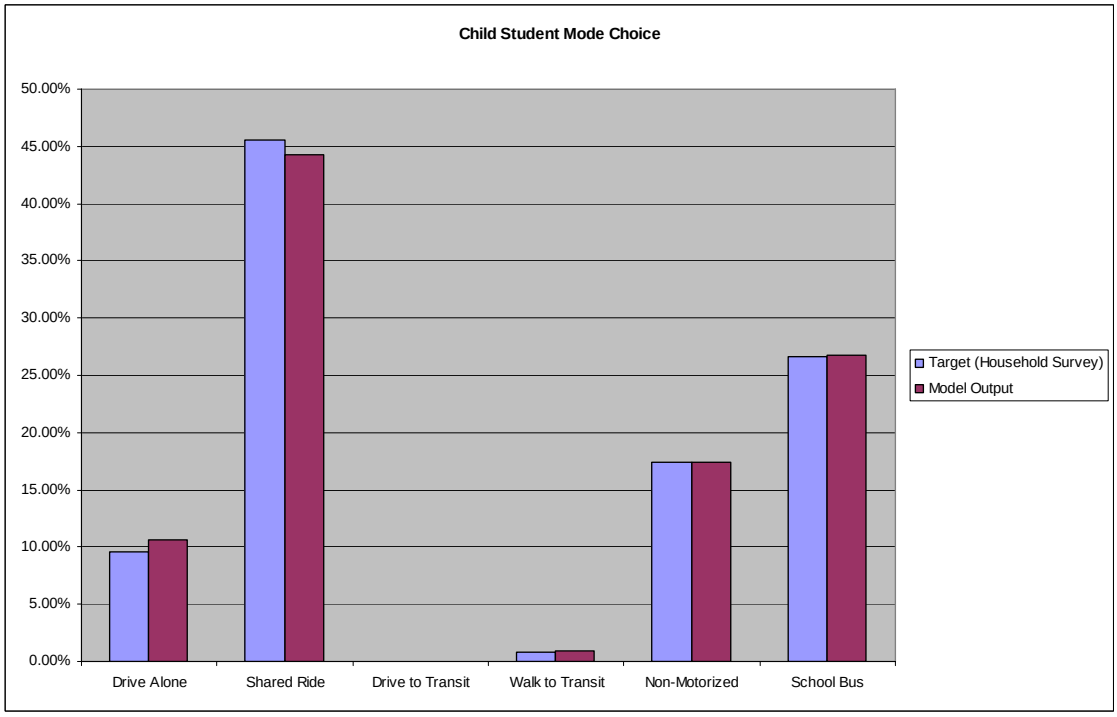
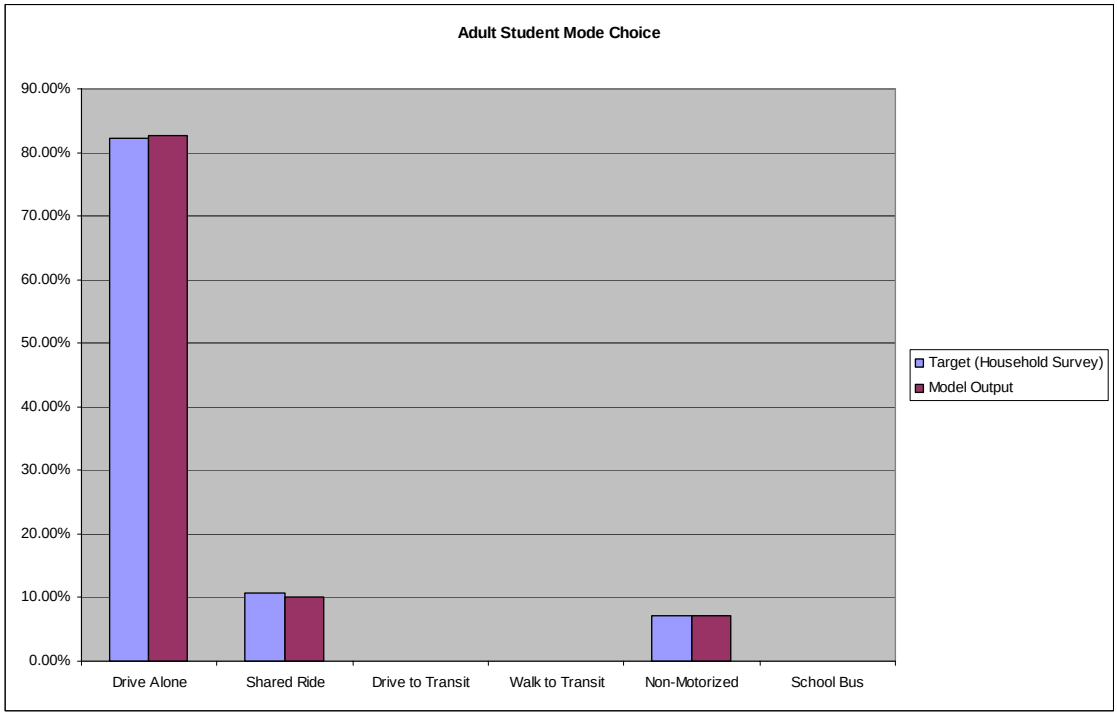


Figure 6.22: Mode choice share comparisons for adult mandatory school tours



CHAPTER 7
Joint Model Tour

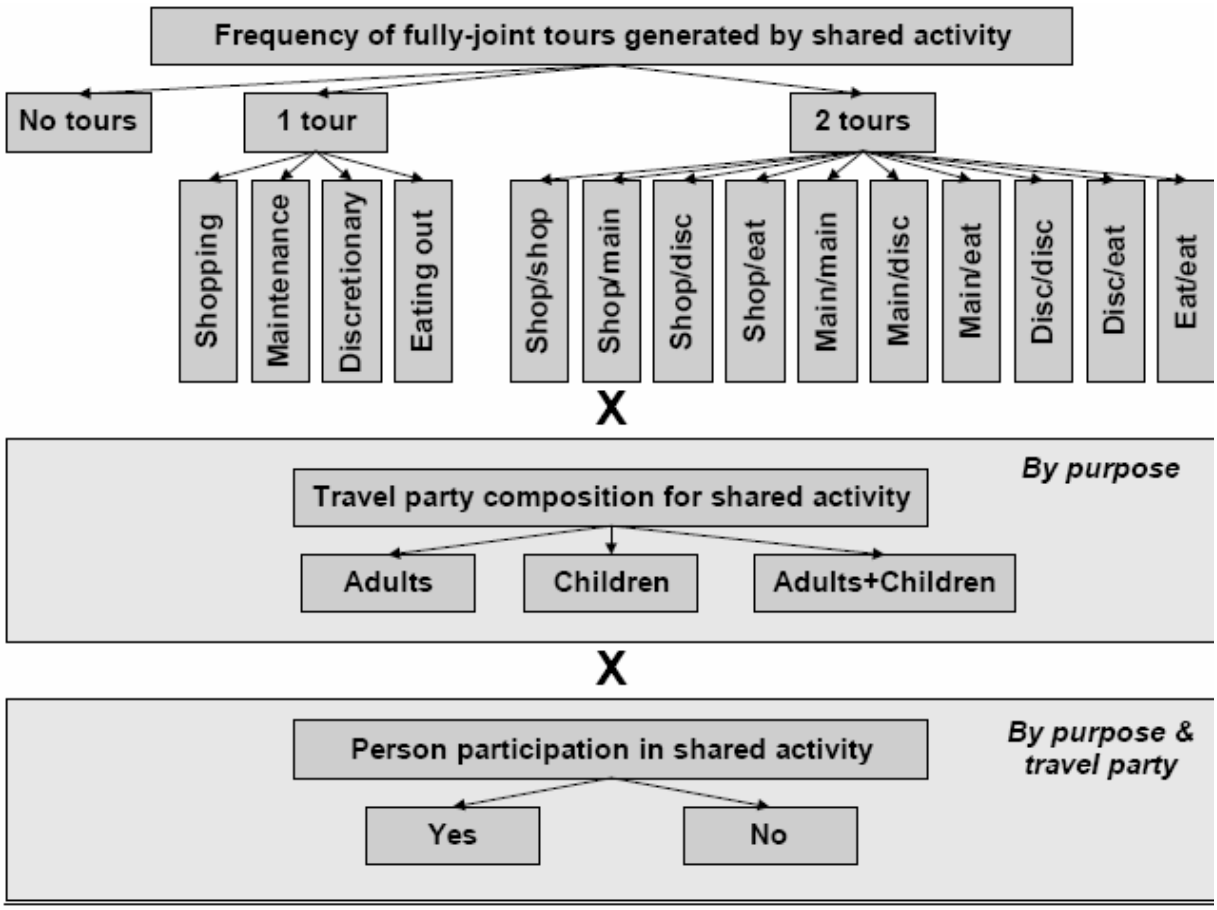
CHAPTER 7 – JOINT TOUR MODEL

7.1 Joint Travel Generation Model

The joint travel types modeled explicitly in the current system are limited to fully joint tours generated by shared non-mandatory activity of several household members. One of the difficulties in modeling joint travel is that it is necessary not only to predict a number of joint tours, but also link them to the appropriate household members and ensure generation and scheduling consistency between the joint and individual tours of each household member. It is implemented by means of a sequence of 3 choice sub-models **(see Figure 7.1)**:

- **Frequency choice**: returns a number of joint tours generated by a household,
- **Travel party composition**: person categories participating in each tour (adults, children, mixed),
- **Person participation** in each tour for each of the household members (yes or no).

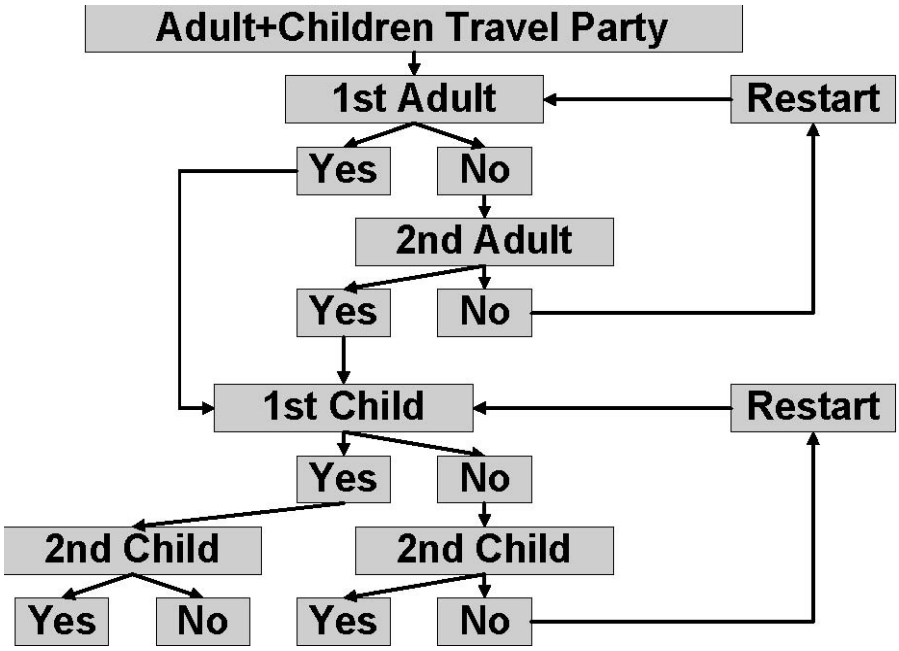
Figure 7.1: Sequence of Choice Sub-models



Generation of joint travel is basically an entire-household function, thus the tour-frequency model comes first and is applied at the household level. In order to link joint travel to the persons in the household, two additional models – travel party composition and person participation – are then applied. It has been found effective to decompose person assignment for joint travel into these two models, because the formulation of a single model that distributes household members by joint tours proved to be too complicated. A travel party composition model allows for narrowing down a subset of household members relevant for each joint travel category, thus making the subsequent person participation model operational.

Participation choice is modeled for each person sequentially. In this approach, only a binary choice model is estimated for each activity, party composition and person type. Quantitatively different alternatives by party size are not distinguished explicitly. A sequence of binary choices is applied for all relevant household members assuming a single possible participation for each person. This approach makes travel party size automatically linked to the household size and composition. For example, if more children are in the household, then it is more likely that a bigger travel party will occur for the relevant joint travel where children are in the party composition. A failure to form a travel party in the model application can be resolved by re-starting the Monte-Carlo simulation until the suitable travel party has been formed. **Figure 7.2** is an example for a household including two adults and two children.

Figure 7.2: Sample Travel Party Decision Tree



Below is the short description of the main structural features for each of the three sub-models.

7.2 Joint Tour Frequency Model

Unit: Household

Segmentation: Full segmentation of alternative specific constants by travel purpose combinations; partial segmentation of the other coefficients by travel purpose

Choice alternatives:

- No fully joint tours
- 1 fully joint tour (available only for households with at least 2 persons not staying at home of which at least one is not a preschool child):
  - Shopping
  - Other maintenance
  - Discretionary
  - Eating out

- 2 fully joint tours (available only for households with at least 2 persons not staying at home of which at least one is not a preschool child):
  - Shopping / Shopping
  - Shopping / Other maintenance
  - Shopping / Discretionary
  - Shopping / Eating out
  - Other maintenance / Other maintenance
  - Other maintenance / Discretionary
  - Other maintenance / Eating out
  - Discretionary / Discretionary
  - Discretionary / Eating out
  - Eating out / Eating out

Main explanatory variables under consideration for utility equation:

- Household size and composition
  - Number of full-time workers
  - Number of part-time workers
  - Number of non-working adults
  - Number of preschool children
  - Number of school pre-driving-age children
  - Number of school driving-age children
  - Large household dummy (4 and more persons)
- Household income
- Car ownership/sufficiency
- Residential area type
- Logged size variable including maximum pair-wise overlaps of residual windows:
  - Adult with adult
  - Adult with child

The results of the calibrated joint tour frequency estimation are presented in **Table 7.2**. Because there are so many alternatives, their names have been abbreviated using the following codes:

Table 7.1: Abbreviations for joint tour estimation results

Tour Type	Abbreviation
Shop	S
Eat	E
Discretionary	D
Other-Maintenance	M

So **S** means one joint shopping tour, and **SE** means two joint tours – one shopping and one eating.

Table 7.2: Joint tour frequency model estimation results

Variable	No Tours	S	E	M	D
Alternative-specific constant (Household size = 2)	0.0250	-5.8430	-6.9940	-5.9010	-5.7110
Alternative-specific constant (Household size > 2)	0.6200	-5.9046	-7.1836	-5.6920	-5.2624
Household size of 4 persons or more					
Number of full-time workers		-0.0921	-0.4811	-0.5254	-0.1004
Number of part-time workers			-0.4083	-0.1475	-0.2514
Number of non-workers			-0.3773	0.1906	0.1447
Number of preschool children		0.5335	-0.2155	0.2426	0.0856
Number of pre-driving school children			-0.3636	0.0911	0.3330
Number of driving school children		0.2815	-0.7610		-0.0949
Low income		0.2839	-0.2051	-0.1856	-0.1941
Medium income		0.0534	-0.0688	0.0687	-0.1485
Number of cars equal to number of workers - dummy			2.1880	0.4372	0.2522
Number of cars greater than number of workers - dummy		0.5228	2.2110	0.4386	
Urban home		0.6143	0.7006	0.1511	0.4364
Suburban home		0.4222	0.2781	0.1439	0.4129
Size variable based on window overlaps		1.0000	1.0000	1.0000	1.0000
Variable	**SS**	**SE**	**SM**	**SD**	**EE**
Alternative-specific constant (Household size = 2)	-9.3600	-9.3400	-7.6530	-7.4580	N/A
Alternative-specific constant (Household size > 2)	-9.3465	-9.3764	-7.7412	-8.3870	N/A
Household size of 4 persons or more	0.1204	0.1204	0.1204	0.1204	0.1204
Number of full-time workers	-0.1843	-0.5732	-0.6175	-0.1925	-0.9622
Number of part-time workers		-0.4083	-0.1475	-0.2514	-0.8166
Number of non-workers		-0.3773	0.1906	0.1447	-0.7546
Number of preschool children	1.0670	0.3180	0.7761	0.6191	-0.4310
Number of pre-driving school children		-0.3636	0.0911	0.3330	-0.7272
Number of driving school children	0.5630	-0.4795	0.2815	0.1866	-1.5220
Low income	0.5678	0.0788	0.0983	0.0898	-0.4102
Medium income	0.1069	-0.0154	0.1221	-0.0951	-0.1377
Number of cars equal to number of workers - dummy		2.1880	0.4372	0.2522	4.3760
Number of cars greater than number of workers - dummy	1.0456	2.7338	0.9614	0.5228	4.4220
Urban home	1.2286	1.3149	0.7654	1.0507	1.4012
Suburban home	0.8444	0.7003	0.5661	0.8351	0.5562
Size variable based on window overlaps	1.0000	1.0000	1.0000	1.0000	1.0000
Variable	**EM**	**ED**	**MM**	**MD**	**DD**
Alternative-specific constant (Household size = 2)	-9.0550	-9.5060	-8.1900	-8.2570	-8.1010
Alternative-specific constant (Household size > 2)	-10.3098	-9.1431	-8.1781	-8.2450	-7.8893
Household size of 4 persons or more	0.1204	0.1204	0.1204	0.1204	0.1204
Number of full-time workers	-1.0065	-0.5815	-1.0508	-0.6258	-0.2008
Number of part-time workers	-0.5558	-0.6597	-0.2950	-0.3989	-0.5028
Number of non-workers	-0.1867	-0.2326	0.3812	0.3353	0.2894
Number of preschool children	0.0271	-0.1299	0.4852	0.3282	0.1712
Number of pre-driving school children	-0.2725	-0.0306	0.1822	0.4241	0.6660
Number of driving school children	-0.7610	-0.8559		-0.0949	-0.1898
Low income	-0.3907	-0.3992	-0.3712	-0.3797	-0.3882
Medium income	-0.0002	-0.2173	0.1373	-0.0798	-0.2970
Number of cars equal to number of workers - dummy	2.6252	2.4402	0.8744	0.6894	0.5044
Number of cars greater than number of workers - dummy	2.6496	2.2110	0.8772	0.4386	
Urban home	0.8517	1.1370	0.3022	0.5875	0.8728
Suburban home	0.4220	0.6910	0.2878	0.5568	0.8258
Size variable based on window overlaps	1.0000	1.0000	1.0000	1.0000	1.0000

7.3 Joint Tour Frequency Model Calibration Results

To perform model calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Figure 7.3a: Joint tour frequency comparison, household size = 2

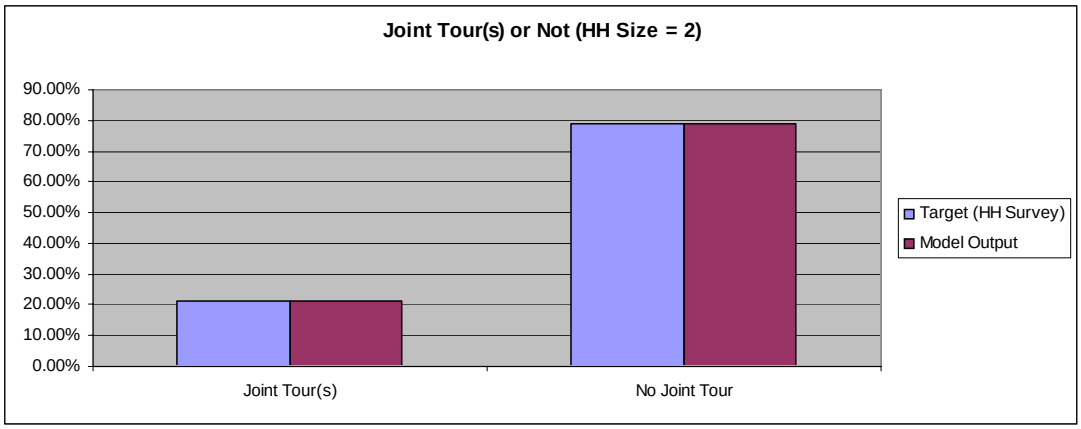


Figure 7.3b: Joint tour frequency comparison, household size = 2

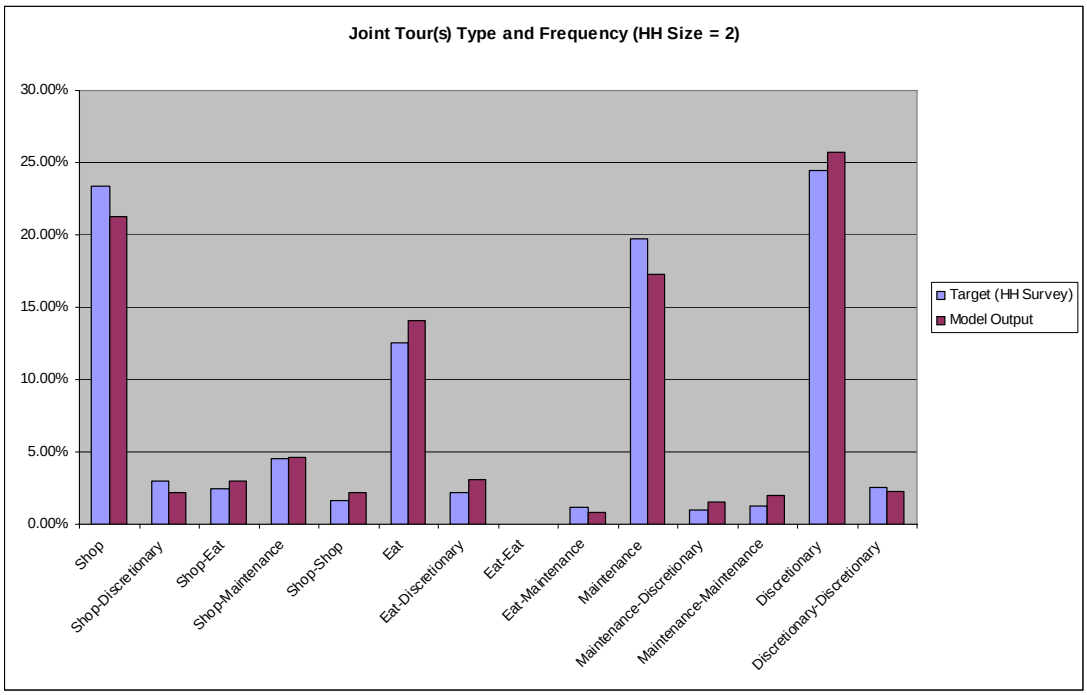


Figure 7.4a: Joint tour frequency comparison, household size > 2

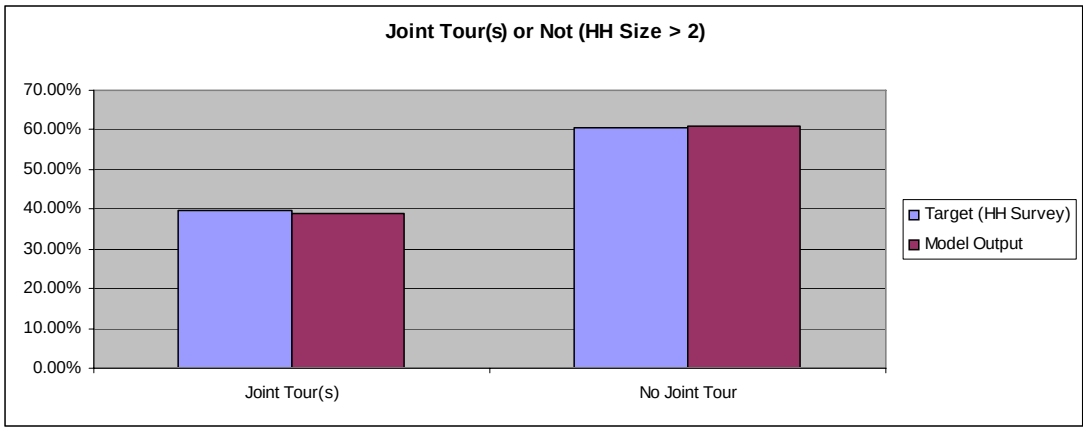
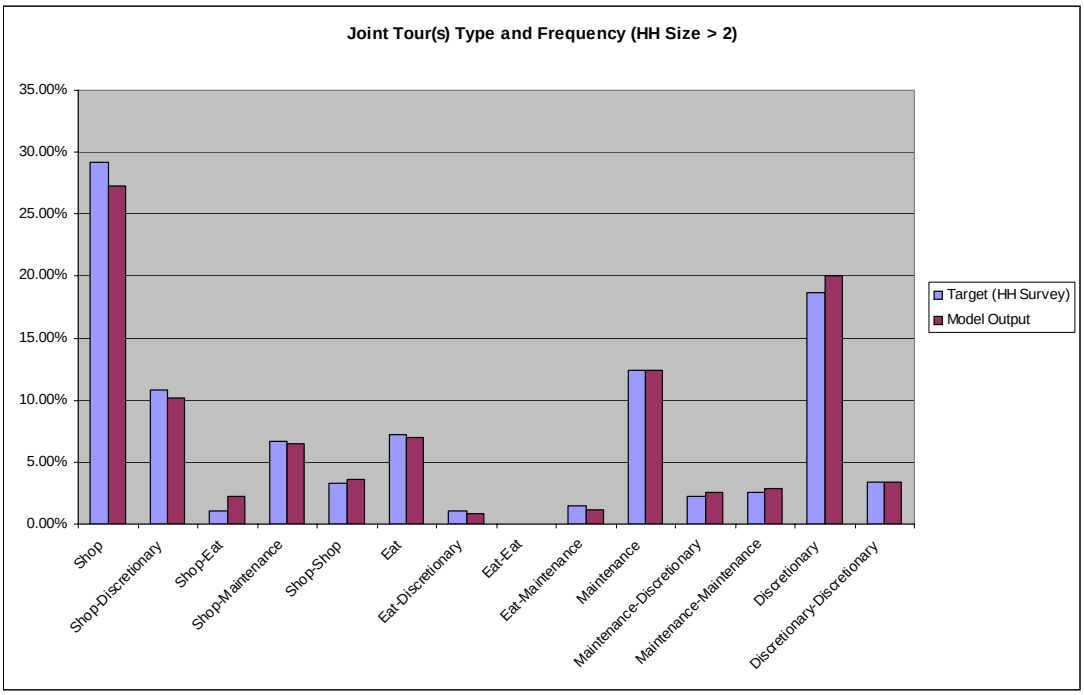


Figure 7.4b: Joint tour frequency comparison, household size > 2



7.4 Travel Party Composition Choice Model

Unit: Fully joint tour for non-mandatory purpose

Segmentation: Partial segmentation of alternative-specific constants by travel purpose

Choice alternatives (2):

- Travel party including adults only (available only for households with at least 2 adults not staying at home)
- Mixed travel party including at least one adult and at least one child (available only for households with at least 1 adult not staying at home and at least 1 child not staying at home)

Main explanatory variables:

- Household size and composition
  - Number of full-time workers
  - Number of part-time workers
  - Number of non-working adults
  - Number of preschool children
  - Number of school pre-driving-age children
  - Number of school driving-age children
- Household income
- Car ownership/sufficiency
- Residential area type
- Logged size variable including maximum pair-wise overlaps of residual windows:
  - Adult with adult (for the adult party alternative)
  - Adult with child (for the mixed party alternative)

The following table presents the results of the joint tour party composition model.

Table 7.3: Joint tour party composition model estimation results

Variable	Adults Only	Mixed
Alternative specific constant		3.5
Eating out tour		-1.92
Discretionary tour		3
Shopping tour		3
Number of full-time workers	1.024	0.3624
Number of part-time workers	0.5412	0.3164
Number of non-workers	0.6263	-0.3724
Number of preschool children		0.7906
Number of pre-driving children		0.3532
Number of driving school children		-0.9399
Low income	1.248	0.5755
Medium income	0.8369	
More autos than workers	1.386	0.751
Urban home	0.5741	
Suburban home	0.5105	0.1283
Log of max window overlaps between adults	1.192	
Log of max window overlaps between adult & child		1.958
Only one active adult in household	N/A	
No travel active adult child pair in household		N/A

7.5 Joint Tour Party Composition Model Calibration

To perform model calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Figure 7.5: Joint tour party composition comparison, household size = 2

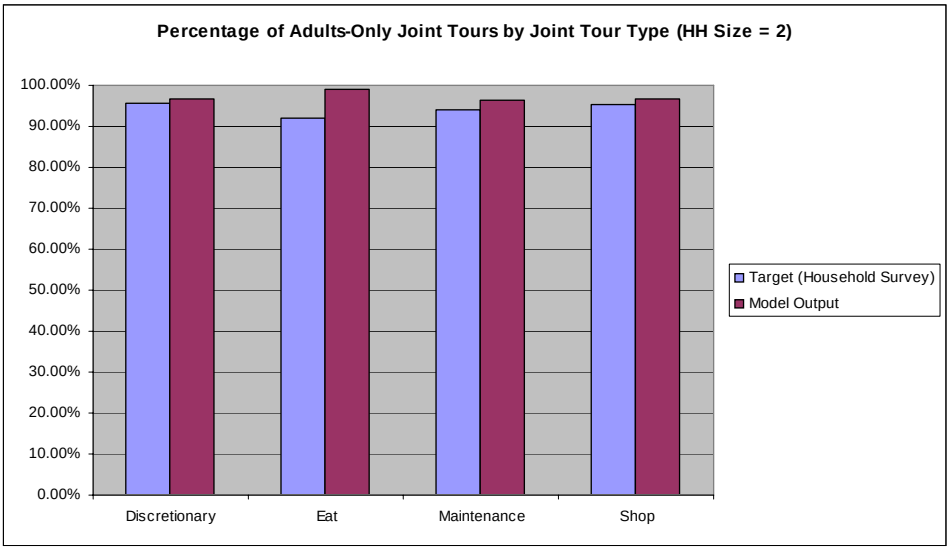
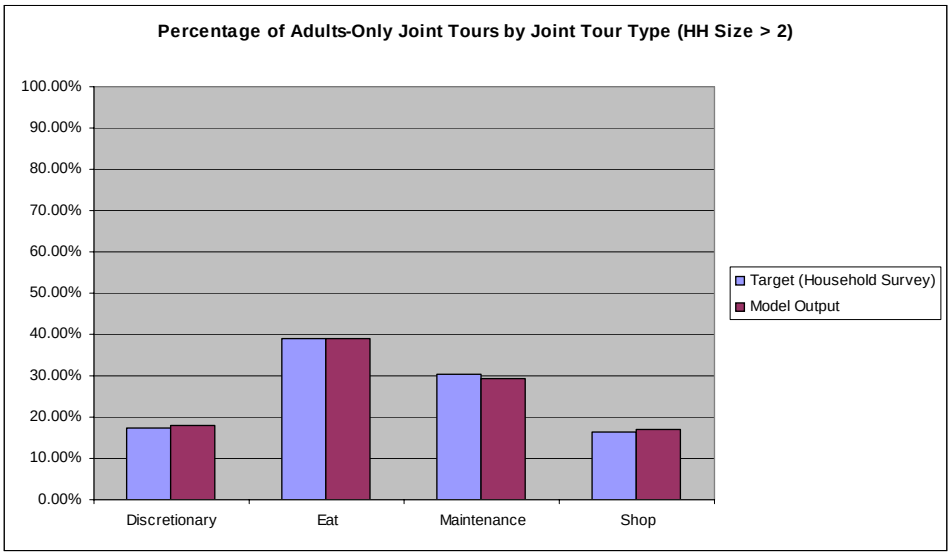


Figure 7.6: Joint tour party composition comparison, household size > 2



7.6 Person Participation in Joint Tours Choice Model

Unit: Possible person-by-tour and travel party combination. It includes each joint tour listed in combination with each household member suitable for the travel party and not staying at home.

Segmentation: Partial segmentation of alternative-specific constants by person type in combination with travel purpose and party composition; partial segmentation of income, car ownership, area type, and other coefficients by aggregate person type (adult, child).

Choice alternatives (2):

- Participate in the joint tour; not available in the following cases:
  - Persons with staying at home daily pattern type
  - Persons not suitable for the chosen travel party, like children for adult parties

- Do not participate in the joint tour; not available for persons whose participation is mandatory to implement the tour:
  - Only 2 adults in the household not staying at home for the adult party
  - The only adult in the household not staying at home for the mixed party
  - The only child in the household not staying at home for the mixed party

Main explanatory variables:

- Presence of "competing" persons of the same type in the household that can participate in the same party
  - Number of other adults in the household if the modeled person is adult
  - Number of other children in the household if the modeled person is child
- Household income
- Car ownership/sufficiency
- Residential area type
- Total number of joint tours implemented by the household
- Logged size variable including maximum pair-wise overlaps of residual windows:
  - The modeled adult with the other adults (for the adult party)
  - The modeled adult with children (for the mixed party)
  - The modeled child with adults (for the mixed party)

The following table presents the results of the joint tour participation model estimation.

Table 7.4: Joint tour person participation model estimation results

Variable	Participates	Does Not Participate
Full time worker, mixed party	-3.5660	0.5000
Part time worker, adult party	-0.3655	
Part time worker, mixed party	-3.0410	
Non-worker, adult party	0.7152	
Non-worker, mixed party	-2.7860	
Preschool child, mixed party	-0.7217	
Pre-driving child, mixed party	-1.8220	
Driving child, mixed party	-2.0410	
Full time worker, eating out tour	0.7157	0.5000
Full time worker, discretionary out tour	0.4392	0.5000
Part time worker, eating out tour	2.1880	
Part time worker, discretionary out tour	0.4850	
Non-worker, eating out tour	0.1617	
Non-worker, discretionary out tour	1.2000	
Preschool child, eating out tour	0.6589	
Preschool child, discretionary out tour	0.3000	
Pre-driving child, eating out tour	1.3910	
Pre-driving child, discretionary out tour	0.6626	
Driving child, eating out tour	2.3440	

7.7 Joint Tour Person Participation Model Calibration

To perform model calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Figure 7.7: Joint tour full-time worker participation, household size = 2

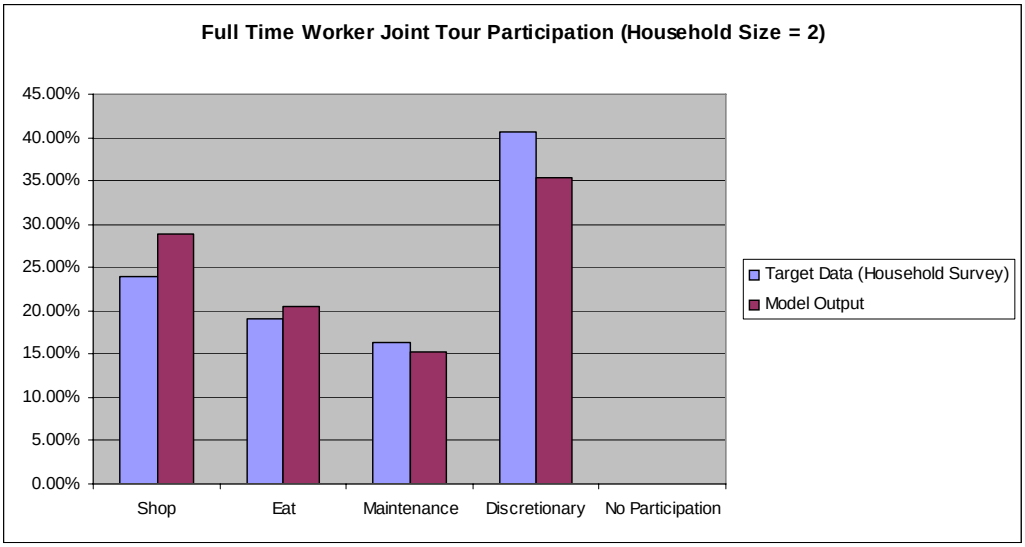


Figure 7.8: Joint tour part-time worker participation, household size = 2

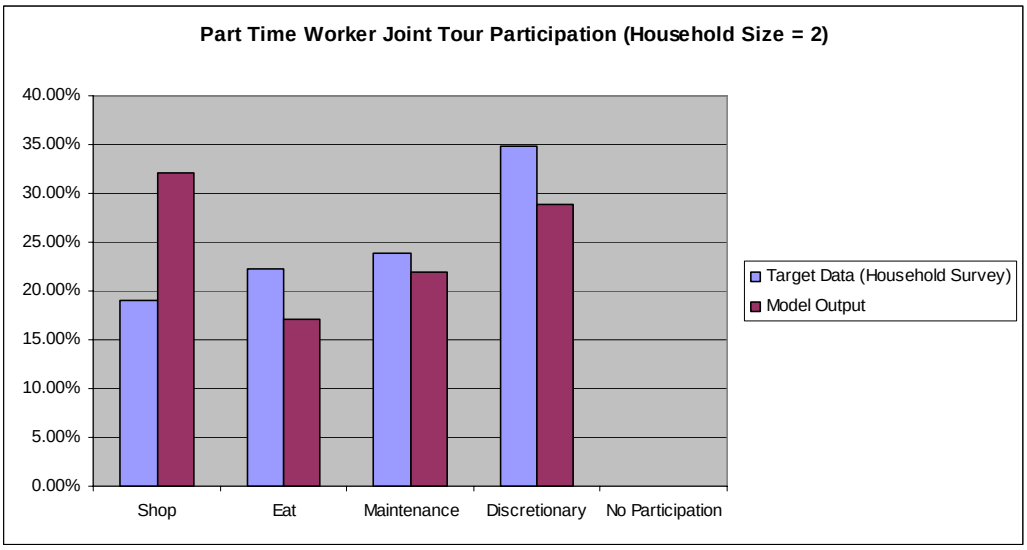


Figure 7.9: Joint tour non-worker participation, household size = 2

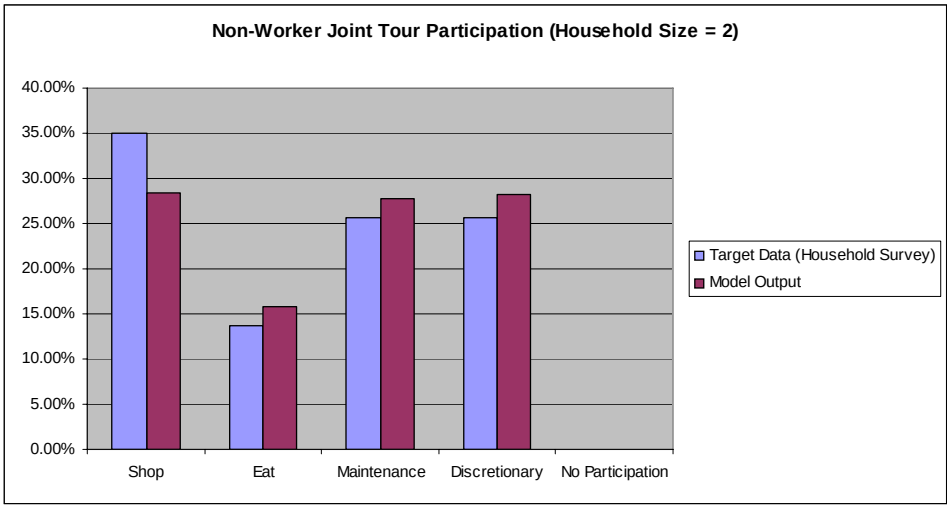


Figure 7.10: Joint tour person (all types) participation, household size = 2

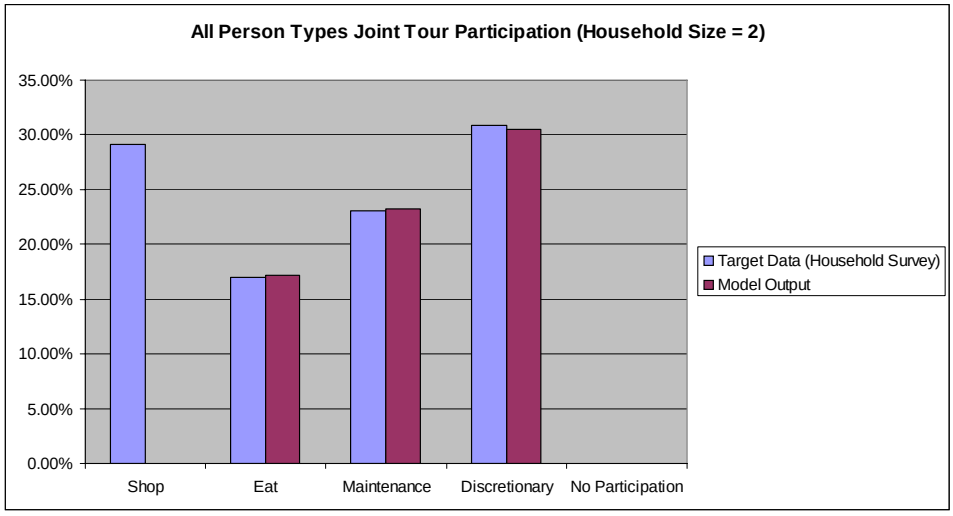


Figure 7.11: Joint tour full-time worker participation, household size > 2

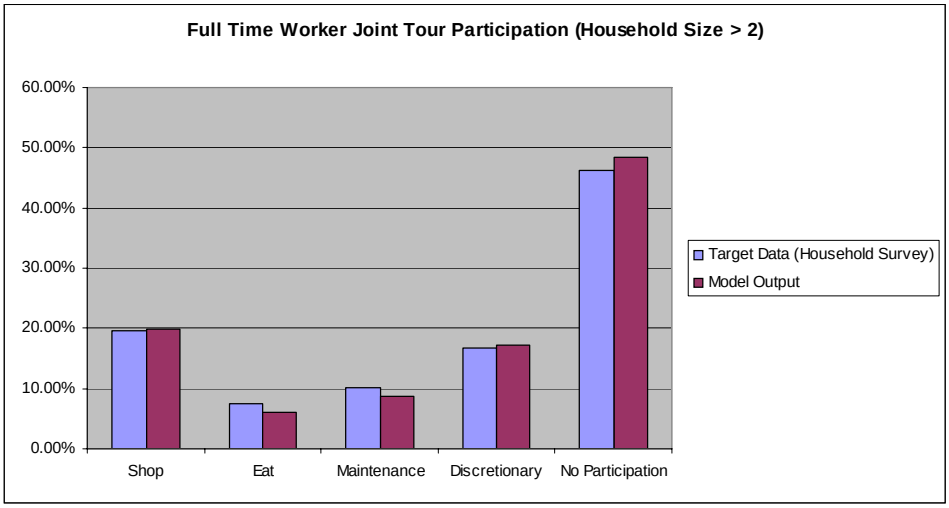


Figure 7.12: Joint tour part-time worker participation, household size > 2

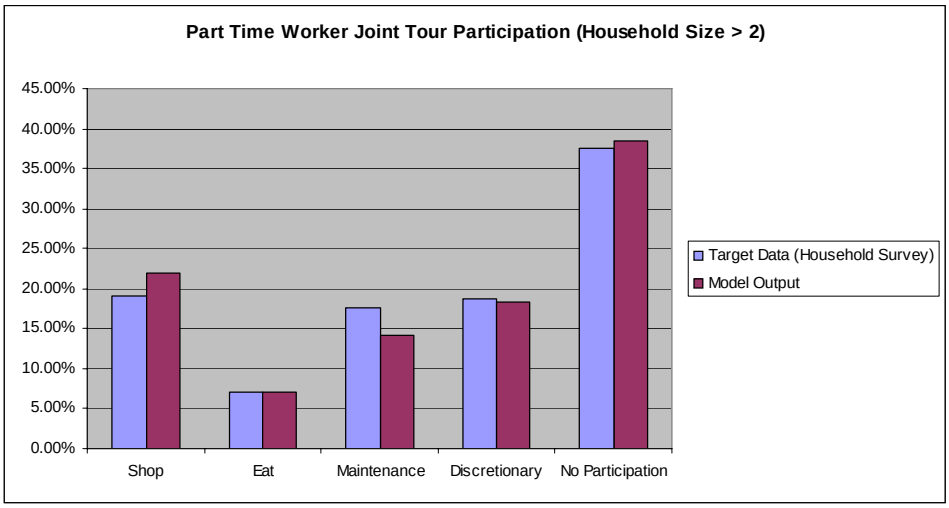


Figure 7.13: Joint tour non-worker participation, household size > 2

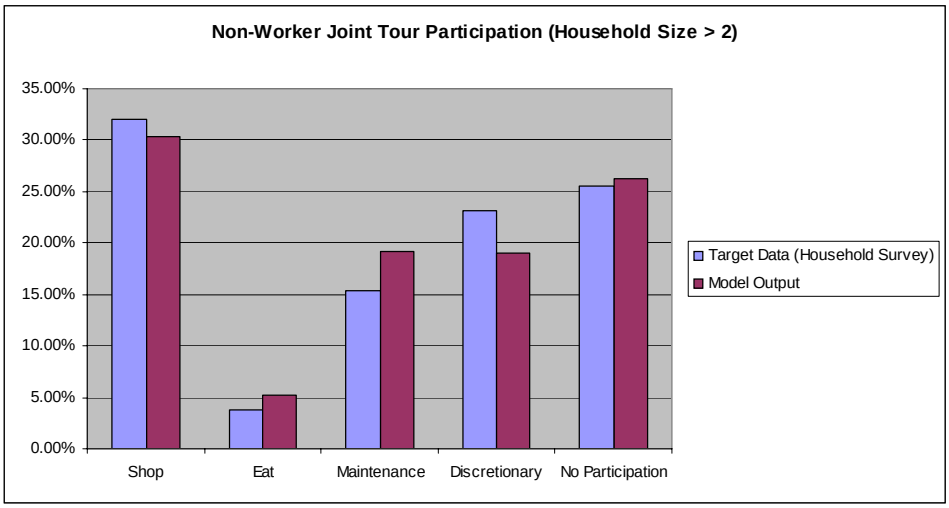


Figure 7.14: Joint tour preschool child participation, household size > 2

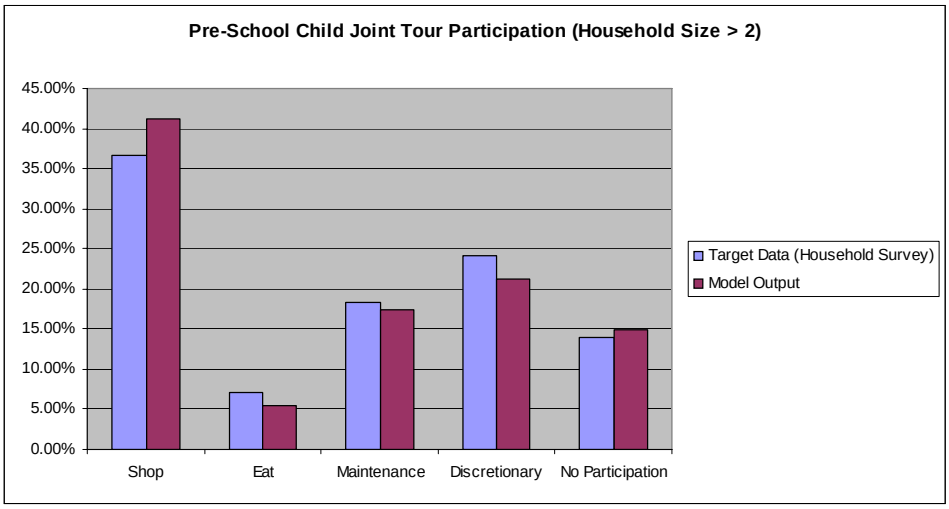


Figure 7.15: Joint tour pre-driving child participation, household size > 2

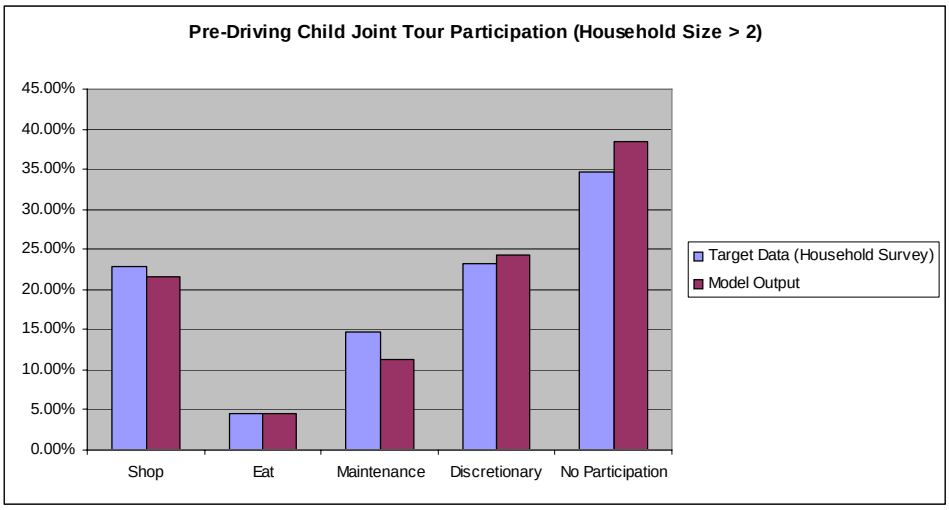
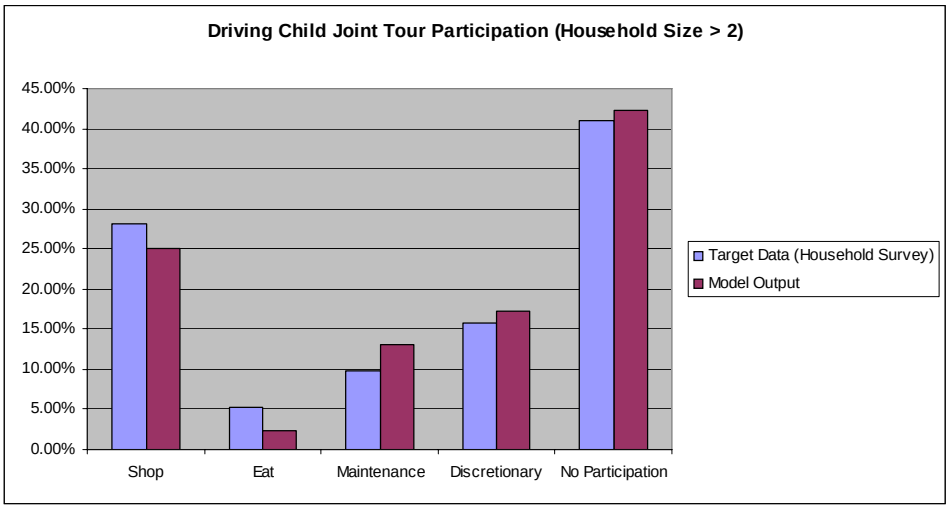


Figure 7.16: Joint tour driving child participation, household size > 2



CHAPTER 8
Joint Tour Destination, Time-of-Day, and Mode Choice Model

CHAPTER 8 – JOINT TOUR DESTINATION, TIME-OF-DAY, AND MODE CHOICE MODEL

8.1 Introduction

If a household chooses to make a joint tour, the joint tour destination, time-of-day, and mode choice model (DTM) determines where that tour will go (the destination), when the tour will happen (the time-of-day), and how the tour participants will travel during the tour (the mode). When the model is applied, each tour party making a joint tour is treated as a separate and independent decision making unit.

8.2 Destination Choice Sub-model

The destination choice model is a multinomial logit model in which each potential destination zone is an alternative. Because the set of available zones in the Tahoe region is relatively small (289), sampling to create a smaller choice set was not necessary. Each zone's attractiveness is calculated from a utility function, where the utility consists of variables such as distance, income level, and area type. To provide a measure of a zone's attractiveness based on tour-specific characteristics, a size term is included in the utility expression. The size terms are stratified by joint tour type and are calculated as the natural logarithm of a sum of particular socio-economic variables. The following table shows which variables were included (1=used, 0=not used) in the size term for each purpose:

Table 8.1 Joint tour destination choice size term specifications

	Size Term Variable Coefficients					
	Total Occupied Units	Employment				
Joint Tour Type		Retail	Service	Gaming	Recreation	Other
Shop	1	1	0	1	0	0
Other-Maintenance	0	0	1	0	0	1
Discretionary	1	0	1	1	1	0
Eat	1	0	1	1	0	1

Also included in the utility expression is the logsum from the mode choice model, which provides an index of accessibility for a destination zone - the higher the logsum, the more "accessible" (by auto, transit, walking) a zone is. Because the mode-choice model uses time-of-day specific skims, a time-of-day choice must be made before its utility can be evaluated. Because the actual time-of-day model occurs after the destination choice model, pre-selected time-of-day choices are used evaluate the mode choice logsums used in the model. These pre-selected choices are based on the expected time-of-day for a given purpose. For joint tours which involve at least one person with a mandatory pattern, the time-of-day choice used for the logsum calculation is PM peak start, late night end. For all other parties, the midday start, midday end time-of-choice is used.

In the Tahoe region, a number of residents actually travel outside of the region to make joint tours. To capture this effect, size terms were assigned to external zones. These size terms are discussed in **Appendix I**. In addition to the size terms, each external zone has an alternative specific constant which allowed for further refinement in the calibration phase of the model development.

The joint tour destination choice model specifications are presented in the following tables.

Table 8.2 Joint tour destination choice model specifications.

	Coefficient by Tour Type			
Variable	Shop	Other-Maintenance	Discretionary	Eat
Distance (miles) - adult party	-0.1217			
Distance (miles) - mixed party	-0.1662			
Distance (miles) - at least one adult mandatory pattern		-0.1937		
Distance (miles) - no adult mandatory patterns		-0.1145		
Distance (miles) - adult party, at least one mandatory pattern			-0.1855	-0.2340
Distance (miles) - adult party, no mandatory pattern			-0.1303	-0.2340
Distance (miles) - mixed party, at least one mandatory pattern			-0.3188	-0.4033
Distance (miles) - mixed party, no mandatory pattern			-0.1184	-0.1655
Mode choice logsum	1.0000			
Size term	1.0000	1.0000	0.7176	0.8021
Rural home, urban destination	0.7401			
Workers Minus Cars in Household (if positive) and Transit Within ¼ Mile at Both Origin and Destination	1.3060			
Preschool child in household, distance < 3 miles	1.0660			
Size term = 0	Alternative Unavailable			
Alternative Specific Constant for External Zone 1	5.6000	2.5434	2.8000	5.0000
Alternative Specific Constant for External Zone 2	5.6000	3.5934	2.4500	-2.0000
Alternative Specific Constant for External Zone 3	1.8100	0.8934	-6.0000	4.4000
Alternative Specific Constant for External Zone 4	-0.0500	-6.6066	-6.0000	0.0000
Alternative Specific Constant for External Zone 5	11.1800	-3.6066	-6.0000	0.0000
Alternative Specific Constant for External Zone 6	-4.4500	-6.6066	-6.0000	-1.5000
Alternative Specific Constant for External Zone 7	3.3000	2.7634	-6.0000	4.9000

8.3 Destination Choice Sub-model Calibration

To calibrate the destination choice sub-model, three primary measures were examined:

- County to county flows
- Tour distance
- Internal to external flows

To perform the calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Table 8.3a: County to county flows for all joint discretionary tours – household travel survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	16.90%	0.00%	0.00%	0.00%	2.66%	1.13%	20.69%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	6.81%	2.29%	0.00%	0.00%	9.10%
El Dorado	0.00%	0.00%	4.79%	31.88%	0.00%	0.81%	37.48%
Placer	3.23%	0.00%	1.85%	2.95%	24.69%	0.00%	32.72%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	20.13%	0.00%	13.45%	37.13%	27.35%	1.94%	100.00%

Table 8.3b: County to county flows for all joint discretionary tours – model

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	11.88%	0.00%	0.36%	0.24%	2.32%	0.95%	15.74%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.24%	0.00%	5.70%	4.33%	0.00%	0.12%	10.39%
El Dorado	0.24%	0.00%	11.34%	46.14%	0.53%	0.24%	58.49%
Placer	3.92%	0.00%	0.06%	0.71%	10.21%	0.48%	15.38%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	16.27%	0.00%	17.46%	51.43%	13.06%	1.78%	100.00%

Table 8.4a: County to county flows for joint eat tours – household travel survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	19.36%	0.00%	0.00%	0.00%	2.84%	0.00%	22.20%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	6.36%	4.87%	0.00%	0.00%	11.23%
El Dorado	0.00%	0.00%	9.51%	29.76%	0.00%	2.99%	42.26%
Placer	2.84%	0.00%	0.00%	0.00%	16.82%	4.66%	24.32%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	22.20%	0.00%	15.87%	34.63%	19.66%	7.65%	100.00%

Table 8.4b: County to county flows for joint eat tours – model

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	10.19%	0.00%	0.16%	0.00%	2.10%	2.59%	15.05%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	5.34%	5.50%	0.00%	0.97%	11.81%
El Dorado	0.00%	0.00%	10.52%	43.37%	1.13%	1.13%	56.15%
Placer	2.10%	0.00%	0.00%	0.16%	11.00%	3.72%	16.99%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	12.30%	0.00%	16.02%	49.03%	14.24%	8.41%	100.00%

Table 8.5a: County to county flows for joint maintenance-other tours – household travel survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	6.64%	0.00%	0.00%	0.00%	4.87%	3.80%	15.30%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	8.87%	2.31%	0.00%	3.19%	14.38%
El Dorado	0.00%	0.00%	5.54%	48.49%	0.00%	5.68%	59.71%
Placer	1.67%	0.00%	0.00%	0.00%	3.94%	5.00%	10.61%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	8.30%	0.00%	14.41%	50.80%	8.80%	17.68%	100.00%

Table 8.5b: County to county flows for joint maintenance-other tours – model

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	8.65%	0.00%	0.00%	0.00%	1.89%	4.45%	14.99%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.16%	0.00%	2.64%	5.52%	0.00%	2.22%	10.54%
El Dorado	0.08%	0.00%	6.67%	43.16%	0.58%	4.61%	55.11%
Placer	2.72%	0.00%	0.08%	0.16%	11.12%	5.27%	19.36%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	11.61%	0.00%	9.39%	48.85%	13.59%	16.56%	100.00%

Table 8.6a: County to county flows for joint shop tours – household travel survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	5.36%	0.00%	0.00%	0.00%	2.60%	9.42%	17.38%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	3.57%	4.03%	0.00%	6.56%	14.15%
El Dorado	0.00%	0.00%	0.00%	32.39%	4.15%	5.47%	42.00%
Placer	1.56%	0.00%	0.00%	0.00%	17.57%	7.34%	26.47%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	6.92%	0.00%	3.57%	36.42%	24.32%	28.78%	100.00%

Table 8.6b: County to county flows for joint shop tours – model

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	3.09%	0.00%	0.05%	0.05%	0.64%	9.23%	13.06%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	3.83%	2.85%	0.00%	2.95%	9.63%
El Dorado	0.10%	0.00%	14.98%	34.97%	1.08%	9.38%	60.51%
Placer	2.46%	0.00%	0.20%	0.44%	7.07%	6.63%	16.80%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	5.65%	0.00%	19.06%	38.31%	8.79%	28.19%	100.00%

Figure 8.1: Distance distribution comparison for joint discretionary work tours

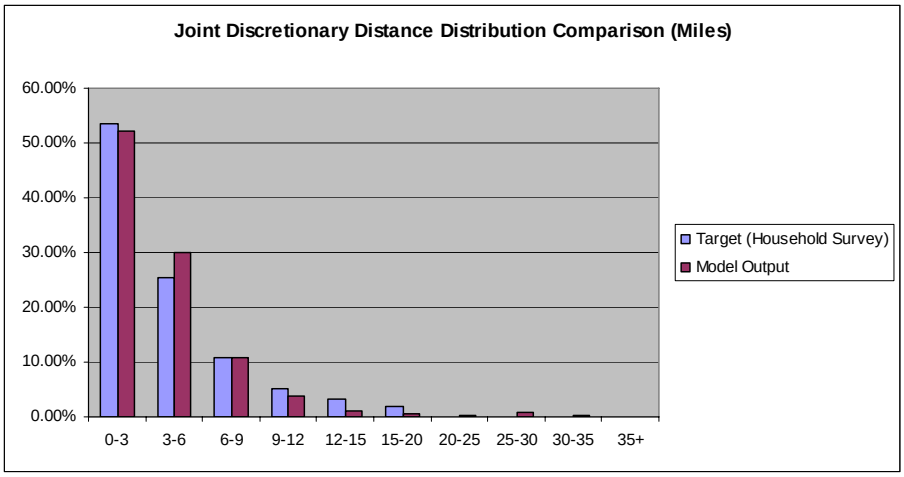


Figure 8.2: Distance distribution comparison for joint maintenance-other work tours

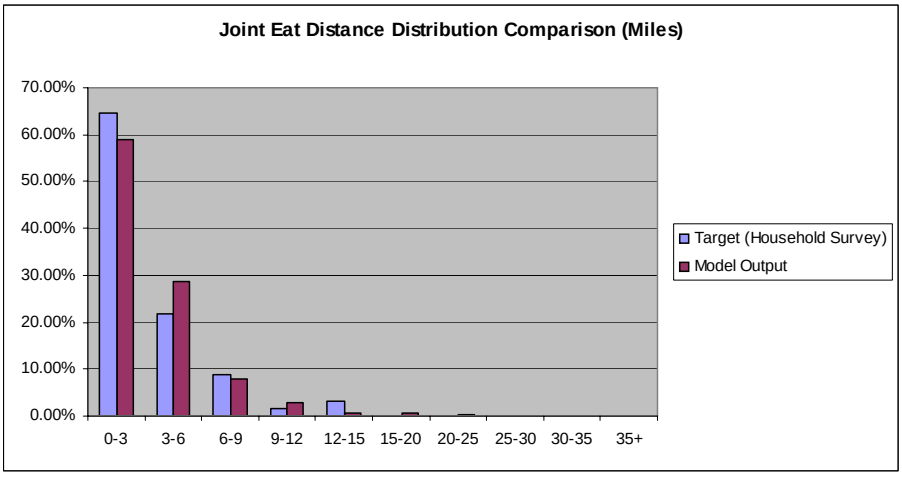


Figure 8.3: Distance distribution comparison for joint eat work tours

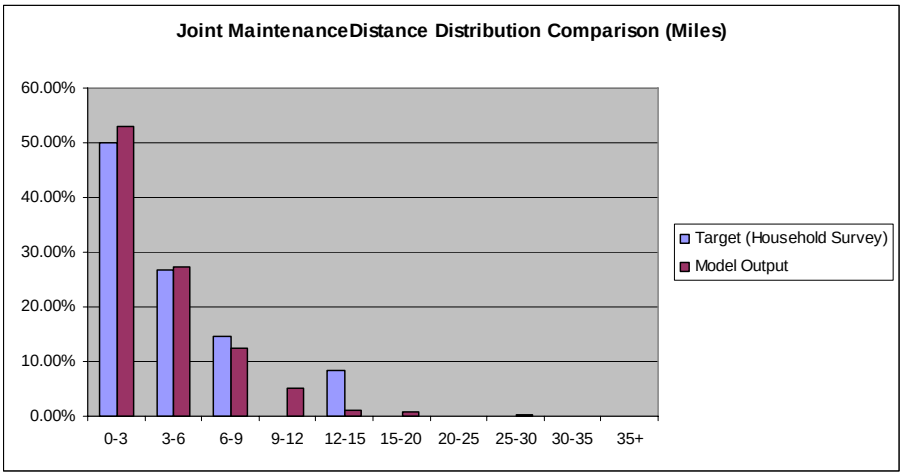


Figure 8.4: Distance distribution comparison for joint shop work tours

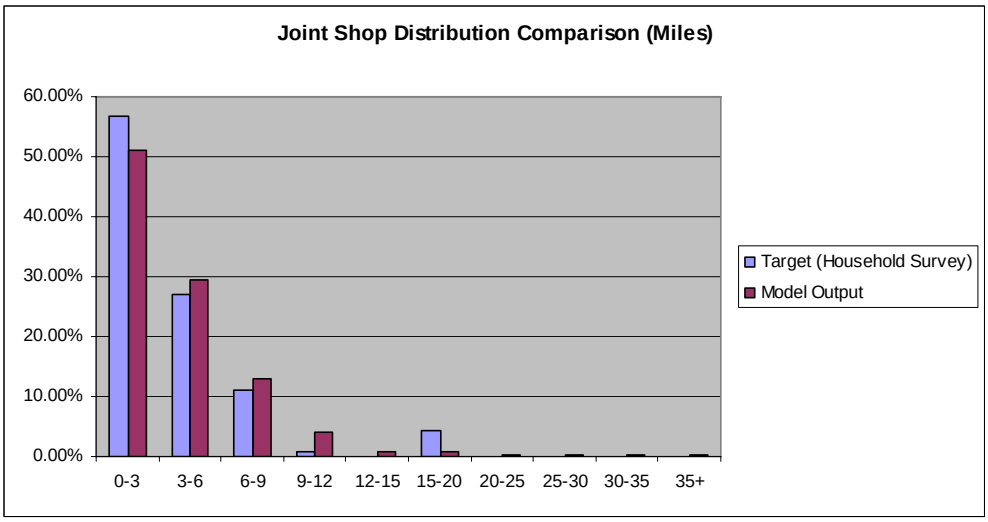


Table 8.7: Joint tour destination choice distance and travel time comparison

	Household Travel Survey				Model			
	Distance		Travel Time		Distance		Travel Time	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
Discretionary	4.012	3.353	7.367	5.105	3.951	4.084	7.408	6.116
Eat	3.185	2.602	6.085	4.236	3.207	2.775	6.275	4.463
Maintenance-Other	3.998	3.511	7.360	5.463	3.825	3.464	7.225	5.427
Shop	3.885	3.754	7.155	5.970	4.011	3.875	7.567	5.961

Figure 8.5: Internal-External destination zone comparison for joint discretionary tours

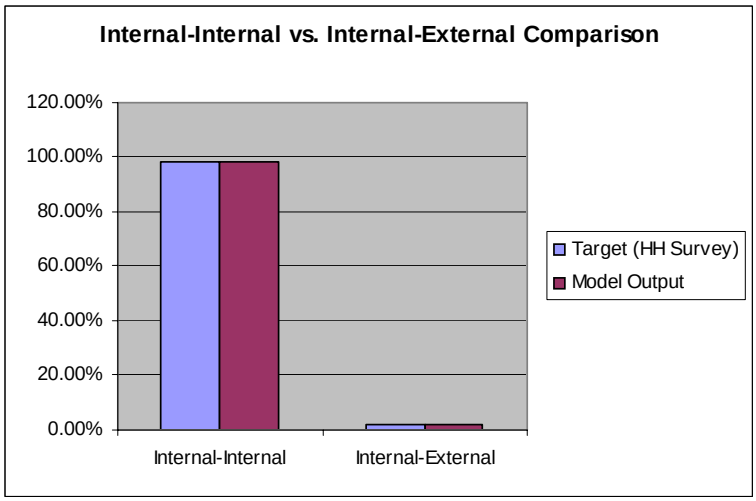


Figure 8.6: External station distribution for joint discretionary tours

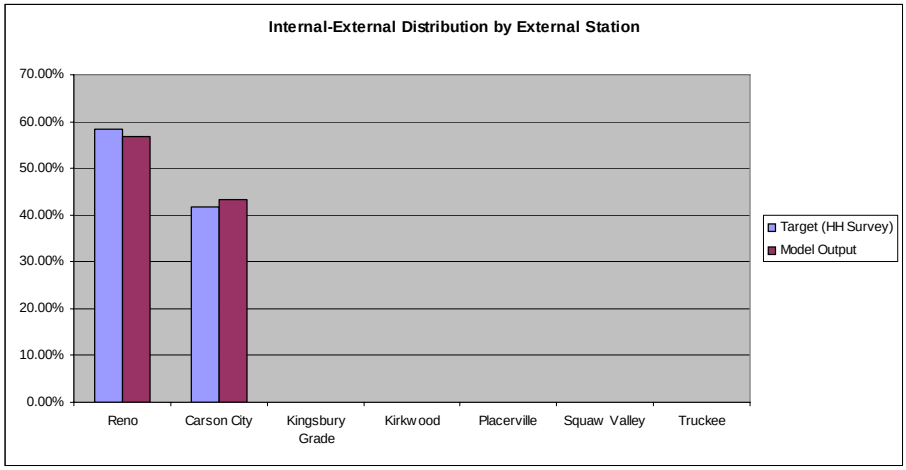


Figure 8.7: Internal-External destination zone comparison for joint eat tours

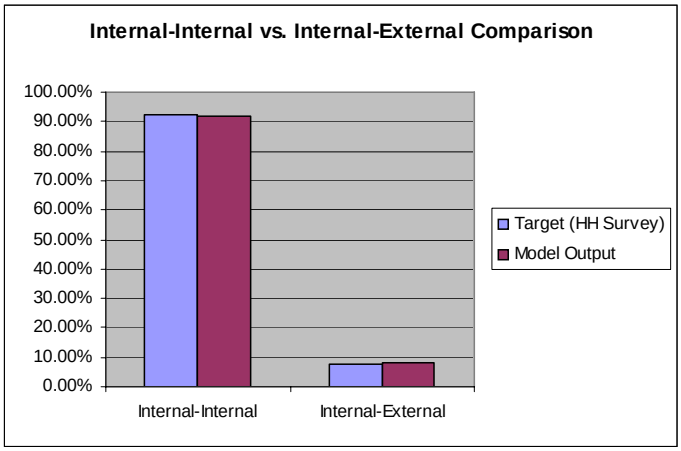


Figure 8.8: External station distribution for joint eat tours

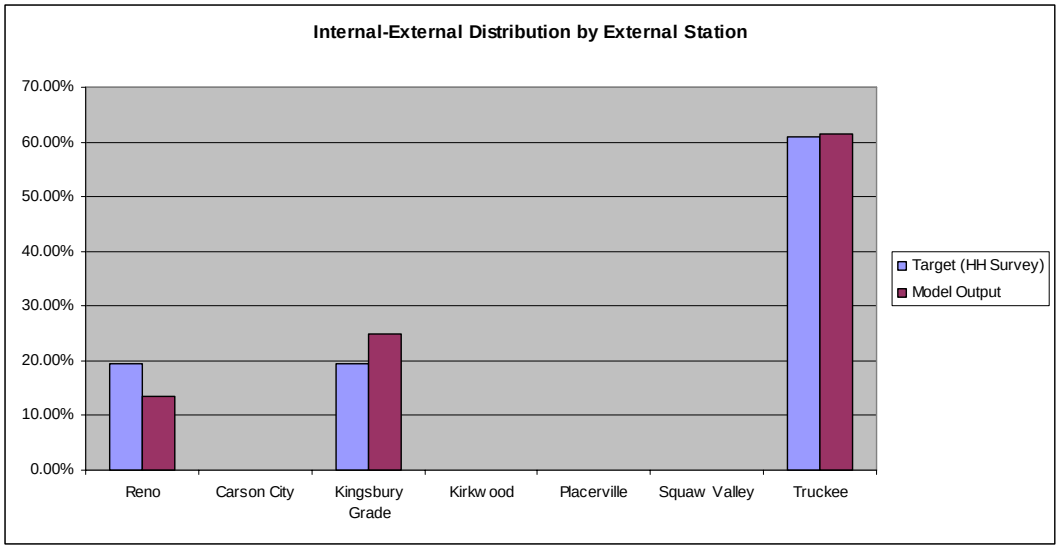


Figure 8.9: Internal-External destination zone comparison for joint maintenance-other tours

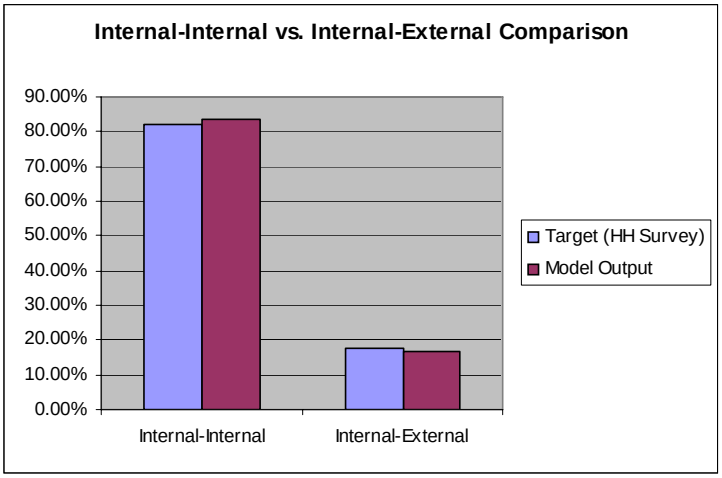


Figure 8.10: External station distribution for joint maintenance-other tours

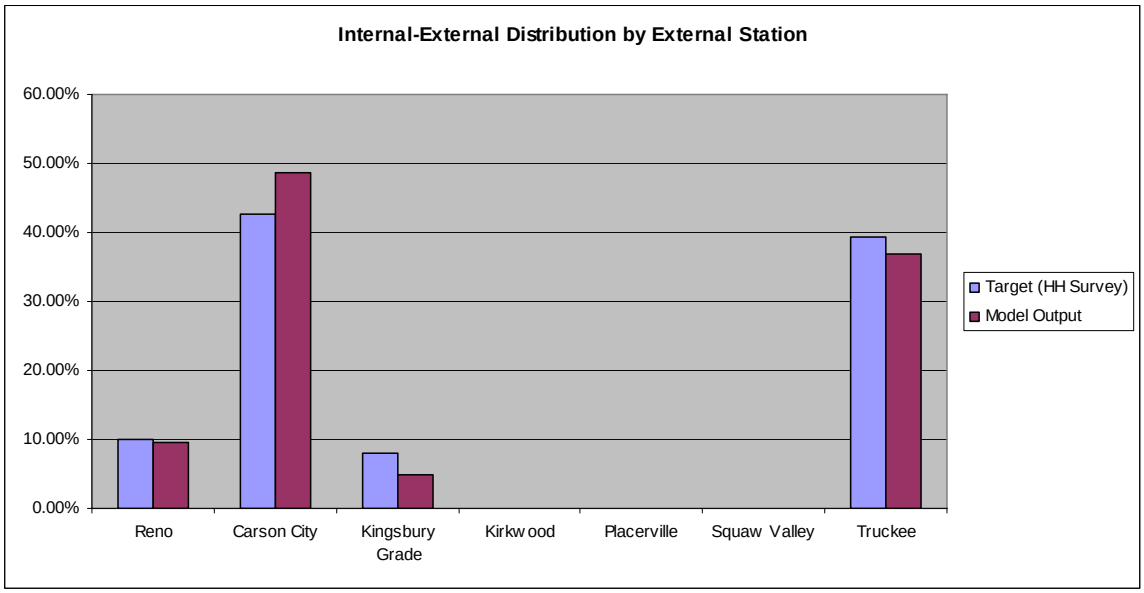


Figure 8.11: Internal-External destination zone comparison for joint shop tours

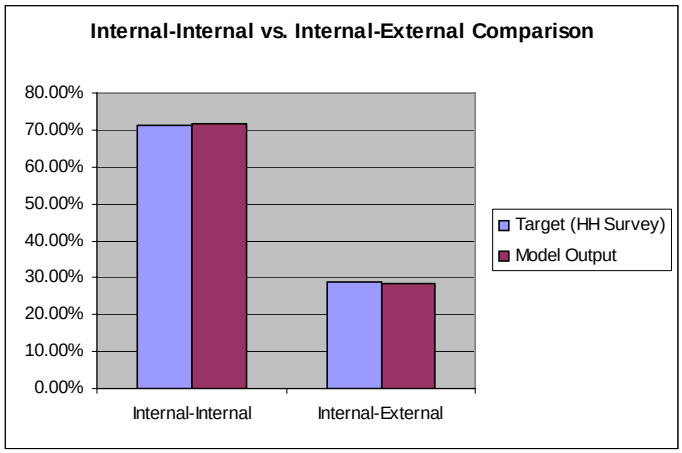
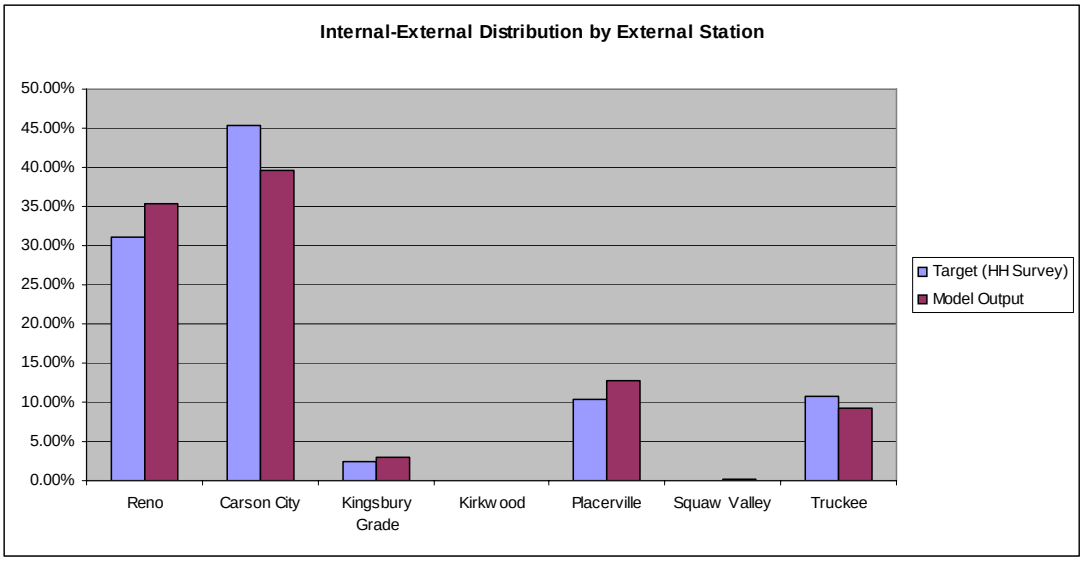


Figure 8.12: External station distribution for joint shop tours



8.4 Time-of-Day Sub-model

The time-of-day sub-model is a multinomial logit model in which start/stop hour pairs make up the alternatives. The earliest allowed start/stop time is 5:00 am (corresponding to the 5:00-6:00 hour), and the latest allowed is midnight (corresponding to the 12:00am-1:00am hour). As far as skim periods are concerned, the following definitions are used:

Table 8.8: Skim period definitions

Skim Period	Start Time	End Time	Duration
AM Peak (AM)	7:00 AM	10:00 AM	3 hours
Midday (MD)	10:00 AM	4:00 PM	6 hours
PM Peak (PM)	4:00 PM	7:00 PM	3 hours
Late Night (LN)	7:00 PM	7:00 AM	12 hours

The time-of-day choice model estimation results are presented in the following tables.

Table 8.9: Time-of-day estimation results for joint tours

Variable	Coefficient
Early start at 5/6	-12.0000
AM peak start at 7	-4.0000
Midday start at 10/11/12	2.0000
AM peak end	-3.0000
PM peak end at 17	-0.5000
PM peak end at 19	-2.0000
PM peak end at 18	-1.0000
Evening end at 20/21	-3.0000
Late end at 22/23	-6.0000
Shop end 16 to 19	-3.0000
Maintenance end > 18	-3.0000

Variable	Coefficient
Maintenance start > 17	-5.5000
Maintenance start at 5	-3.0000
Maintenance departure at 9	4.5000
Maintenance end < 9	-8.0000
Maintenance end 18	-3.0000
Shop end at 21	-4.2000
Maintenance start at 13	3.1000
Discretionary start at 17	2.1000
Maintenance end at 13	3.8000
Shop start at 9	3.6000
Discretionary end at 21	-0.5000
Late end at 23	-9.0000
Maintenance end at 14	1.8000
Eat start at 17/18	3.3000
Shop start 20	-2.3000
Discretionary start at 15/16	1.5000
Shop start 16 to 19	-3.5000
Duration - discretionary purpose	-0.5000
0 duration	-4.4000
Eat duration = 1	3.2000
Eat start 17 to 20	1.2000
Shop start at 8	1.5000
1 duration	-1.2000
Eat and 0 duration	5.8800
Shop start at 9	6.0000
Discretionary end at 11 to 15	1.6000
Shop end at 13/14/15	1.5000
Shop start > 17	-6.2000
Maintenance start > 17	-6.0000
Shop start 10 to 14	8.5000
Maintenance start 10 to 14	4.2000
Maintenance start at 16	-2.3000
Shop start at 16	-2.3000
Discretionary start at 13/14/15	2.1000
Shop end 10 to 12	3.5000
Maintenance end 12 to 15	2.6000
Eat end at 13	4.0000
Eat end at 20	5.0000
Discretionary start at 18	2.0000
Eat start at 11/13	2.0000
Eat start at 12	-2.5000
Shop start < 9	-12.0000
Shop start > 18	-6.0000
Shop end at 19	-3.0000
Shop end at 21	-0.2000

Variable	Coefficient
Shop end at 20	-3.3000
Shop end > 21	-6.0000
Discretionary 1-2 duration	-1.3000
Shop 2 duration	-0.4000
Discretionary 0 duration	-2.8800

8.5 Time-of-day Choice Sub-model Calibration

To calibrate the time-of-day choice sub-model, three primary aspects were examined:

- Start time
- End time
- Duration

To perform the calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Figure 8.13a: Time of day departure time comparison for joint discretionary tours (Coincidence ratio: 0.63)

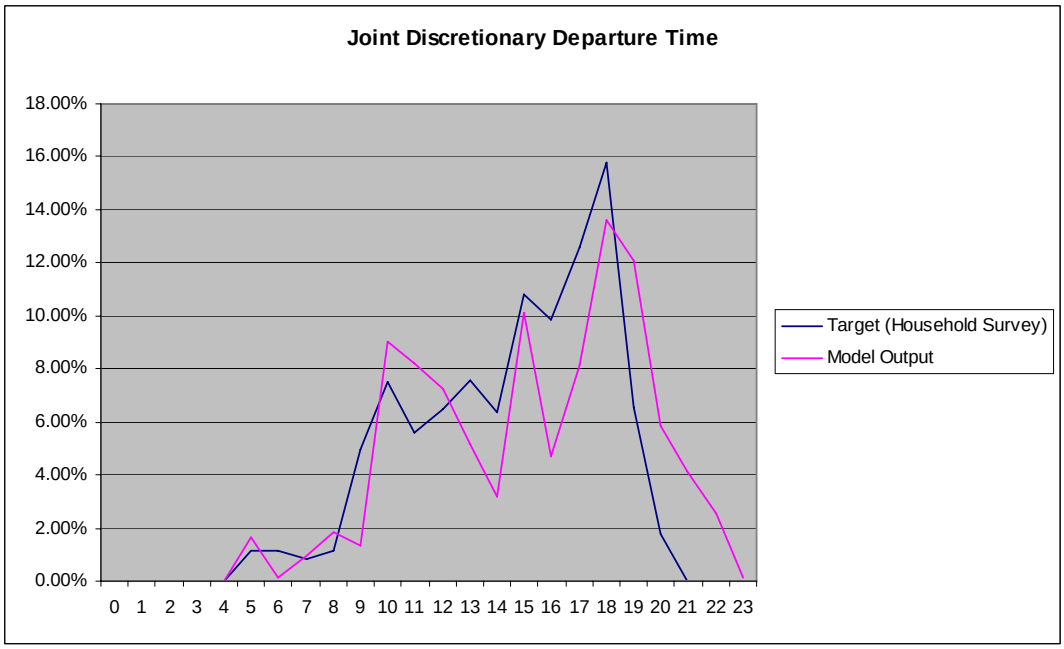


Figure 8.13b: Time of day arrival time comparison for joint discretionary tours (Coincidence ratio: 0.61)

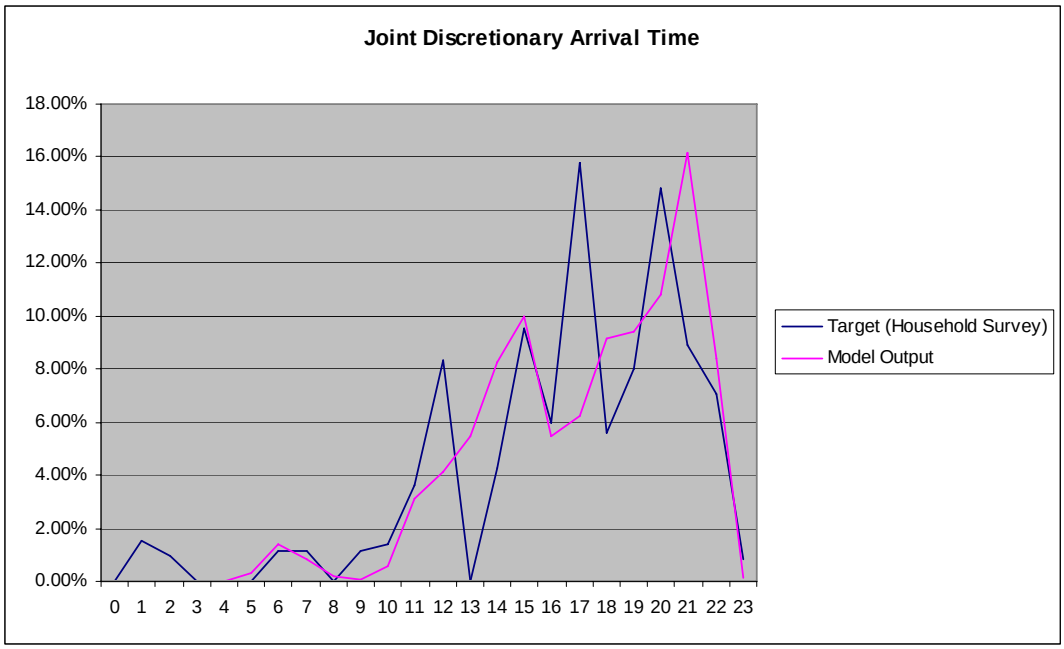


Figure 8.13c: Time of day duration comparison for joint discretionary tours (Coincidence ratio: 0.70)

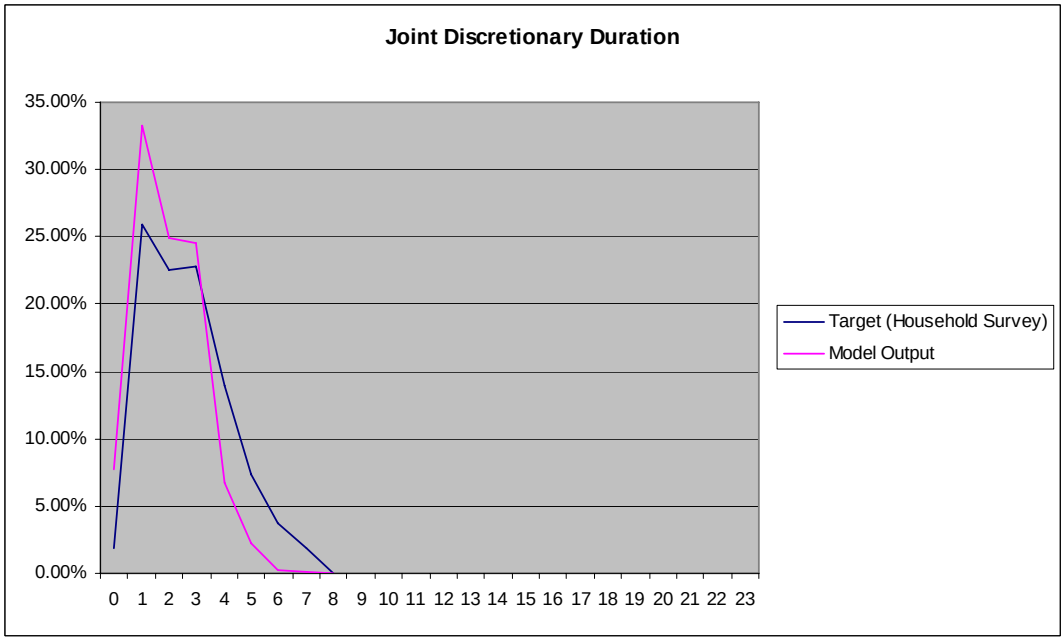


Figure 8.14a: Time of day departure time comparison for joint eat tours (Coincidence ratio: 0.59)

Figure 8.14b: Time of day arrival time comparison for joint eat tours (Coincidence ratio: 0.49)

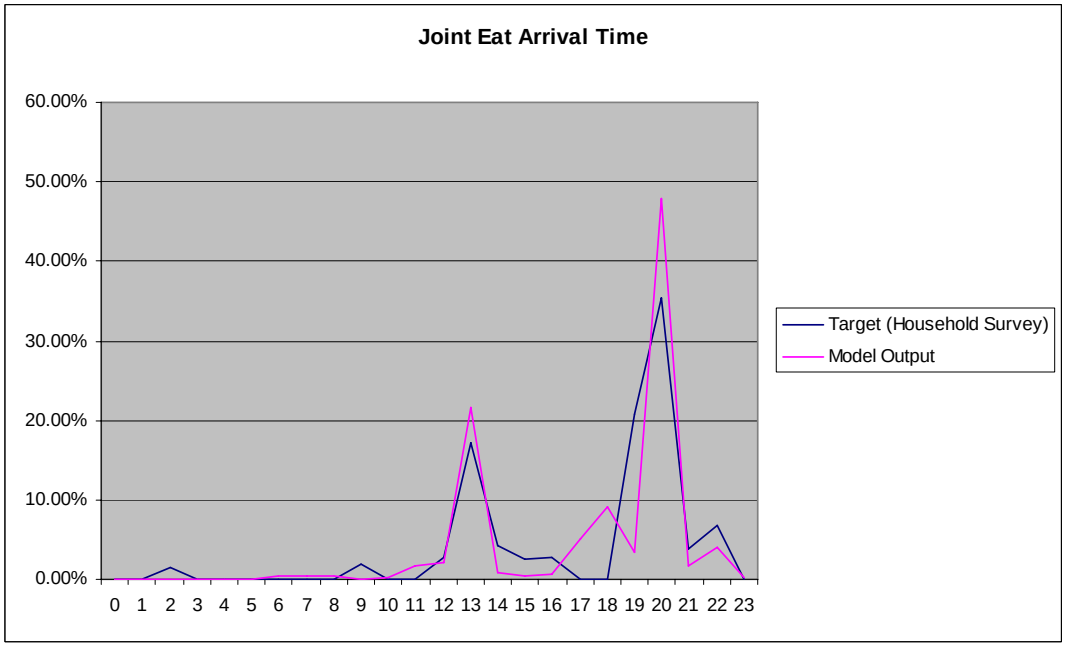
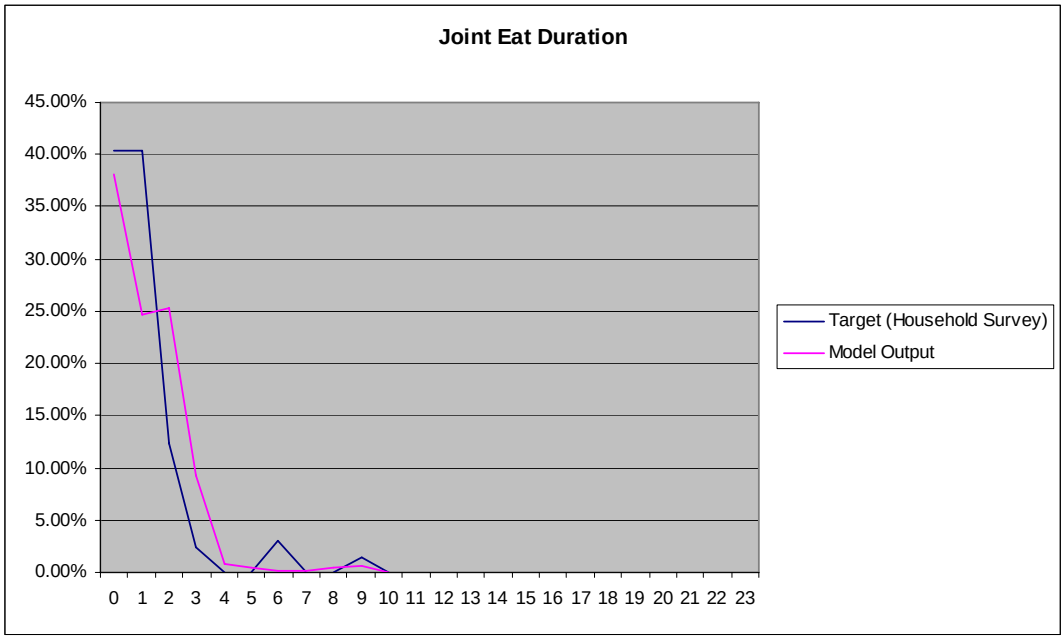


Figure 8.14c Time of day duration comparison for joint eat tours



(Coincidence ratio: 0.64)

Figure 8.15a: Time of day departure time comparison for joint maintenance-other tours (Coincidence ratio: 0.61)

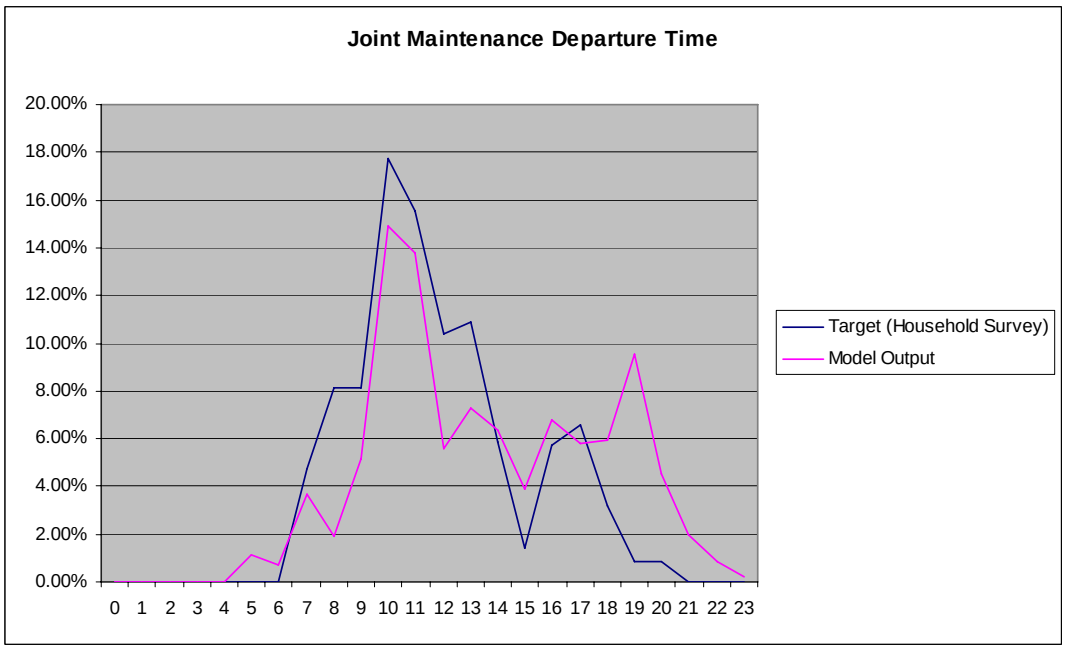


Figure 8.15b: Time of day arrival time comparison for joint maintenance-other tours (Coincidence ratio: 0.51)

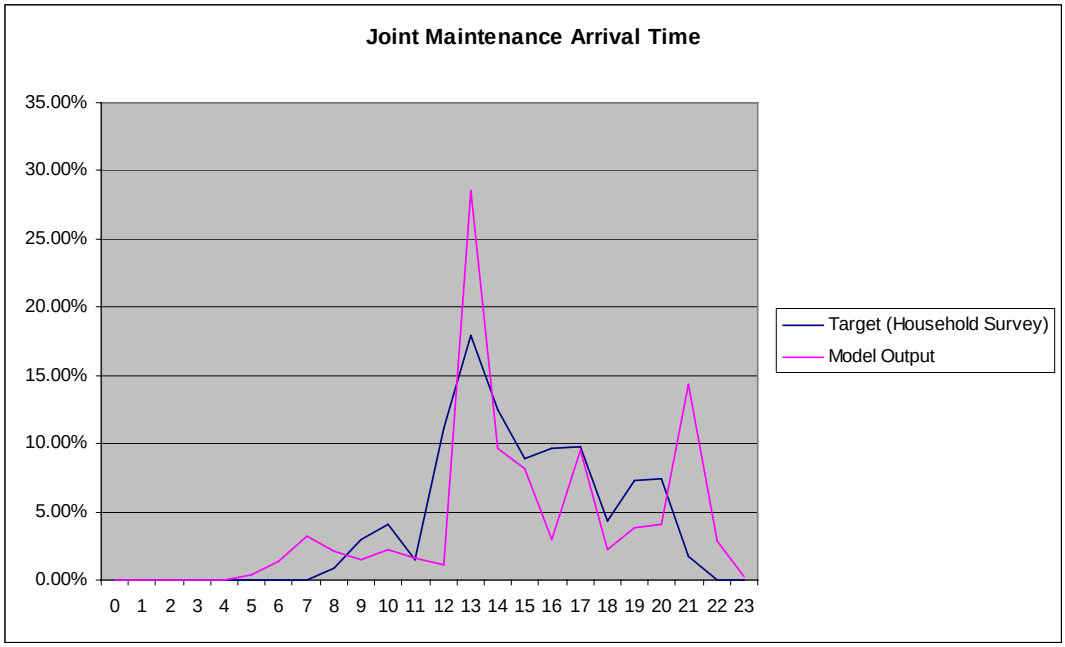


Figure 8.15c: Time of day duration comparison for joint maintenance-other tours (Coincidence ratio: 0.57)

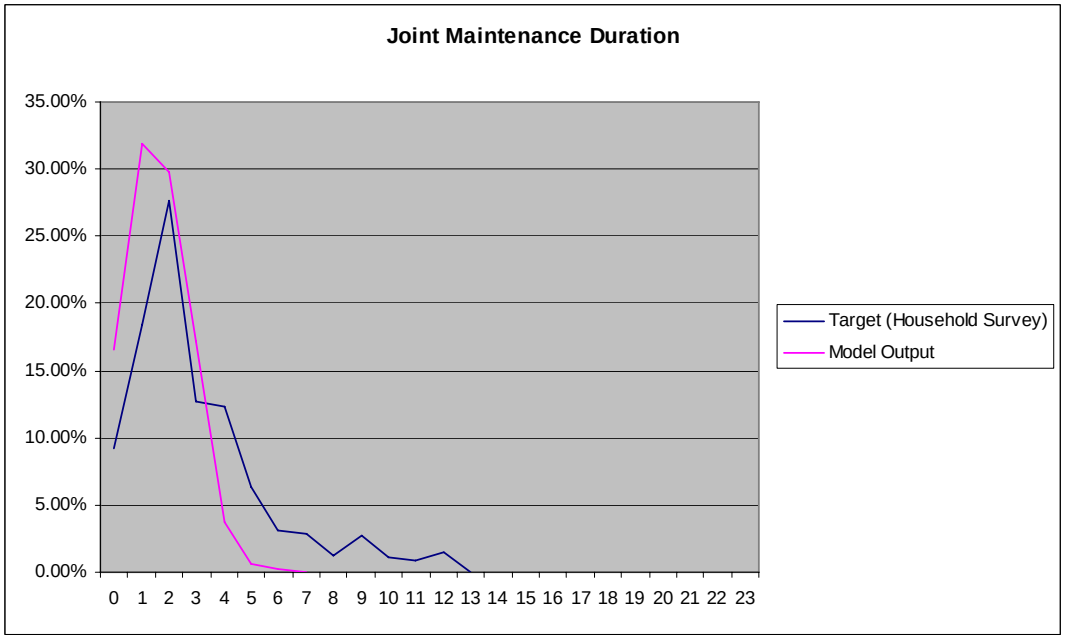


Figure 8.16a: Time of day departure time comparison for joint shop tours (Coincidence ratio: 0.54)

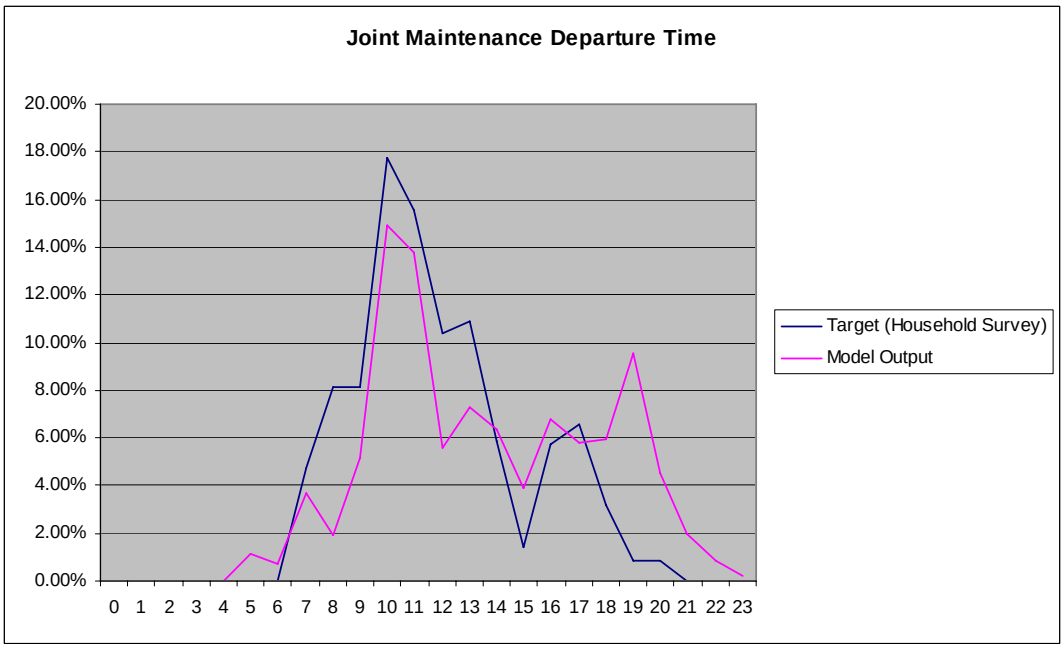


Figure 8.16b: Time of day arrival time comparison for joint shop tours (Coincidence ratio: 0.64)

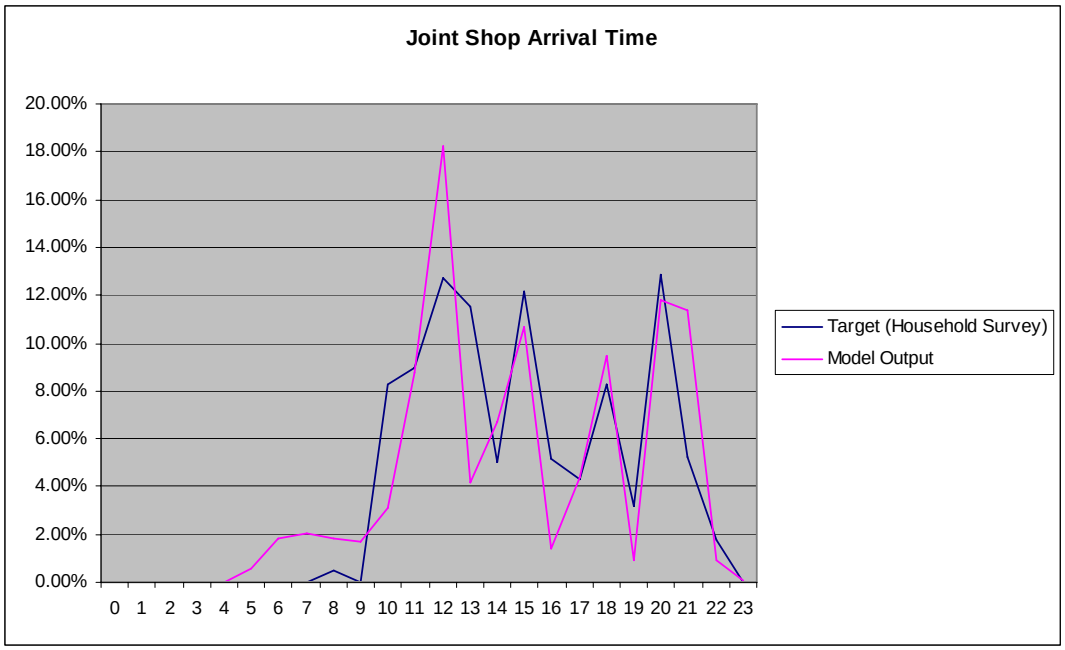


Figure 8.16c: Time of day duration comparison for joint shop tours (Coincidence ratio: 0.60)

8.6 Mode Choice Sub-model

The mode choice model is a multinomial logit model in which each mode is an alternative. For joint tours, the following alternatives are available:

- Shared auto
- Walk to transit
- Drive to transit
- Non-motorized

The primary component of the model is travel time, which uses the same coefficient across all modes. For the modes that have costs associated with them (transit has fares, auto modes have operating costs), a value of time factor was estimated; this factor can transfer dollar costs into time, for which a utility can be calculated using the travel time coefficient.

The mode choice model estimation results are presented in the following table.

Table 8.10: Mode choice estimation results for joint tours

Variable	Shared Auto	Walk to Transit	Drive to Transit	Non-Motorized
Alternative Specific Constant - Shopping		0.6900	-4.4300	0.1417
Alternative Specific Constant - Other-Maintenance		-2.2950	-6.5000	1.8000
Alternative Specific Constant - Discretionary		-4.2950	-6.5000	1.2000
Alternative Specific Constant - Eat		-4.8950	-5.9000	1.9200
Time (minutes)	-0.0151			
Value of Time ($/hour) - Worker	6.5300			
High income	0.8049			
Less autos in household than drivers	-0.4808			
No autos in houshold	-3.2470			
Travel party all adults	1.1180			
Travel party mixed	1.3440			

8.7 Mode Choice Sub-model Calibration

To calibrate the mode choice sub-model, the mode choice shares were examined. To perform this analysis, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Figure 8.17: Mode choice share comparisons for joint discretionary tours

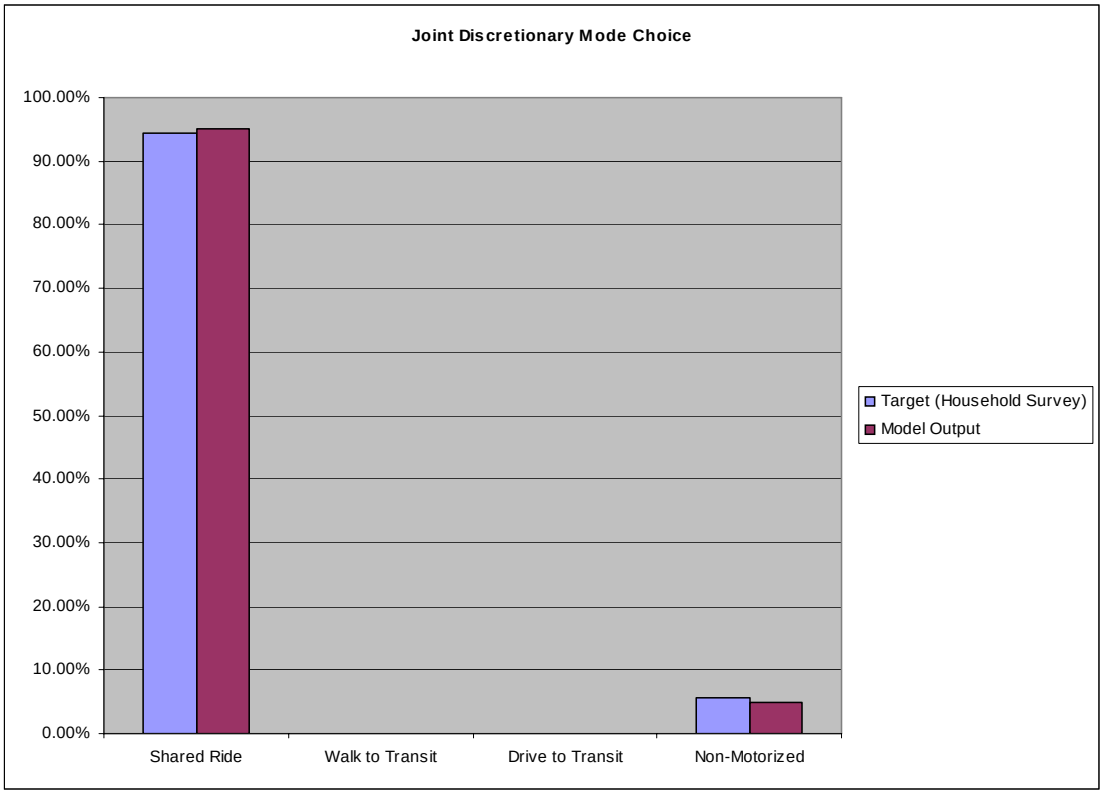


Figure 8.18: Mode choice share comparisons for joint eat tours

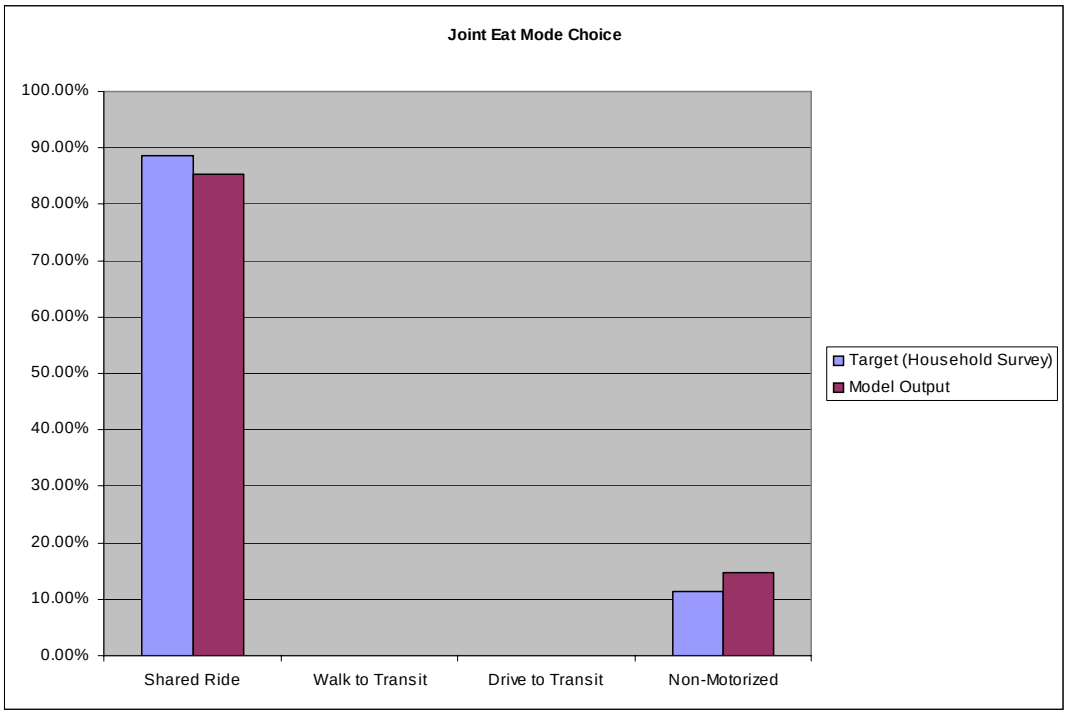


Figure 8.19: Mode choice share comparisons for joint maintenance-other tours

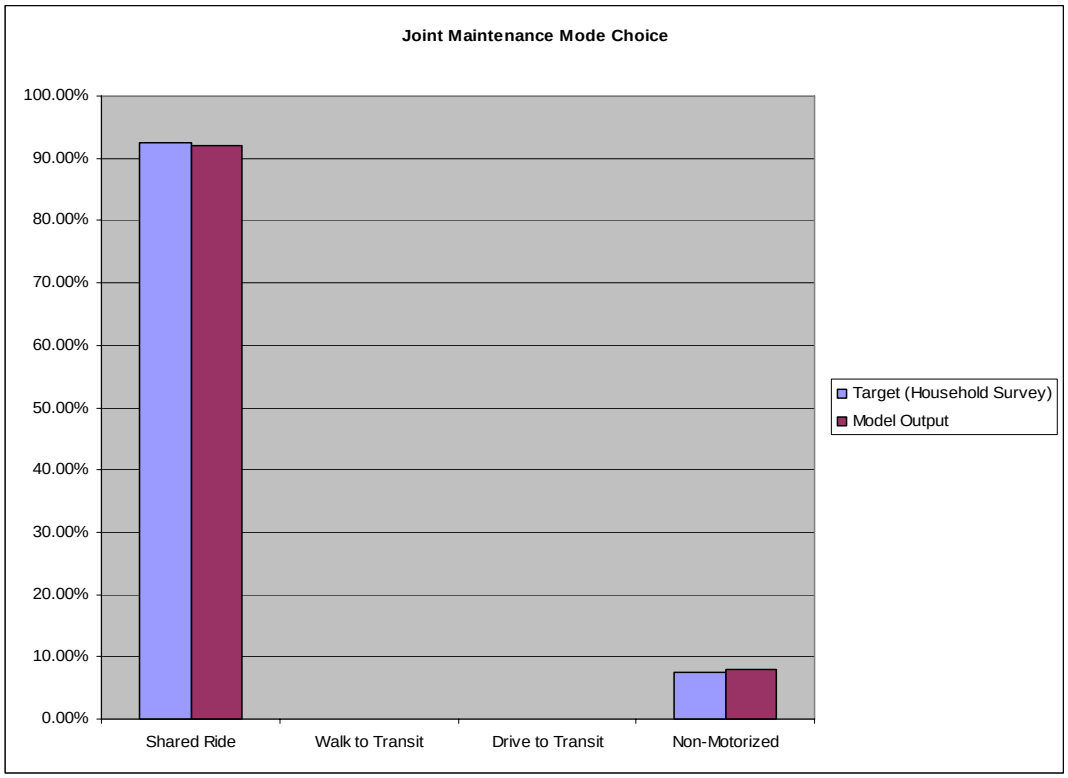
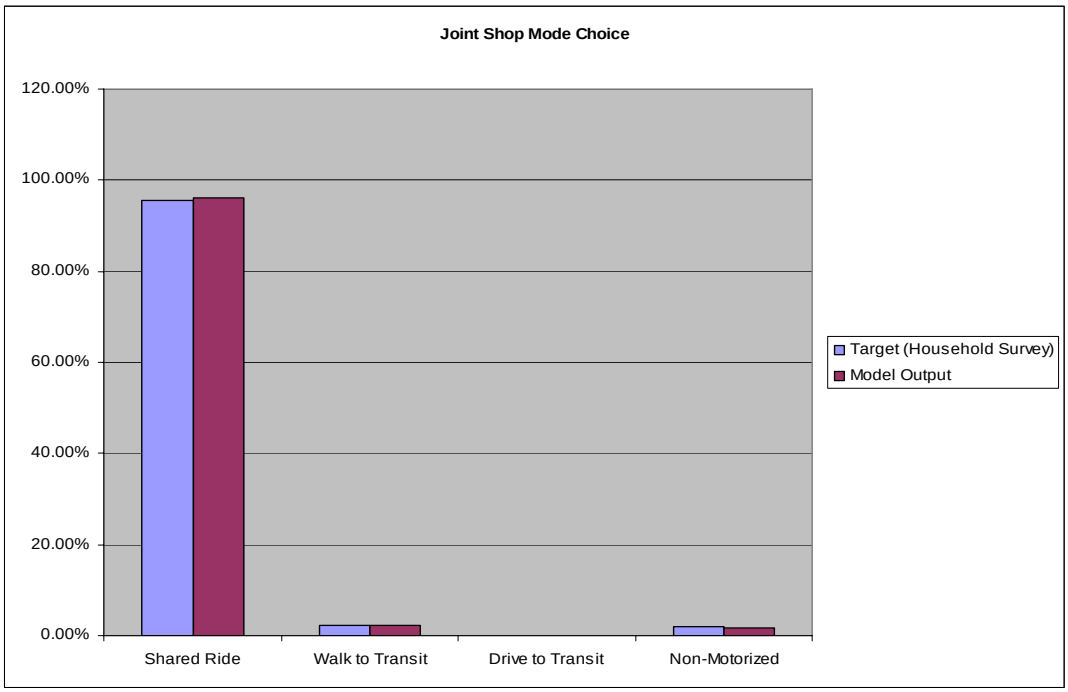


Figure 8.20: Mode choice share comparisons for joint shop tours



CHAPTER 9
Individual Non-Mandatory Tour Model

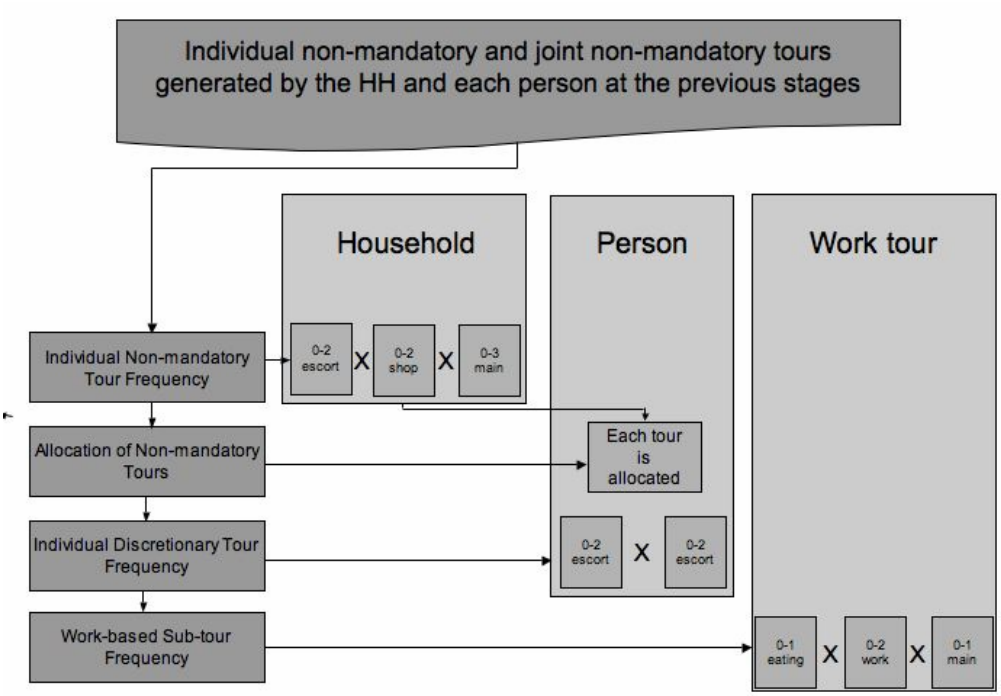
CHAPTER 9 – INDIVIDUAL NON-MANDATORY TOUR MODEL

9.1 Individual Non-Mandatory Tour Generation Model

The individual tour generation model for non-mandatory activity includes 4 choice sub-models applied successively – see **Figure 9.1** below:

- Model for individual tours for household maintenance (i.e. grocery shopping, mail pick-up) activities allocated to the household members. Though these tours are implemented individually, the basic need for this activity relates to the entire household. This model is in subdivided into two successively applied sub-models:
  - Household tour frequency choice sub-model for maintenance activities implemented individually
  - Model for allocation of maintenance tours to a household member
- Sub-model for individual tours for personal discretionary (i.e. going to the movies, taking a drive) activities; it is assumed that these activities are generated and scheduled at the person level without significant interaction among household members (recall that joint tours generated by shared discretionary activity of several household members are modeled beforehand in the model stream).
- Model for non-home-based sub-tours at work.

Figure 9.1: Individual Non-mandatory Model Structure



Individual tours generated by allocated maintenance activities are modeled first for each person conditional upon the chosen daily pattern and participation in joint household tours. Since these activities are generated by the entire household and then allocated to particular members, it is important to follow an underlying intra-household allocation process.

Individual tours for personal discretionary activities are modeled next because they normally have a lower priority in scheduling. Intra-household linkage is less important at this stage. Person availability in terms of time window left

after scheduling the mandatory activities, joint activities, and allocated activities becomes the most crucial determinant.

Work-based sub-tours are modeled last. They are relevant only for those persons who implement at least one work tour. These underlying activities are mostly individual (business-related and eating-out purposes), but may include some household maintenance functions as well that are linked to the person and entire-household maintenance tasks.

Preschool children are not considered in the individual tour model as potential tour makers since they normally do not travel by themselves. However, the presence of preschool children as well as their chosen daily activity patterns (for example, going to kindergarten instead of staying at home because of sickness) is included as an important explanatory variable for the other household members. Additionally, persons who have chosen a stay-at-home daily pattern are also excluded since they do not travel.

Below is the short description of the proposed main structural features for each of the four sub-models.

9.2 Individual Maintenance Tour Frequency Choice Model

Unit: Household

Segmentation: Full segmentation of alternative-specific constants by travel purpose combinations, partial segmentation of the other coefficients by travel purpose

Choice alternatives (36 combinations of 0,1,2 escorting tours with 0,1,2 shopping tours and with 0,1,2,3 other maintenance tours):

- No escorting tour, no shopping tour, no other maintenance tour
- No escorting tour, no shopping tour, 1 other maintenance tour
- No escorting tour, no shopping tour, 2 other maintenance tours

…Etc.

Main explanatory variables:

- Household size and composition
  - Number of full-time workers
  - Presence of a part-time worker
  - Presence of a non-working adult
  - Presence of a school driving-age child
  - Total number of preschool and school pre-driving-age children
  - 1-person household dummy
- Household income
- Car ownership/sufficiency
- Accessibility indices:
- Auto accessibility to retail attractions
- Transit accessibility to retail attractions
  - Walk accessibility to retail attractions
- Logged maximum residual windows:
  - Across household adults
  - Across household children

- Joint tours implemented by the household:
  - At least one shopping tour
  - At least one maintenance tour
  - At least one eating-out tour
- Activity patterns chosen by the household members:
  - Preschool or school pre-driving-age child at home
  - Full-time worker at home
  - Part-time worker at home
  - Non-working adult at home

The results of the calibrated individual maintenance tour frequency model are presented in **Table 9.2**. Because there are so many alternatives, the following abbreviations are used in the estimation results:

Table 9.1: Abbreviations for individual maintenance tour estimation results

Tour Type	Abbreviation
Shop	S
Escort	E
Maintenance	M

Table 9.2: Individual non-mandatory maintenance tour frequency estimation results

Variable	No Tours	M	MM	MMM	E
Alternative-specific constant	-0.1200	-5.0540	-10.8200	-17.0000	-6.0000
Number of full time workers					0.0977
Presence of a part time worker		0.1551	0.3102	0.4653	0.3498
Number of non-workers		0.2542	0.5084	0.7626	
Presence of non-worker					0.4524
Number of non-driving children		0.0822	0.1644	0.2466	0.2639
Presence of driving child		0.4711	0.9422	1.4133	0.2118
Household size = 1					-0.9400
Medium income		0.1681	0.3362	0.5043	
High income		0.2007	0.4014	0.6021	0.1345
No autos in household					-1.3080
Workers minus autos (if positive)					0.4798
Log of max window across household adults		1.5100	3.0200	4.5300	1.1210
Log of max window across household children					0.3338
At least one joint shopping tour made by household					
At least one joint maintenance tour made by household		-0.1526	-0.3052	-0.4578	-0.4045
At least one joint eating-out tour made by household		-0.1947	-0.3894	-0.5841	
Auto accessibility to retail in 30 minutes					0.1055
Transit accessibility to retail in 30 minutes		0.0062	0.0123	0.0185	
Walk accessibility to retail in 20 minutes					0.0668
Non-driving child with at-home pattern		-0.4238	-0.8476	-1.2714	-0.7502
Part-time worker with at-home pattern	0.5392				
Non-worker with at-home pattern	1.0200				

Table 9.2: Individual non-mandatory maintenance tour frequency estimation results continued

Variable	EM	EMM	EMMM	EE	EEM
Alternative-specific constant	-11.4000	-16.8400	-23.7500	-10.5000	-17.4200
Number of full time workers	0.0977	0.0977	0.0977	0.1954	0.1954
Presence of a part time worker	0.5049	0.6600	0.8151	0.6996	0.8547
Number of non-workers	0.2542	0.5084	0.7626		0.2542
Presence of non-worker	0.4524	0.4524	0.4524	0.9048	0.9048
Number of non-driving children	0.3461	0.4283	0.5105	0.5278	0.6100
Presence of driving child	0.6829	1.1540	1.6251	0.4236	0.8947
Household size = 1	-0.9400	-0.9400	-0.9400	-1.8800	-1.8800
Medium income	0.1681	0.3362	0.5043		0.1681
High income	0.3352	0.5359	0.7366	0.2690	0.4697
No autos in household	-1.3080	-1.3080	-1.3080	-2.6160	-2.6160
Workers minus autos (if positive)	0.4798	0.4798	0.4798	0.9596	0.9596
Log of max window across household adults	2.6310	4.1410	5.6510	2.2420	3.7520
Log of max window across household children	0.3338	0.3338	0.3338	0.6676	0.6676
At least one joint shopping tour made by household					
At least one joint maintenance tour made by household	-0.5571	-0.7097	-0.8623	-0.8090	-0.9616
At least one joint eating-out tour made by household	-0.1947	-0.3894	-0.5841		-0.1947
Auto accessibility to retail in 30 minutes	0.1055	0.1055	0.1055	0.2110	0.2110
Transit accessibility to retail in 30 minutes	0.0062	0.0123	0.0185		0.0062
Walk accessibility to retail in 20 minutes	0.0668	0.0668	0.0668	0.1335	0.1335
Non-driving child with at-home pattern	-1.1740	-1.5978	-2.0216	-1.5004	-1.9242
Variable	EEMM	EEMMM	S	SM	SMM
Alternative-specific constant	-25.0100	-29.5700	-4.4000	-9.8000	-16.2400
Number of full time workers	0.1954	0.1954			
Presence of a part time worker	1.0098	1.1649	0.2191	0.3742	0.5293
Number of non-workers	0.5084	0.7626	0.3262	0.5804	0.8346
Presence of non-worker	0.9048	0.9048			
Number of non-driving children	0.6922	0.7744		0.0822	0.1644
Presence of driving child	1.3658	1.8369	0.4705	0.9416	1.4127
Household size = 1	-1.8800	-1.8800			
Medium income	0.3362	0.5043	0.1340	0.3021	0.4702
High income	0.6704	0.8711	0.3063	0.5070	0.7077
No autos in household	-2.6160	-2.6160	-0.3470	-0.3470	-0.3470
Workers minus autos (if positive)	0.9596	0.9596			
Log of max window across household adults	5.2620	6.7720	1.3220	2.8320	4.3420
Log of max window across household children	0.6676	0.6676			
At least one joint shopping tour made by household			-0.4450	-0.4450	-0.4450
At least one joint maintenance tour made by household	-1.1142	-1.2668		-0.1526	-0.3052
At least one joint eating-out tour made by household	-0.3894	-0.5841		-0.1947	-0.3894
Auto accessibility to retail in 30 minutes	0.2110	0.2110			0.0000
Transit accessibility to retail in 30 minutes	0.0123	0.0185	0.0142	0.0204	0.0265
Walk accessibility to retail in 20 minutes	0.1335	0.1335	0.0414	0.0414	0.0414
Non-driving child with at-home pattern	-2.3480	-2.7718	-0.3776	-0.8014	-1.2252

Table 9.2: Individual non-mandatory maintenance tour frequency estimation results continued

Variable	SMMM	SE	SEM	SEMM	SEMMM
Alternative-specific constant	-22.1500	-10.8600	-16.1600	-21.4600	-27.3500
Number of full time workers		0.0977	0.0977	0.0977	0.0977
Presence of a part time worker	0.6844	0.5689	0.7240	0.8791	1.0342
Number of non-workers	1.0888	0.3262	0.5804	0.8346	1.0888
Presence of non-worker		0.4524	0.4524	0.4524	0.4524
Number of non-driving children	0.2466	0.2639	0.3461	0.4283	0.5105
Presence of driving child	1.8838	0.6823	1.1534	1.6245	2.0956
Household size = 1		-0.9400	-0.9400	-0.9400	-0.9400
Medium income	0.6383	0.1340	0.3021	0.4702	0.6383
High income	0.9084	0.4408	0.6415	0.8422	1.0429
No autos in household	-0.3470	-1.6550	-1.6550	-1.6550	-1.6550
Workers minus autos (if positive)		0.4798	0.4798	0.4798	0.4798
Log of max window across household adults	5.8520	2.4430	3.9530	5.4630	6.9730
Log of max window across household children		0.3338	0.3338	0.3338	0.3338
At least one joint shopping tour made by household	-0.4450	-0.4450	-0.4450	-0.4450	-0.4450
At least one joint maintenance tour made by household	-0.4578	-0.4045	-0.5571	-0.7097	-0.8623
At least one joint eating-out tour made by household	-0.5841	0.0000	-0.1947	-0.3894	-0.5841
Auto accessibility to retail in 30 minutes		0.1055	0.1055	0.1055	0.1055
Transit accessibility to retail in 30 minutes	0.0327	0.0142	0.0204	0.0265	0.0327
Walk accessibility to retail in 20 minutes	0.0414	0.1082	0.1082	0.1082	0.1082
Non-driving child with at-home pattern	-1.6490	-1.1278	-1.5516	-1.9754	-2.3992
Variable	SEE	SEEM	SEEMM	SEEMMM	SS
Alternative-specific constant	-15.8400	-23.0700	-26.7400	-32.6500	-9.6000
Number of full time workers	0.1954	0.1954	0.1954	0.1954	
Presence of a part time worker	0.9187	1.0738	1.2289	1.3840	0.4382
Number of non-workers	0.3262	0.5804	0.8346	1.0888	0.6524
Presence of non-worker	0.9048	0.9048	0.9048	0.9048	
Number of non-driving children	0.5278	0.6100	0.6922	0.7744	
Presence of driving child	0.8941	1.3652	1.8363	2.3074	0.9410
Household size = 1	-1.8800	-1.8800	-1.8800	-1.8800	
Medium income	0.1340	0.3021	0.4702	0.6383	0.2680
High income	0.5753	0.7760	0.9767	1.1774	0.6126
No autos in household	-2.9630	-2.9630	-2.9630	-2.9630	-0.6940
Workers minus autos (if positive)	0.9596	0.9596	0.9596	0.9596	
Log of max window across household adults	3.5640	5.0740	6.5840	8.0940	2.6440
Log of max window across household children	0.6676	0.6676	0.6676	0.6676	
At least one joint shopping tour made by household	-0.4450	-0.4450	-0.4450	-0.4450	-0.8900
At least one joint maintenance tour made by household	-0.8090	-0.9616	-1.1142	-1.2668	
At least one joint eating-out tour made by household		-0.1947	-0.3894	-0.5841	
Auto accessibility to retail in 30 minutes	0.2110	0.2110	0.2110	0.2110	
Transit accessibility to retail in 30 minutes	0.0142	0.0204	0.0265	0.0327	0.0284
Walk accessibility to retail in 20 minutes	0.1750	0.1750	0.1750	0.1750	0.0828
Non-driving child with at-home pattern	-1.8780	-2.3018	-2.7256	-3.1494	-0.7552

Table 9.2: Individual non-mandatory maintenance tour frequency estimation results continued

Variable	SSM	SSMM	SSMMM	SSE	SSEM
Alternative-specific constant	-15.5000	-21.2100	-26.8600	-17.3100	-28.8300
Number of full time workers				0.0977	0.0977
Presence of a part time worker	0.5933	0.7484	0.9035	0.7880	0.9431
Number of non-workers	0.9066	1.1608	1.4150	0.6524	0.9066
Presence of non-worker				0.4524	0.4524
Number of non-driving children	0.0822	0.1644	0.2466	0.2639	0.3461
Presence of driving child	1.4121	1.8832	2.3543	1.1528	1.6239
Household size = 1				-0.9400	-0.9400
Medium income	0.4361	0.6042	0.7723	0.2680	0.4361
High income	0.8133	1.0140	1.2147	0.7471	0.9478
No autos in household	-0.6940	-0.6940	-0.6940	-2.0020	-2.0020
Workers minus autos (if positive)				0.4798	0.4798
Log of max window across household adults	4.1540	5.6640	7.1740	3.7650	5.2750
Log of max window across household children				0.3338	0.3338
At least one joint shopping tour made by household	-0.8900	-0.8900	-0.8900	-0.8900	-0.8900
At least one joint maintenance tour made by household	-0.1526	-0.3052	-0.4578	-0.4045	-0.5571
At least one joint eating-out tour made by household	-0.1947	-0.3894	-0.5841		-0.1947
Auto accessibility to retail in 30 minutes				0.1055	0.1055
Transit accessibility to retail in 30 minutes	0.0346	0.0408	0.0469	0.0284	0.0346
Walk accessibility to retail in 20 minutes	0.0828	0.0828	0.0828	0.1496	0.1496
Non-driving child with at-home pattern	-1.1790	-1.6028	-2.0266	-1.5054	-1.9292

Variable	SSEMM	SSEMMM	SSEE
Alternative-specific constant	-26.6700	-35.2200	-21.2600
Number of full time workers	0.0977	0.0977	0.1954
Presence of a part time worker	1.0982	1.2533	1.1378
Number of non-workers	1.1608	1.4150	0.6524
Presence of non-worker	0.4524	0.4524	0.9048
Number of non-driving children	0.4283	0.5105	0.5278
Presence of driving child	2.0950	2.5661	1.3646
Household size = 1	-0.9400	-0.9400	-1.8800
Medium income	0.6042	0.7723	0.2680
High income	1.1485	1.3492	0.8816
No autos in household	-2.0020	-2.0020	-3.3100
Workers minus autos (if positive)	0.4798	0.4798	0.9596
Log of max window across household adults	6.7850	8.2950	4.8860
Log of max window across household children	0.3338	0.3338	0.6676
At least one joint shopping tour made by household	-0.8900	-0.8900	-0.8900
At least one joint maintenance tour made by household	-0.7097	-0.8623	-0.8090
At least one joint eating-out tour made by household	-0.3894	-0.5841	0.0000
Auto accessibility to retail in 30 minutes	0.1055	0.1055	0.2110
Transit accessibility to retail in 30 minutes	0.0408	0.0469	0.0284
Walk accessibility to retail in 20 minutes	0.1496	0.1496	0.2164
Non-driving child with at-home pattern	-2.3530	-2.7768	-2.2556

Table 9.2: Individual non-mandatory maintenance tour frequency estimation results continued

Variable	SSEEM	SSEEMM	SSEEMMM
Alternative-specific constant	-30.1900	-35.8850	-41.5800
Number of full time workers	0.1954	0.1954	0.1954
Presence of a part time worker	1.2929	1.4480	1.6031
Number of non-workers	0.9066	1.1608	1.4150
Presence of non-worker	0.9048	0.9048	0.9048
Number of non-driving children	0.6100	0.6922	0.7744
Presence of driving child	1.8357	2.3068	2.7779
Household size = 1	-1.8800	-1.8800	-1.8800
Medium income	0.4361	0.6042	0.7723
High income	1.0823	1.2830	1.4837
No autos in household	-3.3100	-3.3100	-3.3100
Workers minus autos (if positive)	0.9596	0.9596	0.9596
Log of max window across household adults	6.3960	7.9060	9.4160
Log of max window across household children	0.6676	0.6676	0.6676
At least one joint shopping tour made by household	-0.8900	-0.8900	-0.8900
At least one joint maintenance tour made by household	-0.9616	-1.1142	-1.2668
At least one joint eating-out tour made by household	-0.1947	-0.3894	-0.5841
Auto accessibility to retail in 30 minutes	0.2110	0.2110	0.2110
Transit accessibility to retail in 30 minutes	0.0346	0.0408	0.0469
Walk accessibility to retail in 20 minutes	0.2164	0.2164	0.2164
Non-driving child with at-home pattern	-2.6794	-3.1032	-3.5270

9.3 Individual Non-Mandatory Maintenance Tour Frequency Model Calibration

To perform model calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Figure 9.2: Individual non-mandatory maintenance tour frequency comparison – tour(s) chosen or not

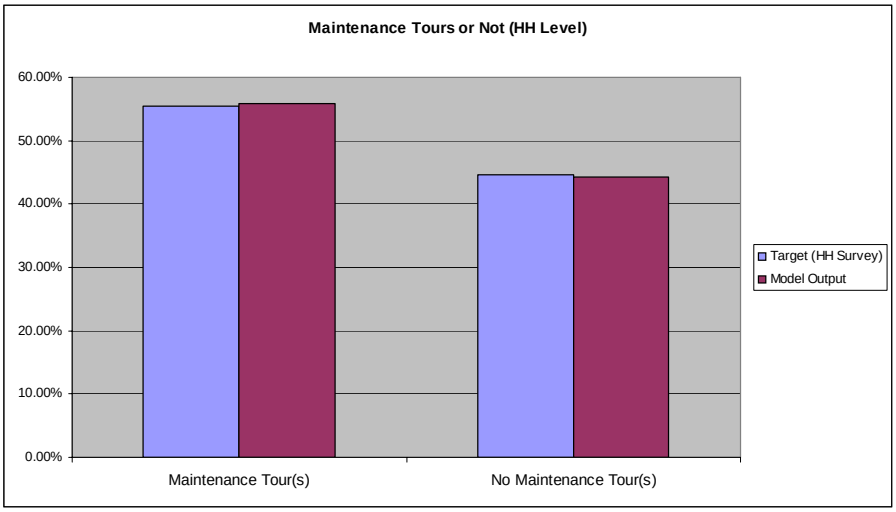


Figure 9.3a: Individual non-mandatory maintenance tour frequency comparison

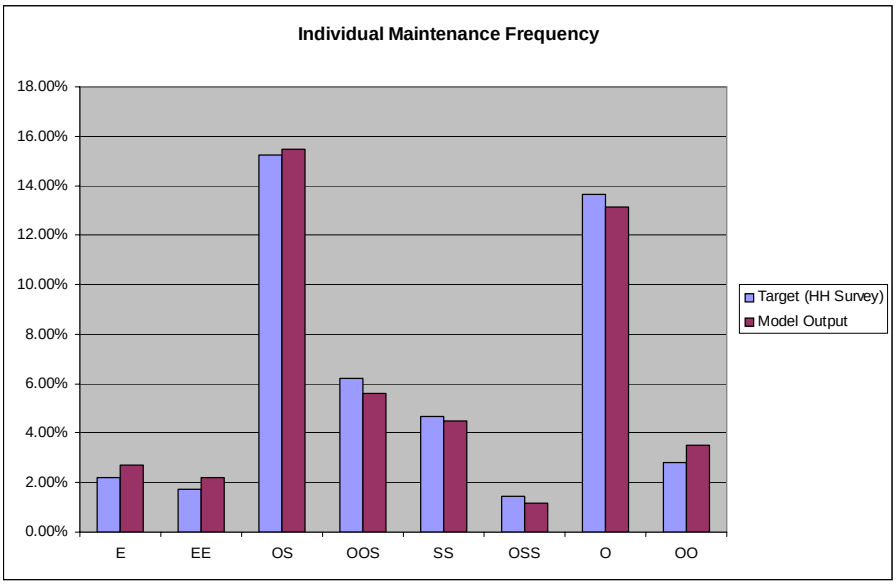
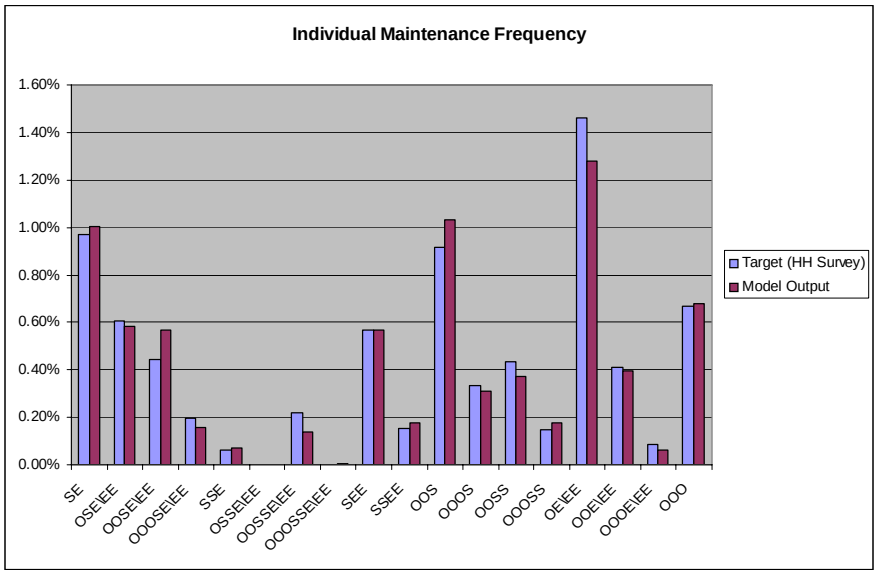


Figure 9.3b: Individual non-mandatory maintenance tour frequency comparison



9.4 Individual Maintenance Tour Allocation Model

Unit: Individual maintenance tour

Segmentation: Full segmentation of alternative-specific constants by travel purpose

Choice alternatives (all household members of 5 person types excluding preschool children and those who have chosen stay-at-home pattern):

- Full-time workers not staying at home for the whole day
- Part-time workers not staying at home for the whole day
- Non-working adults not staying at home for the whole day
- School pre-driving age children not staying at home for the whole day
- School driving age children not staying at home for the whole day

Main explanatory variables:

- Person characteristics:
  - Logged residual time window
  - Non-mandatory daily pattern type dummy
  - Number of joint tour participations
- Household income
- Car ownership/sufficiency
- Residential area type
- Transit accessibility to retail attractions
- Activity patterns combinations chosen by the household members:
  - Preschool or school pre-driving-age child staying at home with other adult
  - Preschool or school pre-driving-age child staying at home alone

Table 9.3 presents the results of the calibrated individual maintenance tour allocation model estimation.

Table 9.3: Individual non-mandatory maintenance tour allocation model estimation results

	Person Type				
Variable	Full Time Worker	Part Time Worker	Non-worker	Pre-Driving Child	Driving Child
Shopping tour	9.4280	11.1230	14.1500	8.3570	8.6060
Escorting tour	9.0300	9.4100	12.9000	3.0000	7.3000
Maintenance tour	8.5000	10.8590	14.2000	7.6540	8.8630
Log of the persons available time window	1.5600	1.4960	5.4070	2.3000	1.9650
Non-mandatory pattern	0.5012	0.4458		0.6382	
Number of joint tour participants in household	-0.3325		-0.4007	-1.3000	
Medium income					
High income				-0.3646	
Non-driving child and adult with at-home pattern	1.4740	2.3940	2.1540		
Non-driving child with at-home pattern (no adult at home)			-0.3892		
Urban home	0.7857	0.8552		0.7766	0.7484
Suburban home	0.7493	0.5524		0.5533	0.6173

9.5 Individual Maintenance Tour Allocation Model Calibration

To perform model calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Figure 9.4: Individual maintenance escort tour frequency comparison

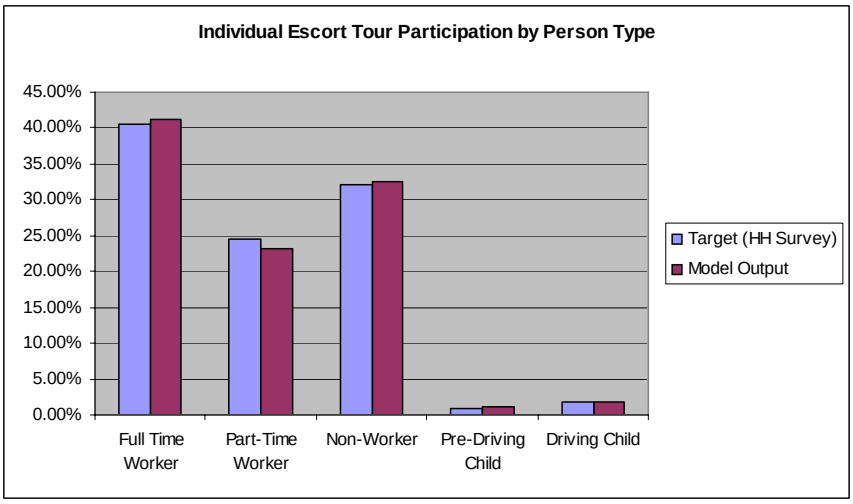


Figure 9.5: Individual maintenance shop tour frequency comparison

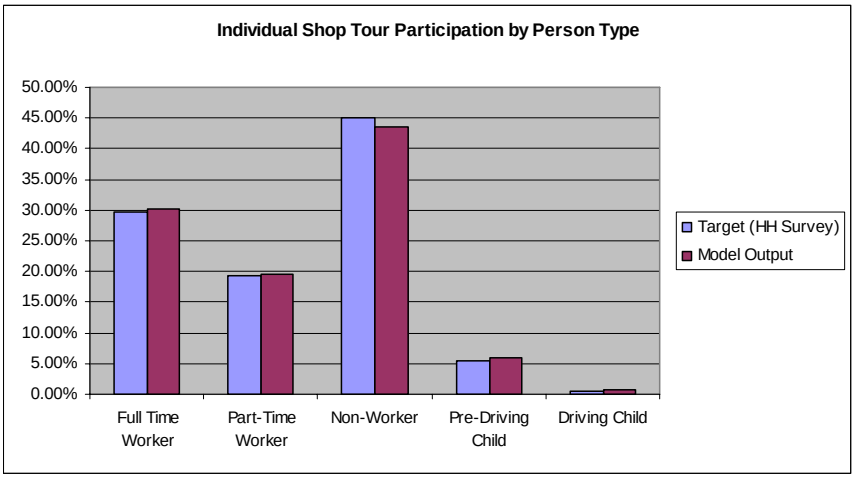
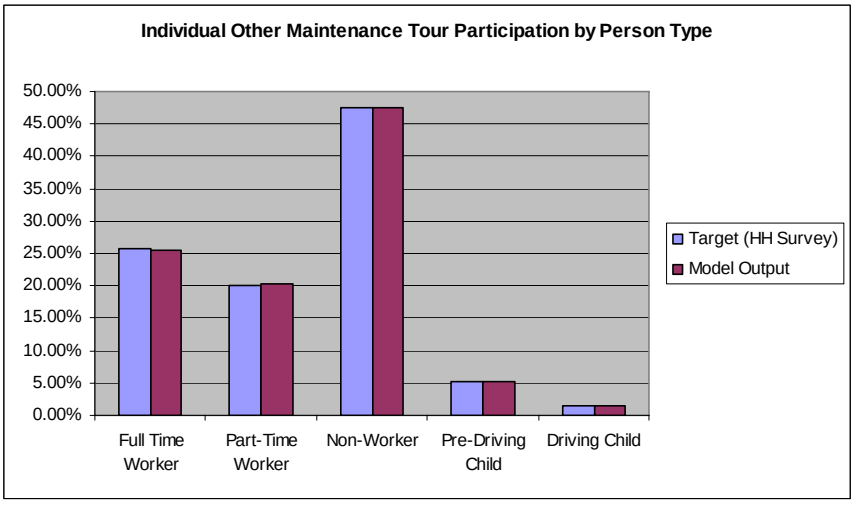


Figure 9.6: Individual maintenance shop tour frequency comparison



9.6 Individual Discretionary Tour Frequency Choice Model

Unit: Person, excluding preschool children and those who have chosen a stay-at-home pattern

Segmentation: Full segmentation of the model by 3 aggregate person types (workers, non-working adults, and children); full segmentation of alternative-specific constants by travel purpose combination and 6 detailed person types, partial segmentation of the other coefficients by travel purpose

Choice alternatives (3):

- No individual discretionary (not available for those who had chosen the non-mandatory travel pattern but was not assigned any joint or individual tour by the subsequent models applied before the current stage)
- 1 individual discretionary tour
- 2 individual discretionary tours

Main explanatory variables:

- Person characteristics:
  - Logged residual time window
  - Joint tour participations:
    - At least one joint shopping tour
    - At least one joint other maintenance tour
    - At least one joint discretionary tour
- Household composition:
  - Presence of a full-time worker other than the modeled person
  - Presence of a part-time worker other than the modeled person
  - Presence of a non-working adult other than the modeled person
  - Presence of a school driving-age child other than the modeled person
  - No of school pre-driving-age children
  - No of preschool children
  - Presence of two or more non-working adults (older household)
- Household income
- Car ownership/sufficiency
- Residential area type
- Accessibility indices:
  - Transit accessibility to retail attractions
  - Walk accessibility to retail attractions
- Activity patterns chosen by the other household members:
  - Preschool or school pre-driving-age child staying at home
  - Full-time worker staying at home
  - Part time worker staying at home
  - Non-working adult staying at home

Tables 9.5-9.7 presents the results of the calibrated individual discretionary tour frequency model. To simplify the alternatives, the following abbreviations are used:

Table 9.4: Abbreviations for individual discretionary tour estimation results

Tour Type	Abbreviation
Discretionary	D
Eat	E

Table 9.5: Individual discretionary tour frequency estimation results for workers

Variable	No Tours	E	D	DD	ED
Full time worker		-6.7310	-5.6880	-12.1900	-11.9200
Part time worker		-6.7430	-5.8050	-12.0500	-11.6500
Another adult in household is full time worker		-0.7100	-0.1319	-0.2638	-0.8419
Another adult in household is part time worker		-0.7899		0.0000	-0.7899
One non-worker in household		-0.3307	-0.0281	-0.0563	-0.3588
More than one non-worker in household		-0.3307	-1.0510	-2.1020	-1.3817
Driving child in household		0.0598	0.0433	0.0866	0.1031
Number of pre-driving children in household		-0.4089	0.0360	0.0720	-0.3729
Number of preschool children in household		-0.5840	-0.0817	-0.1634	-0.6657
Household size = 1		-0.1001	0.6354	1.2708	0.5353
Medium income		1.0000	0.3012	0.6024	1.3012
High income		0.4510	0.3702	0.7404	0.8212
Workers minus autos (if positive)		-0.2822	-0.0594	-0.1189	-0.3416
Log of available time window		1.1030	1.1860	2.3720	2.2890
Participated in at least one joint shop/maint/eat tour			-0.4391	-0.8782	-0.4391
Participated in at least one joint shop/maint tour		-1.6010		0.0000	-1.6010
Participated in at least one joint discretionary tour		-0.9057	-1.0440	-2.0880	-1.9497
Participated in at least one joint eat tour		-1.1370		0.0000	-1.1370
Urban home		0.1580	0.3371	0.6742	0.4951
Suburban home		0.2779	0.1596	0.3192	0.4375
Transit accessibility to retail in 30 minutes		0.0095		0.0000	0.0095
Preschool child with at-home pattern in household		-0.7777	-0.9045	-1.8090	-1.6822
Full time worker with at-home pattern in household	0.6277				
Part time worker or non-worker with at-home pattern in household	0.4463				
Non-mandatory pattern and no joint tour participation	Unavailable				
At-home pattern		Unavailable	Unavailable	Unavailable	Unavailable

Table 9.6: Individual discretionary tour frequency estimation results for non-workers

Variable	No Tours	E	D	DD	ED
Alternative-specific constant		-6.3610	-5.1760	-7.2220	-8.0440
Presence of full time worker in household		-0.7871	-0.1612	-0.3224	-0.9483
Presence of part time worker in household		-0.4724	-0.0756	-0.1512	-0.5480
Presence of another non-worker in household		-0.2710	-0.3737	-0.7474	-0.6447
Presence of driving child in household		0.3127	0.3418	0.6836	0.6545
Number of preschool children in household		-0.5101	-0.3904	-0.7808	-0.9005
Number of pre-driving children in household		-0.5101	-0.0233	-0.0465	-0.5334
Medium income		0.2042	0.2102	0.4204	0.4144

Variable	No Tours	E	D	DD	ED
High income		0.3409	0.2102	0.4204	0.5511
No autos in household		-1.1400	-0.9822	-1.9644	-2.1222
Workers minus autos (if positive)		-0.2365	-0.1036	-0.2072	-0.3401
Log of available time window			0.0888	0.1776	0.0888
Participated in at least one joint shop/main tour		-0.7579	-0.3461	-0.6922	-1.1040
Participated in at least one joint discretionary tour		-0.3233	-0.2527	-0.5054	-0.5760
Participated in at least one joint eat tour		-0.1431		0.0000	-0.1431
Urban home		0.2842	0.2663	0.5326	0.5505
Suburban home		0.1874	0.1213	0.2426	0.3087
Walk accessibility to retail in 20 minutes		0.0786		0.0000	0.0786
Preschool child with at-home pattern in household		-1.7950	-1.9010	-3.8020	-3.6960
Pre-driving child with at-home pattern in household			-0.8036	-1.6072	-0.8036
Full or part-time worker with at-home pattern in household	0.2852				
Non-mandatory pattern and no joint tour participation	Unavailable				
At-home pattern		Unavailable	Unavailable	Unavailable	Unavailable

Table 9.7: Individual discretionary tour frequency estimation results for children

Variable	No Tours	E	D	DD	ED
Pre-driving child		-11.3800	-5.4080	-12.0300	-16.5200
Driving child		-11.4900	-4.9010	-11.5300	-16.5700
Presence of full-time worker in household		1.8050	0.3370	0.6740	2.1420
Presence of part-time worker in household		-0.4533	0.2528	0.5056	-0.2005
Presence of non-worker in household		-0.1248		0.0000	-0.1248
Exactly one non-worker in household			0.0478	0.0956	0.0478
Two or more non-workers in household			0.5464	1.0928	0.5464
Presence of preschool child in household		-0.4277	-0.1939	-0.3878	-0.6216
Presence of school pre-driving child other than the modeled person in household		-0.3761	-0.0555	-0.1111	-0.4316
Presence of school driving child other than the modeled person in household		0.0895	0.4810	0.9620	0.5705
Medium income		-0.8842	0.6513	1.3026	-0.2329
High income		-1.1500	0.7571	1.5142	-0.3929
Adults minus autos (if positive) - driving child			-0.5101	-1.0202	-0.5101
Autos minus adults (if positive) - driving child		0.5547	0.1254	0.2508	0.6801
Log of the persons available time window		2.5020	1.1230	2.2460	3.6250
Participated in at least one joint shop/main/eat tour			-0.8967	-1.7934	-0.8967
Participated in at least one joint shop/main tour		-2.8410		0.0000	-2.8410
Participated in at least one joint discretionary tour			-0.5792	-1.1584	-0.5792
Participated in at least one joint eat tour		-1.0980		0.0000	-1.0980
Urban home		-1.6890		0.0000	-1.6890
Suburban home		0.2201	0.1990	0.3980	0.4191
Transit accessibility to retail in 30 minutes		0.0391		0.0000	0.0391
Preschool child with at-home pattern in household		-1.6690	-1.0950	-2.1900	-2.7640

Variable	No Tours	E	D	DD	ED
Pre-driving child with at-home pattern in household		-2.0770	-1.5090	-3.0180	-3.5860
Full or part time worker with at-home pattern in household	2.5610				
Non-worker with at-home pattern in household	0.8578				
Non-mandatory pattern and no joint tour participation	Unavailable				
At-home pattern		Unavailable	Unavailable	Unavailable	Unavailable

9.7 Individual Discretionary Tour Frequency Choice Model Calibration

To perform model calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Figure 9.7: Individual discretionary tour participation comparison – workers

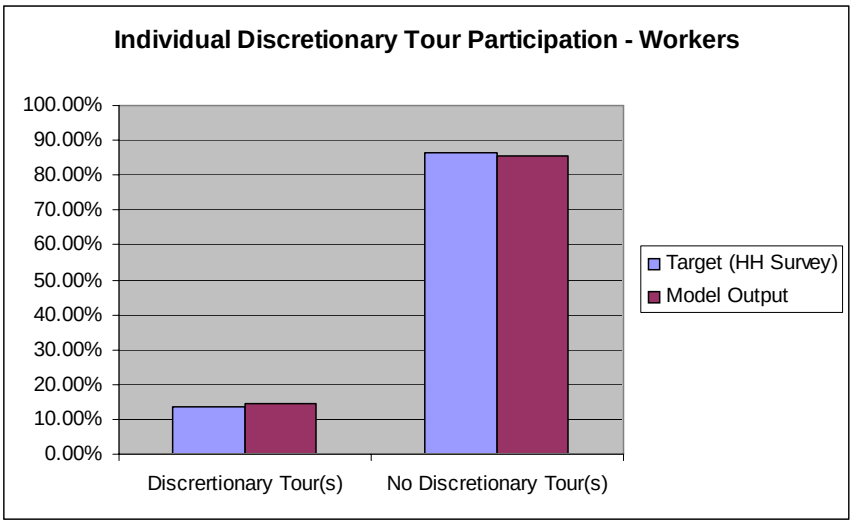


Figure 9.8: Individual discretionary tour frequency comparison – workers

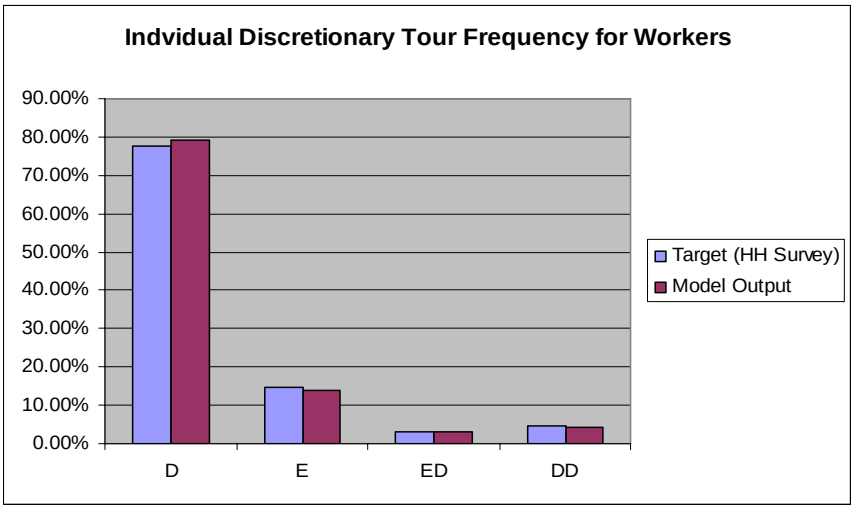


Figure 9.9: Individual discretionary tour participation comparison – non-workers

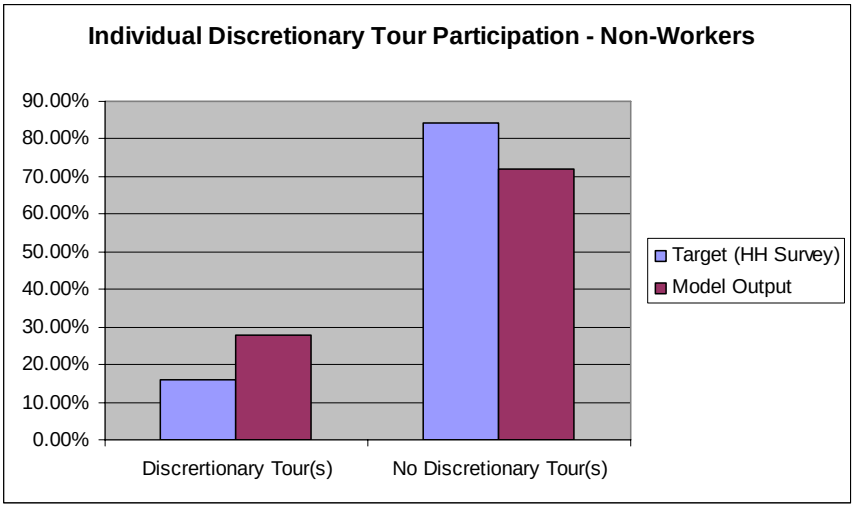


Figure 9.10: Individual discretionary tour frequency comparison – non-workers

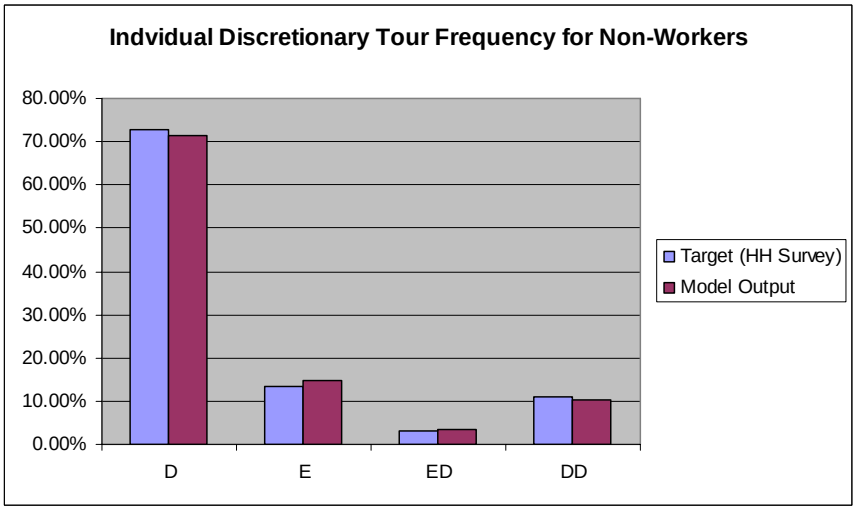


Figure 9.11: Individual discretionary tour participation comparison – children

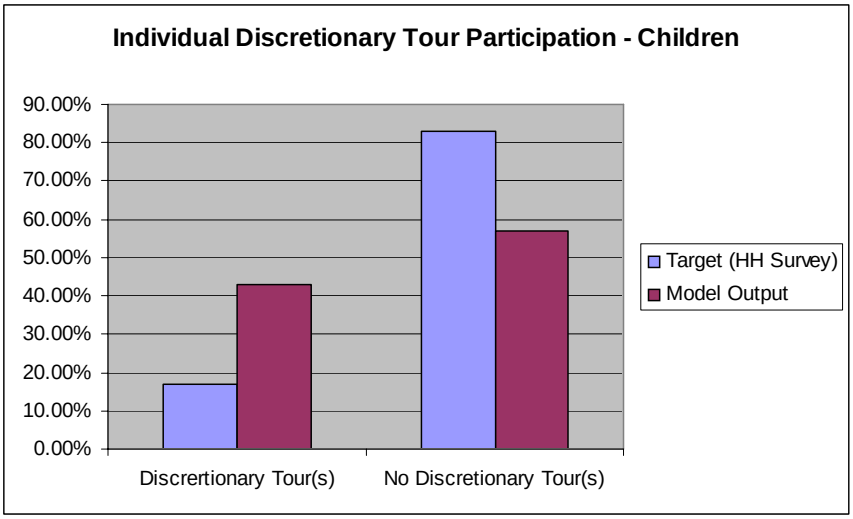
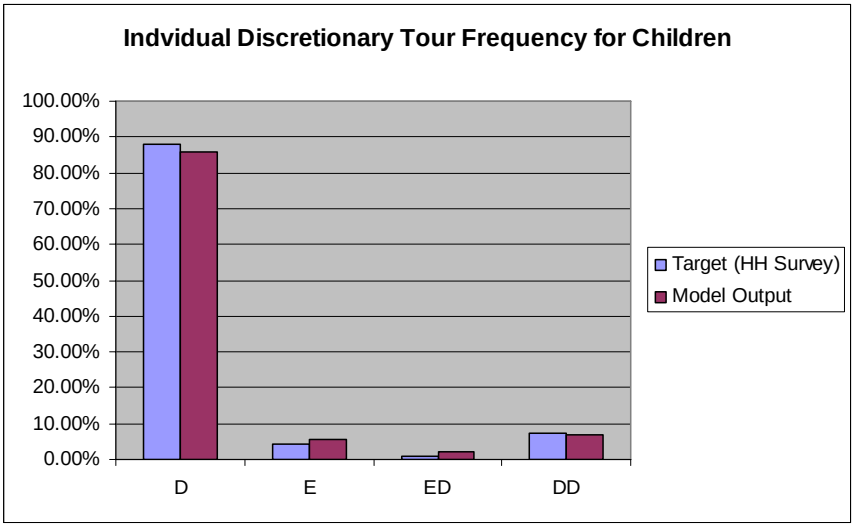


Figure 9.12: Individual discretionary tour frequency comparison – children



9.8 Work-Based Sub-tour Frequency Choice Model

Unit: Work tour

Segmentation: Full segmentation of alternative-specific constants by travel purpose combination and 2 aggregate person types (full-time worker vs. the other types), partial segmentation of the other coefficients by travel purpose.

Choice alternatives (4):

- No at-work sub-tours
- 1 at-work sub-tour for business-related purpose
- 1 at-work sub-tour for other (maintenance) purpose
- 2 at-work sub-tours for business-related purpose

Main explanatory variables:

- Work tour characteristics:
  - Work tour duration
  - Drive-alone mode dummy
- Person characteristics:
  - 2 work tours dummy
  - Joint tour participations:
    - At least one joint shopping/maintenance/eating-out tour
    - At least one joint discretionary tour
  - Individual non-mandatory tours:
    - At least one escorting/shopping/other maintenance tour
    - At least one discretionary tour
- Household income
- Zero auto ownership
- Workplace area type
- Accessibility indices from the workplace:

  - Auto accessibility to retail attractions
  - Walk accessibility to retail attractions
- Activity patterns chosen by the other household members:
  - Full-time worker with non-mandatory pattern
  - Part time worker with non-mandatory pattern

Table 9.9 presents the results of the calibrated individual work-based sub-tour frequency model. To simplify the alternatives, the following abbreviations are used:

Table 9.8: Abbreviations for individual work-based sub-tour estimation results

Tour Type	Abbreviation
Eat	E
Work-Related	W
Other	O

Table 9.9: Individual work-based sub-tour frequency estimation results

Variable	No Sub-Tours	E	W	O	WW	EW
Full-time worker		-6.9300	-6.1550	-7.4080	-12.8700	-14.1200
Not full-time worker		-8.0540	-6.8690	-7.2790	-12.2700	-13.9800
Not full or part-time worker		0.6000	-3.5500	-4.4000	-3.0500	-6.3800
Medium income		0.6100	0.5555	0.1527	1.1110	1.1655
High income		0.8693	1.0660	0.1651	2.1320	1.9353
No cars in household		-0.3391		0.1762	0.0000	-0.3391
Full-time worker, individual discretionary tour already chosen		0.2334	0.7045	0.5061	1.4090	0.9379
Part-time worker, individual discretionary tour already chosen		0.6776	0.7045	0.5061	1.4090	1.3821
Individual eat-out tour already chosen		0.5491	0.5434	0.9166	1.0868	1.0925
Full-time worker, individual maintenance/shop/ escort tour already chosen		-0.0520	-0.1903	0.1446	-0.3806	-0.2423
Part-time worker, individual maintenance/ shop/escort tour already chosen		-0.3099	-0.1903	-0.2723	-0.3806	-0.5002
Joint shop/main/eat tour already chosen		0.2458	0.0830	0.0803	0.1660	0.3288
Joint discretionary tour already chosen		0.3588	-0.2637	0.5822	-0.5274	0.0951
Natural log of the work tour duration		1.5500	1.1420	1.6590	2.2840	2.6920
Drove alone to work		0.4804	0.9901	1.1530	1.9802	1.4705
Chose two work tours		-0.9862	0.3753	-0.2312	0.7506	-0.6109
Urban work location		-0.4182	-0.2235	-0.1479	-0.4470	-0.6417
Suburban work location		-0.2916	-0.1102		-0.2204	-0.4018
Auto accessibility to retail in 30 minutes		0.0150	0.0534	0.0265	0.1067	0.0683
Walk accessibility to retail in 20 minutes		0.1256		0.0806		0.1256
Non-mandatory pattern				-0.3573		

9. 9 Work-Based Sub-tour Frequency Choice Model Calibration

To perform model calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Figure 9.13: Individual work-based sub-tour participation comparison.

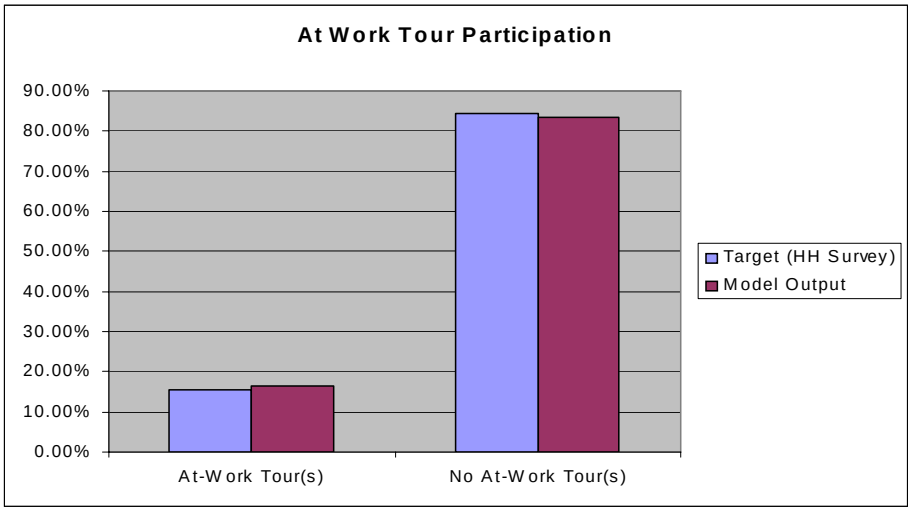
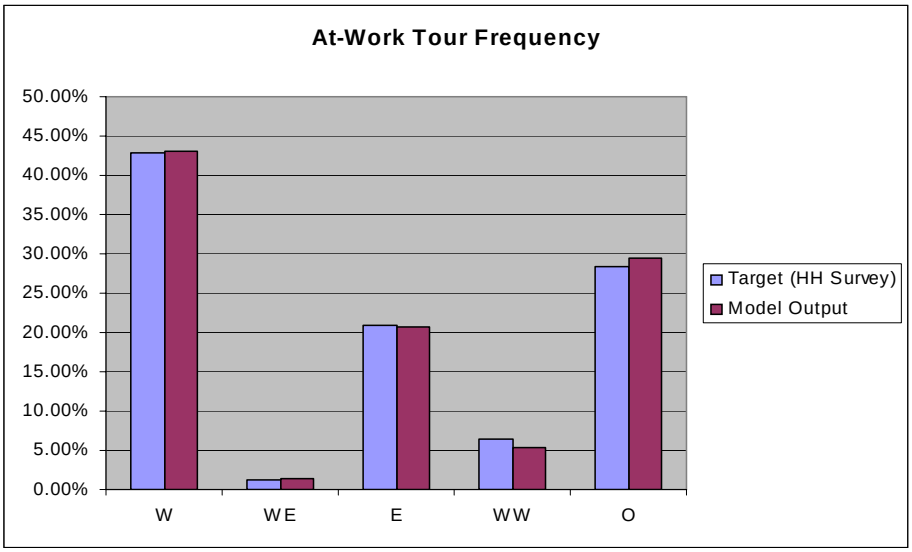


Figure 9.14: Individual work-based sub-tour frequency comparison.



CHAPTER 10

Individual Non-Mandatory Tour Destination, Time-of-Day and Mode Choice Model

CHAPTER 10 – INDIVIDUAL NON-MANDATORY TOUR DESTINATION, TIME-OF-DAY AND MODE CHOICE MODEL

10.1 Introduction

If a person chooses to make an individual non-mandatory tour, the individual non-mandatory tour destination, time-of-day, and mode choice model (DTM) determines where that tour will go (the destination), when the tour will happen (the time-of-day), and how the tour participants will travel during the tour (the mode).

10.2 Destination Choice Sub-model

The destination choice model is a multinomial logit model in which each potential destination zone is an alternative. Each zone's attractiveness is calculated from a utility function, where the utility consists of variables such as distance, income level, and area type. To provide a measure of a zone's attractiveness based on tour-specific characteristics, a size term is included in the utility expression. The size terms are stratified by individual non-mandatory tour type and are calculated as the natural logarithm of a sum of variables. The following table summarizes the specification (1= variable was used, 0= variable was not used):

Table 10.1: Individual non-mandatory tour destination choice size term specification

	Size Term Variable Coefficients						
		Employment					
Individual Tour Type	Total Occupied Units	Retail	Service	Gaming	Recreation	Other	School Enrollment
Shop	1	1	0	1	0	0	0
Maintenance	0	0	1	0	0	1	0
Discretionary	1	0	1	1	1	0	0
Eat	1	0	1	1	0	1	0
Escort	1	0	1	0	1	0	1
Work-Based	0	0	1	0	0	1	1

Also included in the utility expression is the logsum from the mode choice model, which provides an index of accessibilities for a destination zone - the higher the logsum, the more "accessible" (by auto, transit, walking) a zone is. Because the mode-choice model uses time-of-day specific skims, a time-of-day choice must be made before its utility can be evaluated. Because the actual time-of-day model occurs after the destination choice model, pre-selected time-of-day choices are used evaluate the mode choice logsums used in the model. These pre-selected choices are based on the expected time-of-day for a given purpose. For tours made by a person with a mandatory pattern and which are not escorting or work-based, the time-of-day choice used for the logsum calculation is PM peak start, late night end. For all other persons and/or tour types, the midday start, midday end time-of-choice is used.

In the Tahoe region, a number of residents actually travel outside of the region to make individual tours. To capture this effect, size terms were assigned to external zones. These size terms are discussed in **Appendix I**. In addition to the size terms, each external zone has an alternative specific constant which allowed for further refinement in the calibration phase of the model development.

The individual non-mandatory tour destination choice model specifications are presented in the following tables.

Table 10.2: Individual non-mandatory home-based tour destination choice estimation results

Variable	Escort	Shop	Maintenance	Discretionary	Eat
Distance (miles) - adult	-0.4584	-0.2980			-0.2074
Distance (miles) - child	-0.4303	-0.2980	-0.4948	-0.4197	-0.2074
Distance (miles) - adult with mandatory pattern			-0.4419	-0.2404	
Distance (miles) - adult with non-mandatory pattern			-0.3568	-0.1955	
Mode choice logsum	1.0000				
Size term	0.7337	0.8417			
Urban origin, urban destination	0.4332				
Rural origin, suburban destination	-0.2494				
No Cars in Household and Transit Within ¼ Mile at Both Origin and Destination	2.1730				
Workers Minus Cars in Household (if positive) and Transit Within ¼ Mile at Both Origin and Destination	1.6330				
Workers Minus Cars in Household (if positive) and Transit Between ¼ and ½ Mile at Both Origin and Destination	0.5508				
Preschool child with at-home pattern in household, distance < 3 miles	0.8743				
Pre-driving child with at-home pattern in household, distance < 3 miles	0.7665				
Size term = 0	Not Available				
Alternative Specific Constant for External Zone 1 (Summer)	9.0000	4.5000	3.6500	0.2000	-6.0000
Alternative Specific Constant for External Zone 1 (Winter)	1.0000	-0.5000	-1.3500	-1.8000	-6.0000
Alternative Specific Constant for External Zone 2		6.0500	3.5000	3.5450	-8.0000
Alternative Specific Constant for External Zone 3		-4.6000	1.9000	2.7450	-6.0000
Alternative Specific Constant for External Zone 4		-0.6000	-3.0500	5.0950	-6.0000
Alternative Specific Constant for External Zone 5		12.3000	4.2500	-0.5000	
Alternative Specific Constant for External Zone 6		-1.2500	3.2500	3.4500	-8.0000
Alternative Specific Constant for External Zone 7	4.0000	3.2500	3.0500	3.6500	2.8000

Table 10.3: Individual work-based tour destination choice estimation results

Variable	At-Work
Distance (miles) - Full time worker, work-based tour	-3.2000
Distance (miles) - Not full time worker, work-based tour	-3.5640
Distance (miles) - Full time worker, eat tour	-3.9660
Distance (miles) - Not full time worker, eat tour	-5.6050
Distance (miles) - Full time worker, other tour	-3.1680
Distance (miles) - Not full time worker, other tour	-4.8760
Mode choice logsum	1.0000
Size term - work based tour	0.4610
Size term - eat based tour	0.6904
Size term - other based tour	0.6166
Did not drive alone to work, and transit within ¼ mile at both origin (work) and destination	2.4850
Size term = 0	Not Available

10.3 Destination Choice Sub-model Calibration

To calibrate the destination choice sub-model, three primary aspects were examined:

- County to county flows
- Tour distance
- Internal to external flows

To perform the calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Table 10.4a: County to county flows for escort tours – household travel survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	15.34%	0.00%	0.00%	0.00%	1.15%	3.91%	20.40%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	9.30%	1.89%	0.00%	0.50%	11.69%
El Dorado	0.00%	0.00%	3.82%	40.98%	2.17%	0.00%	46.97%
Placer	0.90%	0.00%	0.00%	0.00%	20.03%	0.00%	20.93%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	16.24%	0.00%	13.12%	42.87%	23.36%	4.41%	100.00%

Table 10.4b: County to county flows for escort tours – model

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	8.17%	0.00%	0.00%	0.00%	0.33%	6.31%	14.81%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	5.61%	5.18%	0.00%	0.00%	10.79%
El Dorado	0.00%	0.00%	2.89%	54.00%	0.60%	0.00%	57.49%
Placer	1.73%	0.00%	0.00%	0.30%	13.72%	1.16%	16.90%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	9.90%	0.00%	8.50%	59.48%	14.65%	7.47%	100.00%

Table 10.5a: County to county flows for individual shop tours – household travel survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	17.81%	0.00%	0.00%	0.00%	3.10%	3.73%	24.64%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	5.57%	5.96%	0.00%	1.30%	12.82%
El Dorado	0.15%	0.00%	1.15%	35.55%	1.89%	2.38%	41.12%
Placer	0.97%	0.00%	0.00%	0.00%	17.95%	2.51%	21.42%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	18.93%	0.00%	6.72%	41.50%	22.94%	9.91%	100.00%

Table 10.5b: County to county flows for individual shop tours - model

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	8.43%	0.00%	0.01%	0.00%	1.35%	6.48%	16.27%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.01%	0.00%	5.95%	4.19%	0.01%	2.02%	12.19%
El Dorado	0.01%	0.00%	10.68%	41.61%	0.48%	1.04%	53.81%
Placer	2.72%	0.00%	0.02%	0.45%	11.97%	2.57%	17.73%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	11.18%	0.00%	16.66%	46.25%	13.80%	12.11%	100.00%

Table 10.6a: County to county flows for individual maintenance tours – household survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	15.68%	0.00%	0.26%	0.00%	0.96%	1.85%	18.76%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	10.42%	1.46%	0.14%	1.00%	13.02%
El Dorado	0.23%	0.00%	1.49%	38.45%	1.90%	1.74%	43.80%
Placer	0.31%	0.00%	0.00%	0.00%	22.03%	2.07%	24.41%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	16.22%	0.00%	12.17%	39.91%	25.04%	6.67%	100.00%

Table 10.6b: County to county flows for individual maintenance tours – model

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	12.16%	0.00%	0.00%	0.01%	0.94%	1.89%	15.00%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.02%	0.00%	6.06%	4.76%	0.01%	1.05%	11.91%
El Dorado	0.06%	0.00%	5.47%	46.53%	1.13%	1.95%	55.14%
Placer	2.37%	0.00%	0.01%	0.11%	13.25%	2.22%	17.96%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	14.61%	0.00%	11.54%	51.41%	15.34%	7.10%	100.00%

Table 10.7a: County to county flows for individual eat tours – household travel survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	18.47%	0.00%	0.00%	0.00%	9.28%	0.00%	27.75%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	9.06%	3.57%	0.00%	0.00%	12.64%
El Dorado	0.00%	0.00%	6.09%	34.82%	1.30%	0.00%	42.21%
Placer	2.39%	0.00%	0.00%	0.00%	12.98%	2.02%	17.40%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	20.86%	0.00%	15.15%	38.40%	23.56%	2.02%	100.00%

Table 10.7b County to county flows for individual eat tours – model

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	12.19%	0.00%	0.35%	0.00%	2.47%	0.63%	15.64%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.14%	0.00%	7.19%	4.72%	0.00%	0.00%	12.05%
El Dorado	0.21%	0.00%	13.46%	40.87%	0.70%	0.00%	55.25%
Placer	4.09%	0.00%	0.00%	0.70%	10.36%	1.90%	17.05%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	16.63%	0.00%	21.00%	46.30%	13.53%	2.54%	100.00%

Table 10.8a County to county flows for individual discretionary tours – household travel survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	19.14%	0.00%	0.78%	0.00%	0.64%	0.39%	20.94%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	8.83%	2.28%	0.00%	1.27%	12.37%
El Dorado	0.33%	0.00%	5.09%	34.04%	0.85%	2.50%	42.82%
Placer	1.41%	0.00%	0.00%	0.00%	16.94%	5.52%	23.86%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	20.88%	0.00%	14.70%	36.32%	18.43%	9.68%	100.00%

Table 10.8b County to county flows for individual discretionary tours - model.

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	10.24%	0.00%	0.08%	0.04%	1.37%	2.25%	13.99%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.05%	0.00%	5.86%	4.14%	0.01%	1.09%	11.15%
El Dorado	0.13%	0.00%	13.15%	41.80%	0.68%	1.67%	57.43%
Placer	2.88%	0.00%	0.06%	0.62%	9.93%	3.93%	17.42%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	13.30%	0.00%	19.16%	46.60%	11.99%	8.95%	100.00%

Table 10.9a County to county flows for work-based tours – household travel survey

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	10.08%	0.00%	0.00%	0.00%	0.00%	0.00%	10.08%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	11.63%	0.00%	0.00%	0.00%	11.63%
El Dorado	0.00%	0.00%	0.00%	50.07%	0.00%	0.00%	50.07%
Placer	0.00%	0.00%	0.00%	0.00%	28.21%	0.00%	28.21%
External	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	10.08%	0.00%	11.63%	50.07%	28.21%	0.00%	100.00%

Table 10.9b County to county flows for work-based tours - model

	Washoe	Carson City	Douglas	El Dorado	Placer	External	Sum
Washoe	14.88%	0.00%	0.00%	0.00%	0.69%	0.00%	15.57%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	17.33%	13.45%	0.00%	0.00%	30.79%
El Dorado	0.00%	0.00%	0.56%	24.56%	0.08%	0.00%	25.20%
Placer	0.00%	0.00%	0.00%	0.00%	12.69%	0.00%	12.69%
External	0.00%	0.00%	0.00%	0.00%	0.00%	15.75%	15.75%
Sum	14.88%	0.00%	17.90%	38.01%	13.45%	15.75%	100.00%

Figure 10.1: Distance distribution comparison for escort tours

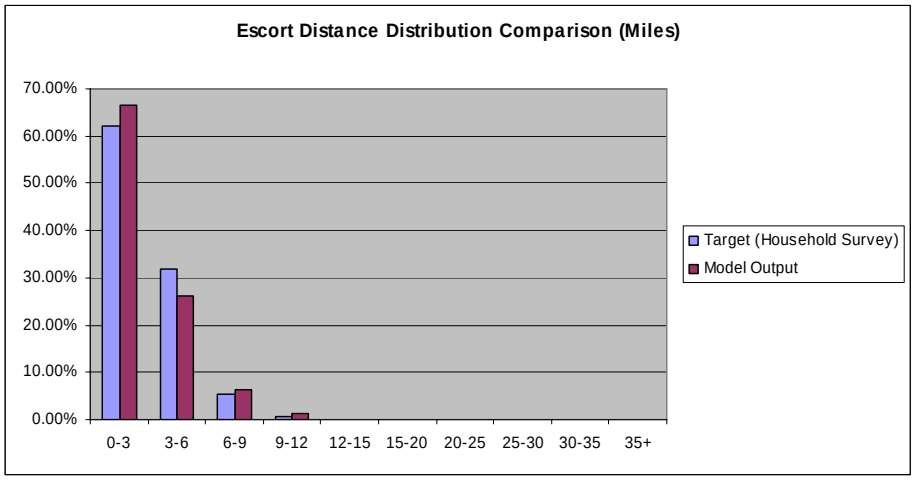


Figure 10.2: Distance distribution comparison for individual shop tours

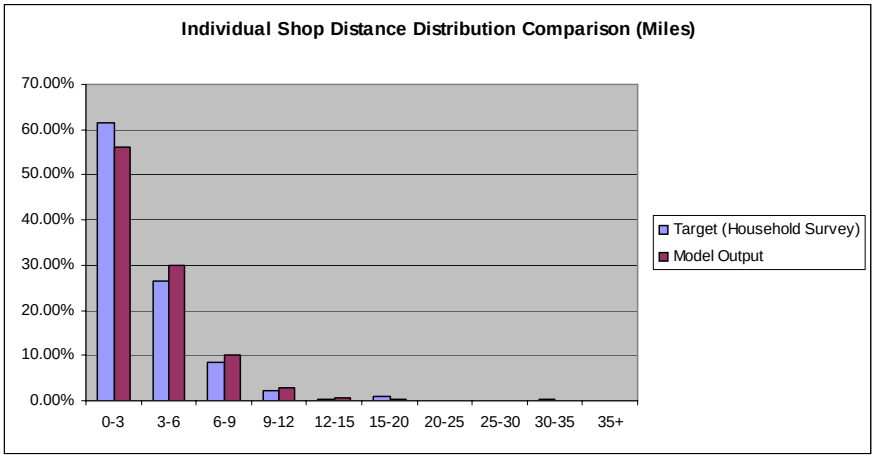


Figure 10.3: Distance distribution comparison for individual maintenance-other tours

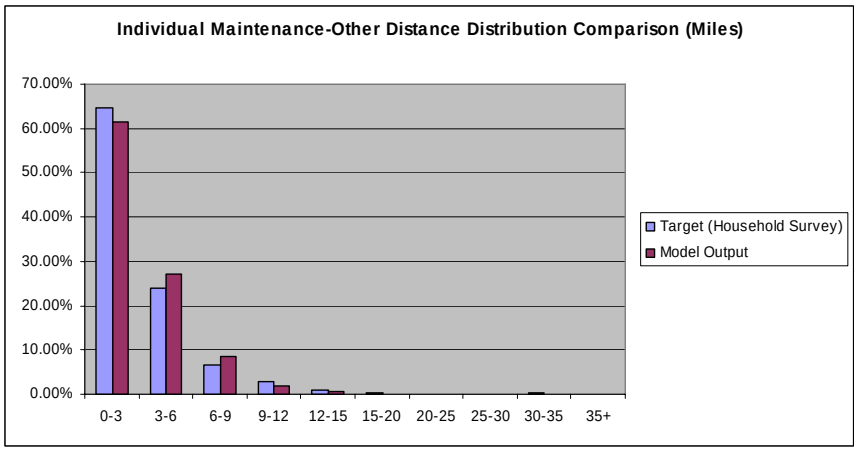


Figure 10.4: Distance distribution comparison for individual eat tours

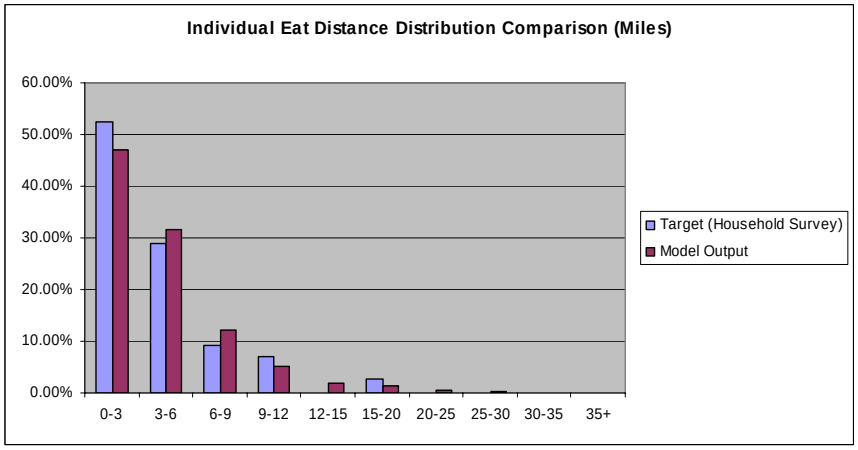


Figure 10.5: Distance distribution comparison for individual discretionary tours

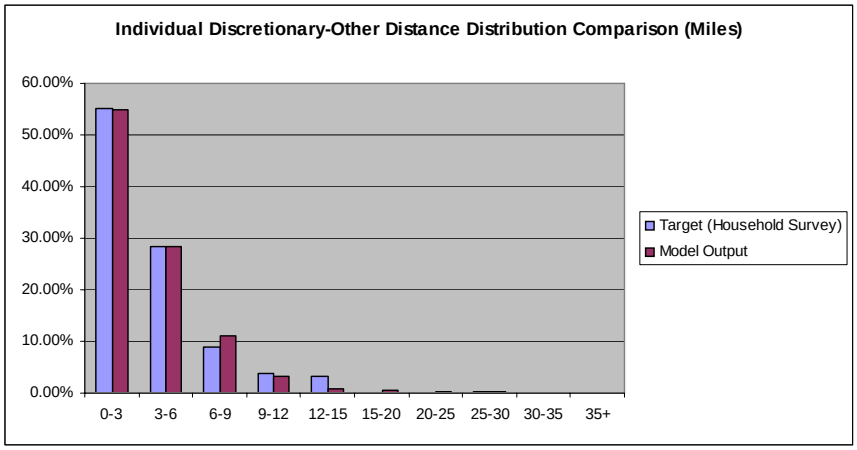


Figure 10.6: Distance distribution comparison for work-based tours

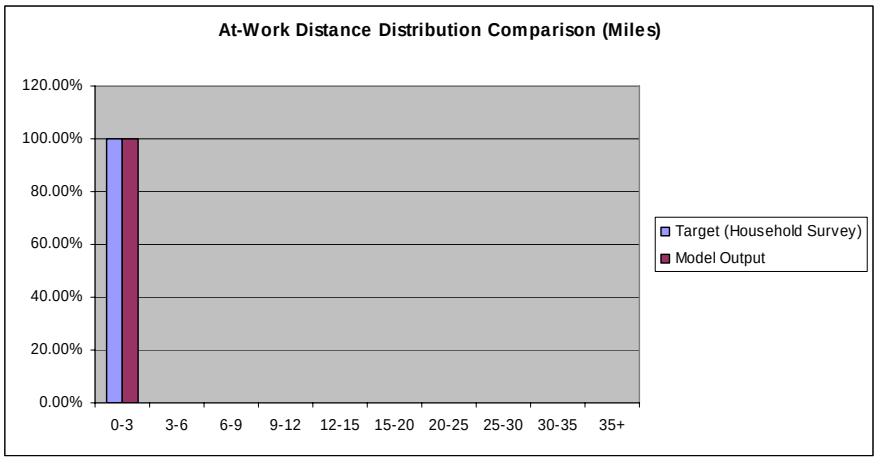


Table 10.10: Individual non-mandatory tour destination choice distance and travel time comparison

	Household Travel Survey				Model			
	Distance		Travel Time		Distance		Travel Time	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
Escort	2.716	1.969	5.299	3.139	2.726	2.048	5.469	3.356
Shop	3.233	3.040	6.055	4.710	3.399	2.667	6.584	4.270
Maintenance	3.082	3.140	5.870	4.777	3.106	2.665	6.055	4.233
Eat	3.944	3.547	7.358	5.818	4.226	3.700	7.935	5.734
Discretionary	3.566	3.394	6.651	5.150	3.697	3.419	7.060	5.285
Work-Based	0.730	0.346	1.981	0.728	0.731	0.362	1.973	0.783

Figure 10.7: Internal-External destination zone comparison for escort tours

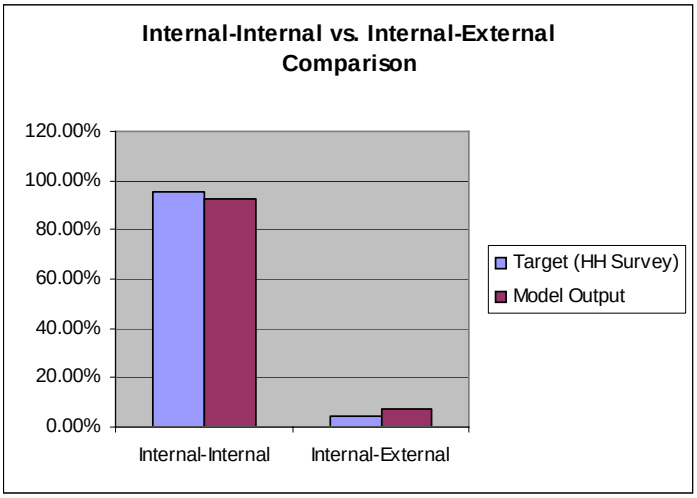


Figure 10.8: External station distribution for escort tours

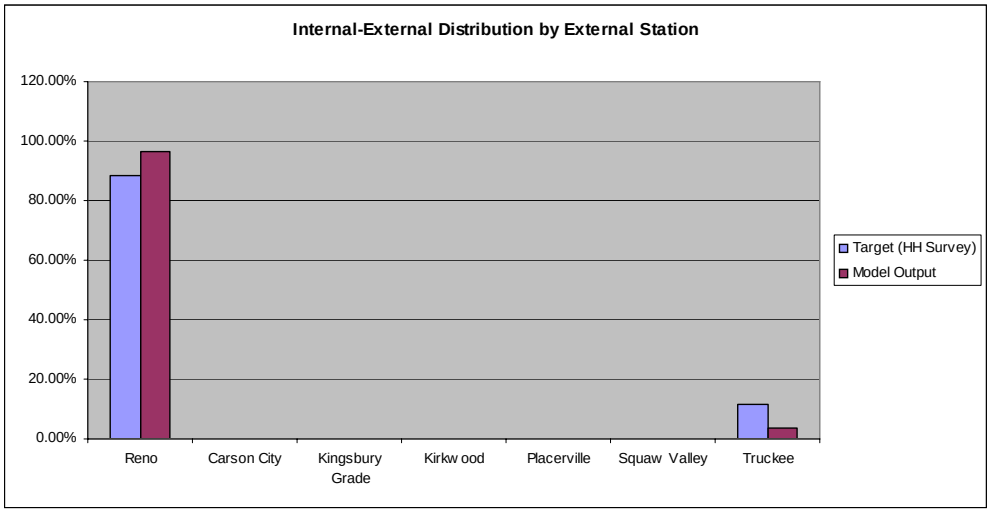


Figure 10.9: Internal-External destination zone comparison for individual shop tours

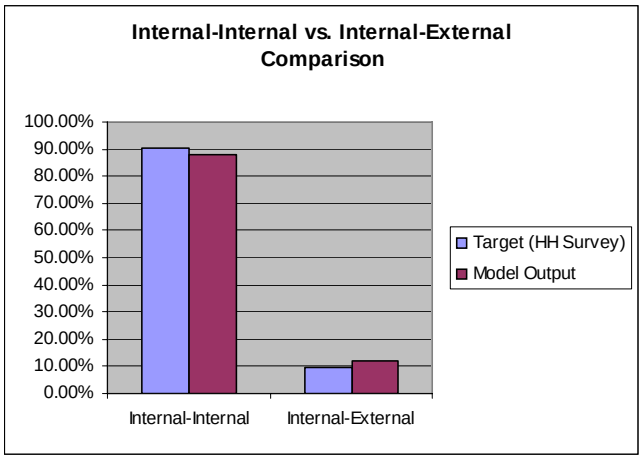


Figure 10.10: External station distribution for individual shop tours

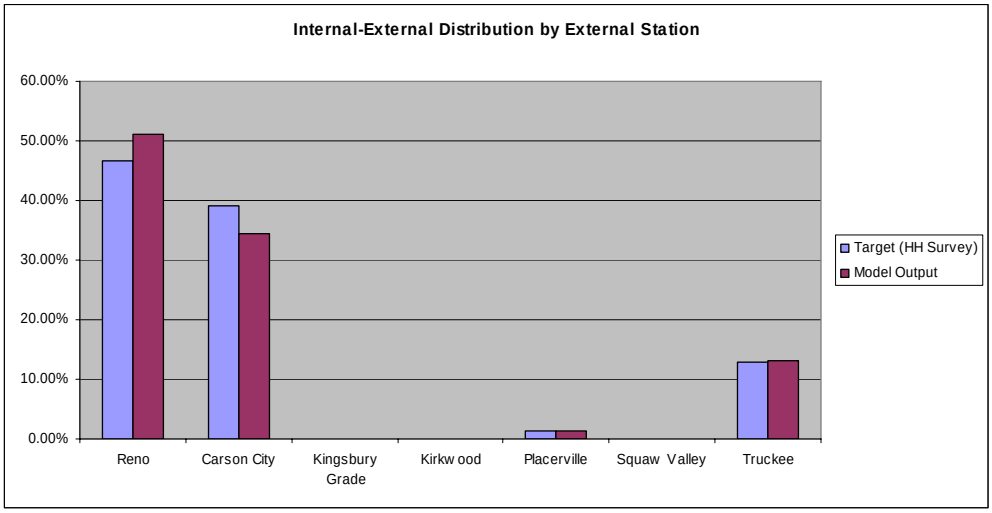


Figure 10.11: Internal-External destination zone comparison for individual maintenance tours

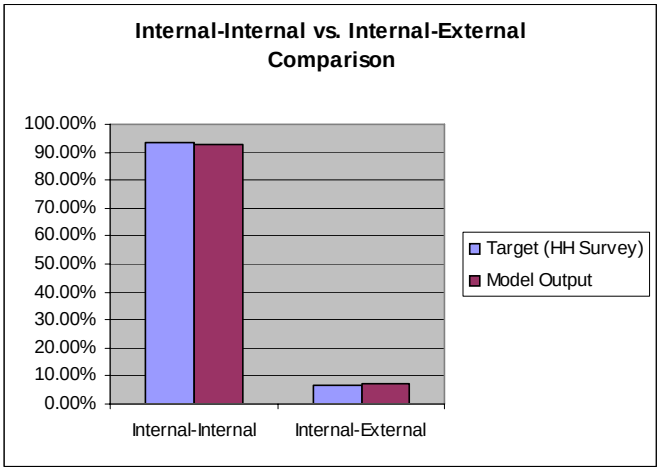


Figure 10.12: External station distribution for individual maintenance tours

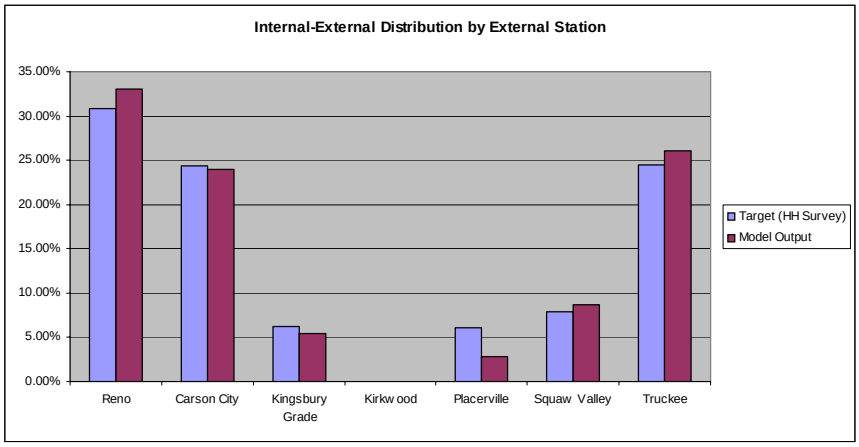


Figure 10.13: Internal-External destination zone comparison for individual eat tours

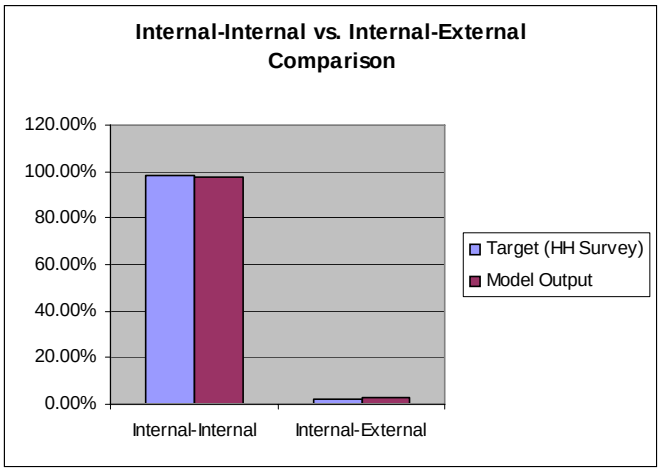


Figure 10.14: External station distribution for individual eat tours

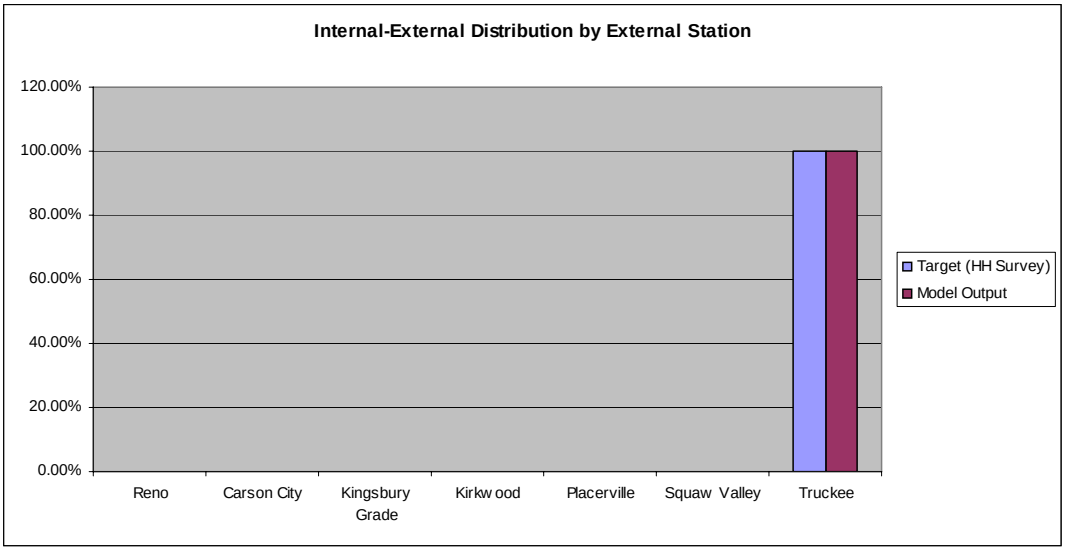


Figure 10.15: Internal-External destination zone comparison for individual discretionary tours

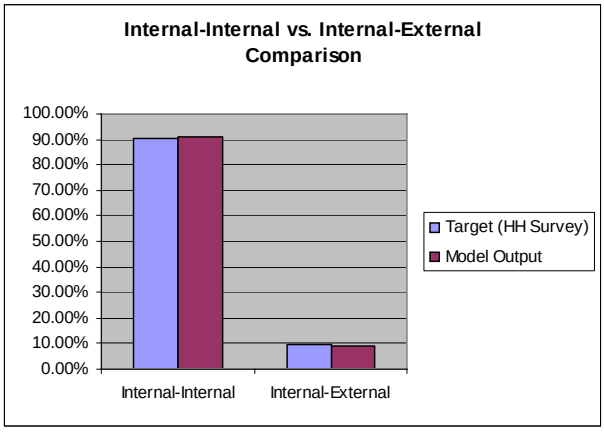
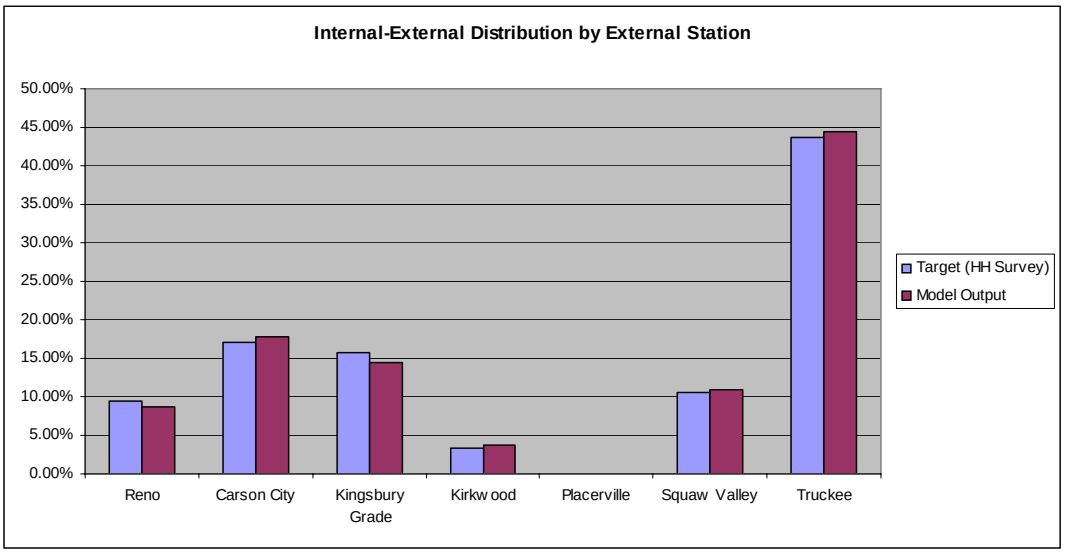


Figure 10.16 External station distribution for individual discretionary tours



10.4 Time-of-Day Sub-model

The time-of-day sub-model is a multinomial logit model in which start/stop hour pairs make up the alternatives. The earliest allowed start/stop time is 5:00 am (corresponding to the 5:00-6:00 hour), and the latest allowed is midnight (corresponding to the 12:00am-1:00am hour). As far as skim periods are concerned, the following definitions are used:

Table 10.11: Skim period definitions

Skim Period	Start Time	End Time	Duration
AM Peak (AM)	7:00 AM	10:00 AM	3 hours
Midday (MD)	10:00 AM	4:00 PM	6 hours
PM Peak (PM)	4:00 PM	7:00 PM	3 hours
Late Night (LN)	7:00 PM	7:00 AM	12 hours

More details on the model specifics are available in **Chapter 2**. The time-of-day choice model estimation results are presented in the following tables.

Table 10.12: Time-of-day estimation results for non-mandatory escorting tours

Variable	Coefficient
Early start at 5/6	-2.9730
AM peak start at 7	-1.2000
AM peak start at 8	0.0000
AM peak start at 9	0.1744
Midday start at 10/11/12	-0.7562
Midday start at 13/14	-0.7339
PM peak start at 16/17/18	-1.0740
Evening start at 19/20/21	-1.9160
Late start at 22/23	-1.8380
Early end at 5/6	-0.4865
AM peak end	0.3601

Variable	Coefficient
Midday end at 10/11/12	-0.6343
Midday end at 13/14/15	-0.3730
PM peak end at 16	0.5240
PM peak end at 18	-0.3192
Evening end at 19/20/21	-0.1801
Late end at 22/23	-1.3070
Duration of 0 hours	-0.6500
Duration of 2 to 3 hours	-0.8429
Duration of 4 to 5 hours	-1.5280
Duration of 6 to 7 hours	-1.9990
Duration of 8 to 10 hours	-1.6910
Duration of 11 to 13 hours	-2.5630
Duration of 14 to 18 hours	-2.5630
Start time	0.0007
Duration	0.0034
Mode choice logsum for EA start, AM/MD/PM/NT end	0.2924
Mode choice logsum for AM/MD/PM start, NT end	0.2924
Mode choice logsum for AM/MD/PM start, AM/MD/PM end	0.5848
Start time - adult, at least one child in household	-0.0463
Duration - adult, at least one child in household	-0.1256
Start time - Medium income	0.0354
Duration - Medium income	-0.0030
Start time - High income	0.0885
Duration - High income	-0.0075
Start time - urban destination	0.0047
Duration - urban destination	0.1221
Start time - if this is first tour of this purpose	-0.2169
Duration - if this is first tour of this purpose	-0.4130
Start time - if this is not first tour of this purpose	-0.0975
Duration - if this is not first tour of this purpose	-0.3795
Start time times number of mandatory tours made by person	0.0173
Duration times number of mandatory tours made by person	-0.1552
Start time times number of joint tours person participated in	0.0098
Duration times number of joint tours person participated in	-0.1095
Start time times number of non-mandatory tours (except escort) made by person	0.0516
Duration times number of non-mandatory tours (except escort) made by person	-0.1563
Number of non-mandatory tours made by person - start 5 to 7	0.8435
Number of non-mandatory tours made by person - end 22 to 23	0.3727
Midday start at 16	1.4000
End at 8	0.3000

Table 10.13 Time-of-day estimation results for non-mandatory (non-escorting) tours

Variable	Coefficient
Early start at 5/6	-1.631
AM peak start at 7	-0.6182
AM peak start at 9	0.5489
Midday start at 10/11/12	0.6382
Midday start at 13/14/15	0.6420
PM peak start at 16/17/18	1.3180
Evening start at 19	1.6690
Evening start at 20/21	0.9690
Late start at 22/23	0.0223
Early end at 5/6	-1.6630
AM peak end	-0.8588
Midday end at 10/11/12	0.0704
Midday end at 13/14/15	0.2656
PM peak end at 16	0.2630
PM peak end at 18	-0.2794
Evening end at 19/20/21	-0.6389
Late end at 22/23	-3.2
Duration of 0 hours	-1.2423
Duration of 1 hour	-0.2423
Duration of 4 to 5 hours	-0.5791
Duration of 6 to 7 hours	-1.0300
Duration of 8 to 10 hours	-1.2420
Duration of 11 to 13 hours	-1.3920
Duration of 14 to 18 hours	-1.1320
Start time	0.0007
Duration	0.0049
Start time - adult, at least one child in household	0.0453
Duration - adult, at least one child in household	0.0553
Start time - Driving child	0.0724
Duration - Driving child	0.1089
Start time - Pre-driving child	0.0970
Duration - Pre-driving child	0.1941
Start time - shopping tour	-0.0472
Duration - shopping tour	-0.2132
Start time - maintenance tour	-0.1272
Duration - maintenance tour	-0.0817
Start time - eat tour	0.0000
Duration - eat tour	0.0000
Start time - Medium income	-0.0189
Duration - Medium income	-0.0042
Start time - High income	-0.0473
Duration - High income	-0.0104
Start time - urban destination	-0.1465
Duration - urban destination	0.2384

Variable	Coefficient
Start time - if this is first tour of this purpose	-0.2493
Duration - if this is first tour of this purpose	-0.2558
Start time - if this is not first tour of this purpose	-0.1222
Duration - if this is not first tour of this purpose	-0.0128
Start time times number of mandatory tours made by person	0.0149
Duration times number of mandatory tours made by person	0.0765
Start time times number of non-mandatory tours (except escort) made by person	0.0061
Start time times number of individual tours of this purpose made by person	-0.0061
Duration times number of non-mandatory tours (except escort) made by person	-0.0691
Duration times number of individual tours of this purpose made by person	0.0691
Shop tour - start 5-8	-0.7622
Shop tour - end 22-23	-0.5661
Maintenance tour - start 5-7	-0.8421
End 22-23 - pre-driving child	-1.2430
End 22-23 – non-worker	0.7844
Start 5-7 - all adults in household work, and a child in the household	0.7349
End 19-21 - adult making tour and child in household	0.3101
Start 16-18 – non-worker	-0.5481
Discretionary tour - duration < 2	-0.6657
Shop tour - duration < 2	0.5000
Start 17/18 - discretionary tour	1.3000
Start 16/17 - eat tour	2.2000
Start 15 - eat tour	0.8000
Start 12-14 - eat tour	-0.8000
Start 19	-2.4000
Shop tour - start < 7	-8.0000
Maintenance tour - start 10-15	1.4000
Maintenance tour - start at 5	-4.0000
Maintenance tour - start 6-9	0.9000
End at 23	-4.0000
Discretionary tour - end at 15	0.7000
Dummy for maintenance tour and end >18	-1.1000
Shop tour - start at 10-13	0.4000
Shop tour - start > 19	-2.2000
Eat tour - duration > 7	-3.0000
Discretionary tour - start at 8	0.6000
Maintenance tour - end < 8	-1.4000
Eat tour - start at 10	0.6000
Maintenance tour - end at 5	-1.4000
Eat tour - duration of 1	1.5000
Eat tour - end at 17	-0.4000
Maintenance tour - end at 21	-0.5000
Late start at 22/23	-0.6000
Shop tour - end at 15/16/17	0.8000
Discretionary tour - end 20/21	-0.4000

Table 10.14 Time-of-day estimation results for individual work-based tours

Variable	Coefficient
Early start at 5/6	-0.9779
AM peak start at 7	-0.9622
AM peak start at 9	0.2557
Midday start at 10/11/12	1.0460
Midday start at 13/14/15	0.5435
PM peak start at 16/17/18	0.0329
Evening start at 19/20/21	-0.7292
Late start at 22/23	-1.5360
Early end at 5/6	Not available
AM peak end	-0.7492
Midday end at 10/11/12	0.3228
Midday end at 13/14/15	1.1770
PM peak end at 16	0.7669
PM peak end at 18	-1.0410
Evening end at 19/20/21	-0.2075
Late end at 22/23	1.443
Duration of 0 hours	-2.5000
Duration of 1 hour	-1.2000
Duration of 2 to 3 hours	-1.1270
Duration of 4 to 5 hours	-1.8560
Duration of 6 to 7 hours	-1.3480
Duration of 8 to 10 hours	0.3322
Duration of 11 to 13 hours	-0.6504
Duration of 14 to 18 hours	-0.6504
Start time	0.0007
Duration	0.0098
Start time - work-related sub-tour	-0.1113
Duration - work-related sub-tour	0.2646
Start time - first sub-tour (of this tour)	-0.5433
Duration - first sub-tour (of this tour)	-0.3992
Start time - not first sub-tour (of this tour)	-0.1844
Duration - not first sub-tour (of this tour)	-0.2492
Start time times number of mandatory tours made by person	-0.0193
Duration times number of mandatory tours made by person	-0.7702
Start time times number of joint tours person participated in	-0.0206
Duration times number of joint tours person participated in	-0.2497
Start time times number of non-mandatory tours (except escort) made by person	-0.0128
Duration times number of non-mandatory tours (except escort) made by person	-0.0422
Work-related sub-tour - duration 0-1	-1.5430
Eat sub-tour - duration of 1	0.3999
Eat sub-tour - start at 11	1.5110
Eat sub-tour - start at 12	2.721
Eat sub-tour - start at 13	2.1220

10.5 Time-of-day Choice Sub-model Calibration

To calibrate the time-of-day choice sub-model, three primary aspects were examined:

- Start time
- End time
- Duration

To perform the calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Figure 10.17a: Time of day departure time comparison for escort tours (Coincidence ratio: 0.70)

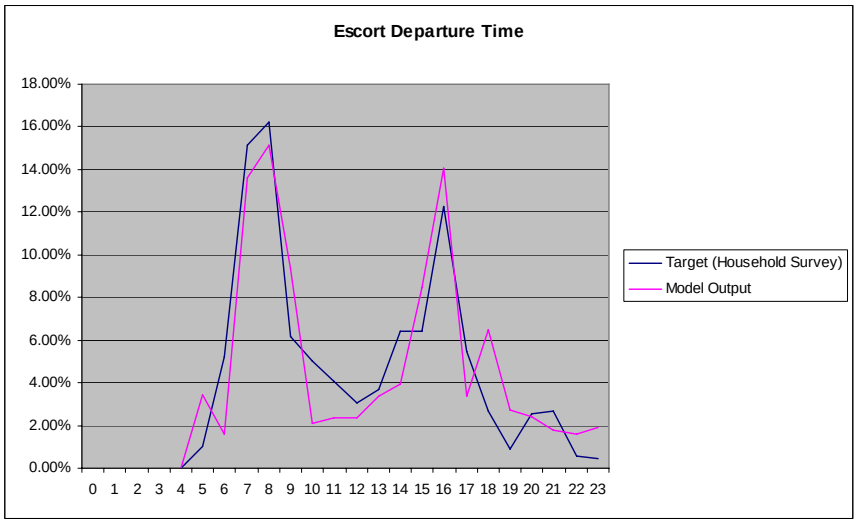


Figure 10.17b Time of day arrival time comparison for escort tours (Coincidence ratio: 0.65)

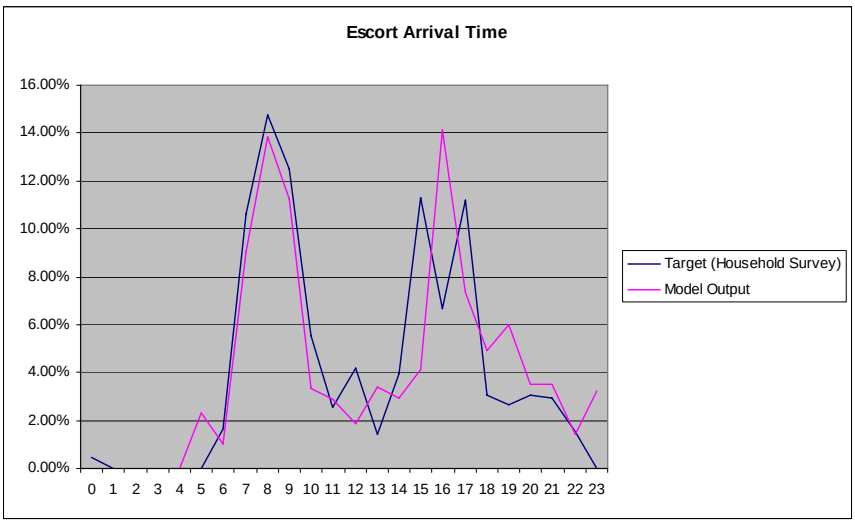


Figure 10.17c Time of day duration comparison for escort tours (Coincidence ratio: 0.83)

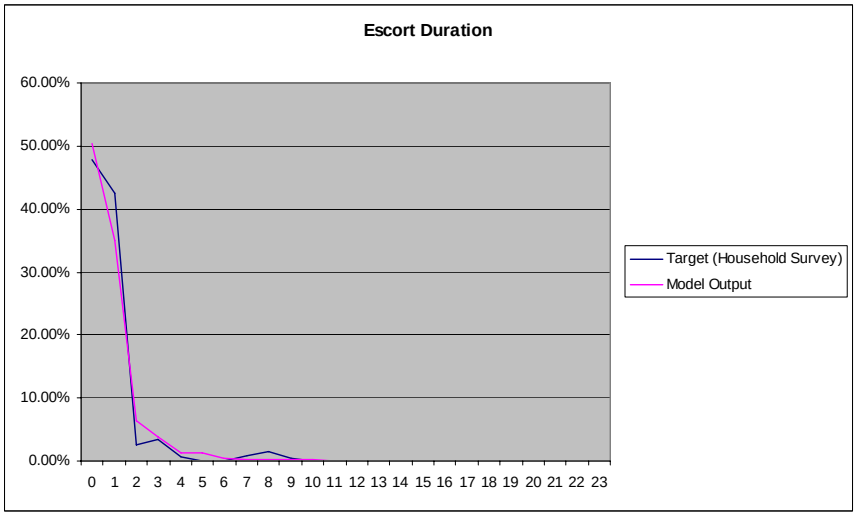


Figure 10.18a: Time of day departure time comparison for individual shop tours (Coincidence ratio: 0.71)

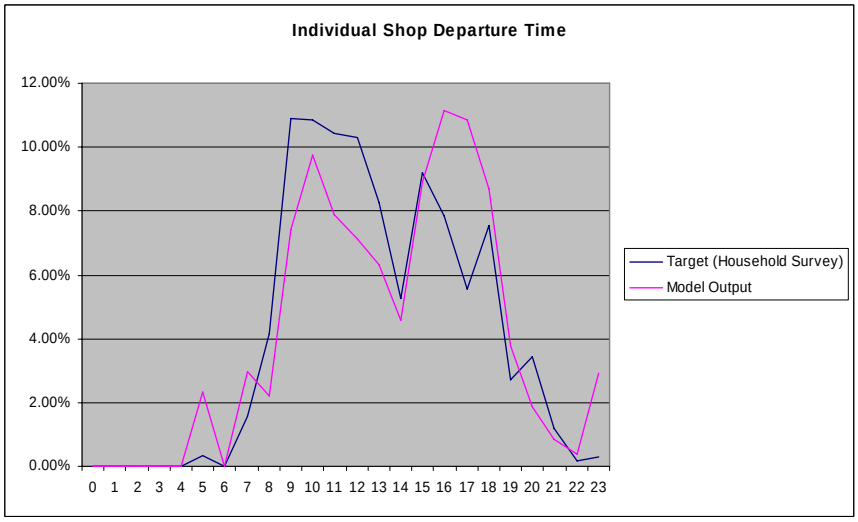


Figure 10.18b: Time of day arrival time comparison for individual shop tours (Coincidence ratio: 0.66)

Figure 10.18c: Time of day duration comparison for individual shop tours (Coincidence ratio: 0.79)

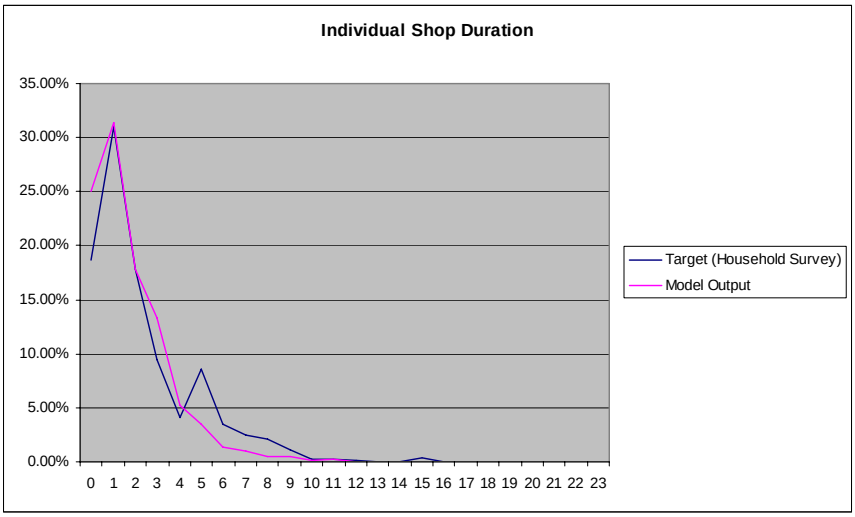


Figure 10.19a: Time of day departure time comparison for individual maintenance tours (Coincidence ratio: 0.79)

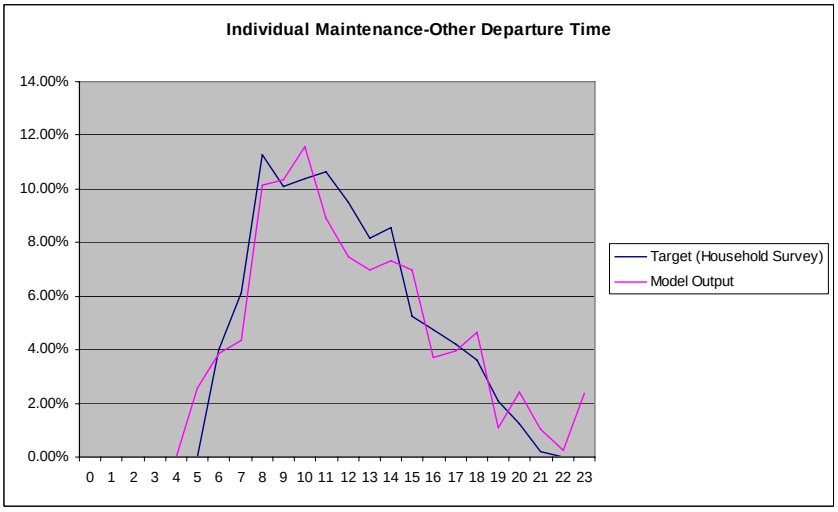


Figure 10.19b: Time of day arrival time comparison for individual maintenance tours (Coincidence ratio: 0.78)

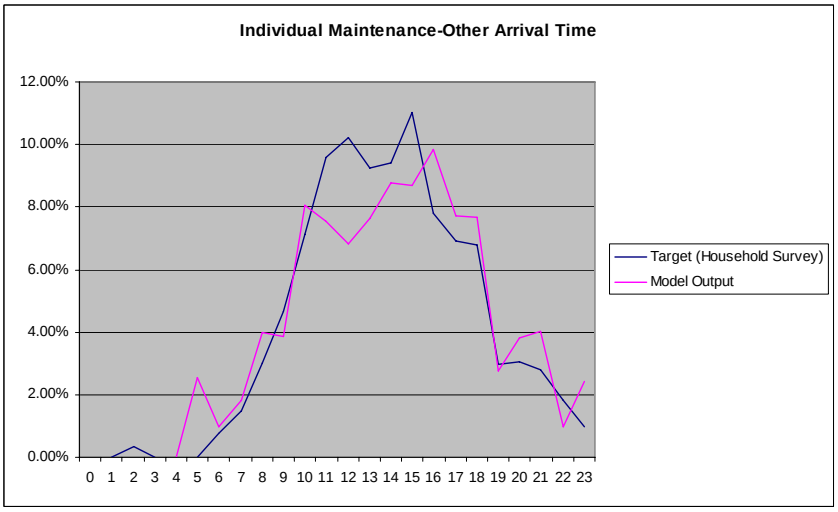


Figure 10.19c: Time of day duration comparison for individual maintenance tours (Coincidence ratio: 0.80)

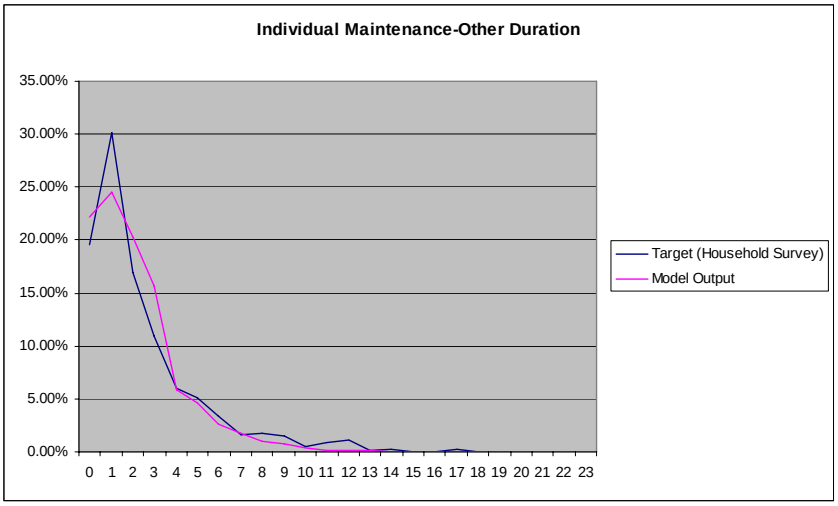


Figure 10.20a: Time of day departure time comparison for individual eat tours (Coincidence ratio: 0.66)

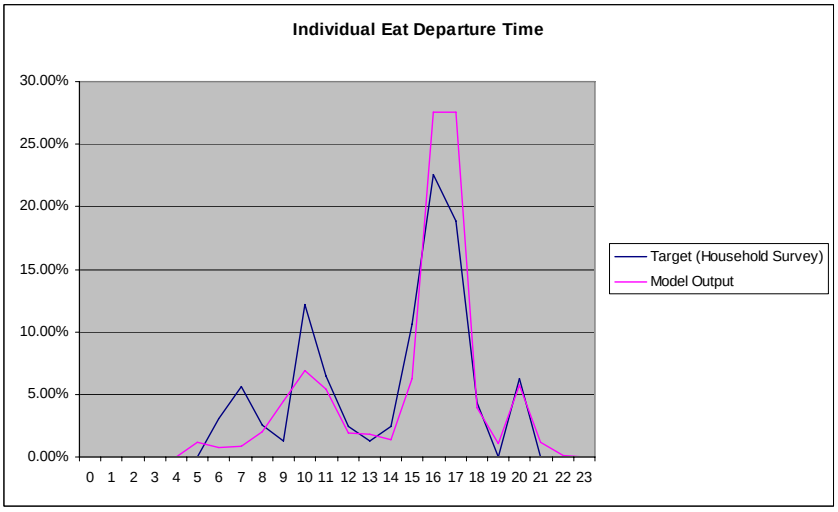


Figure 10.20b: Time of day arrival time comparison for individual eat tours (Coincidence ratio: 0.55)

Figure 10.20c: Time of day duration comparison for individual eat tours (Coincidence ratio: 0.71)

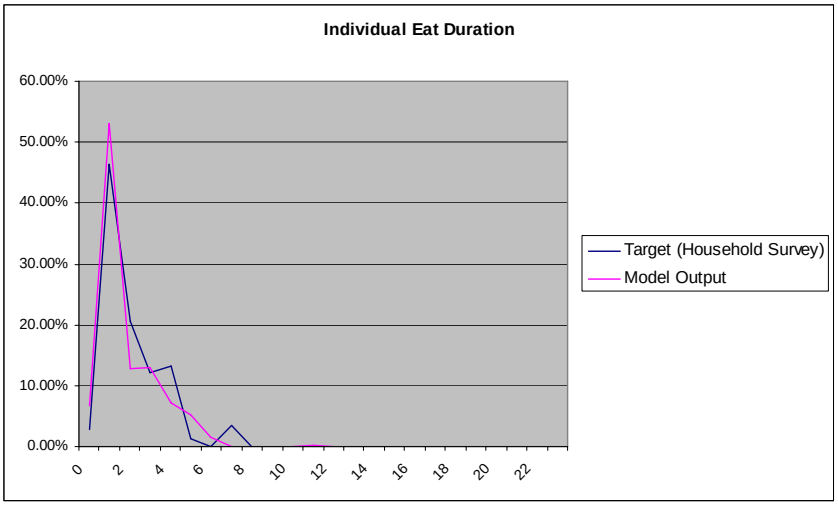


Figure 10.21a: Time of day departure time comparison for individual discretionary tours (Coincidence ratio: 0.72)

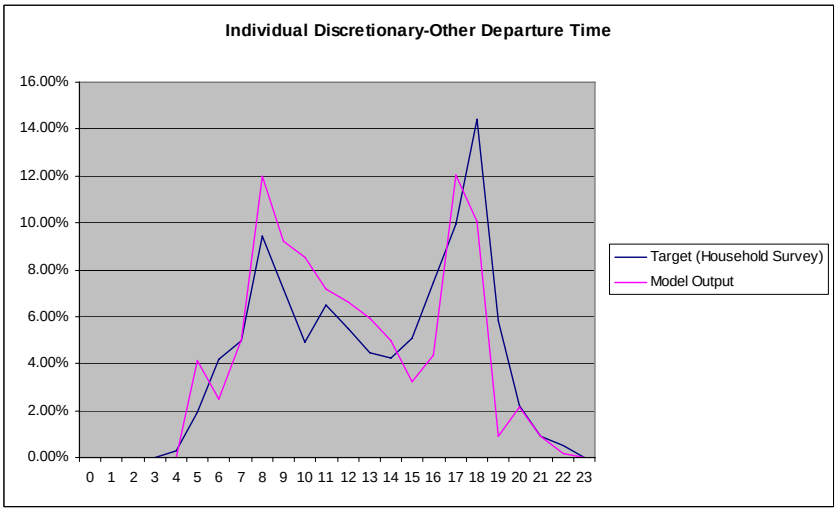


Figure 10.21b: Time of day arrival time comparison for individual discretionary tours (Coincidence ratio: 0.72)

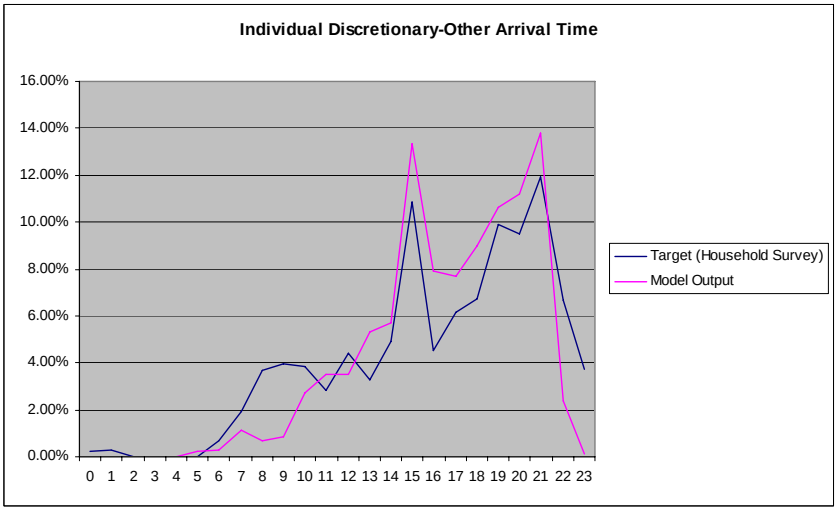


Figure 10.21c: Time of day duration comparison for individual discretionary tours (Coincidence ratio: 0.68)

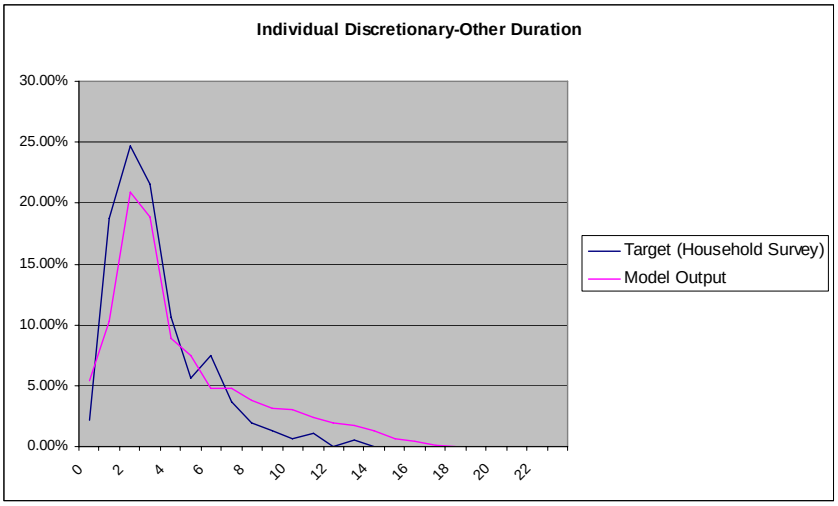


Figure 10.22a Time of day departure time comparison for work-based tours (Coincidence ratio: 0.76)

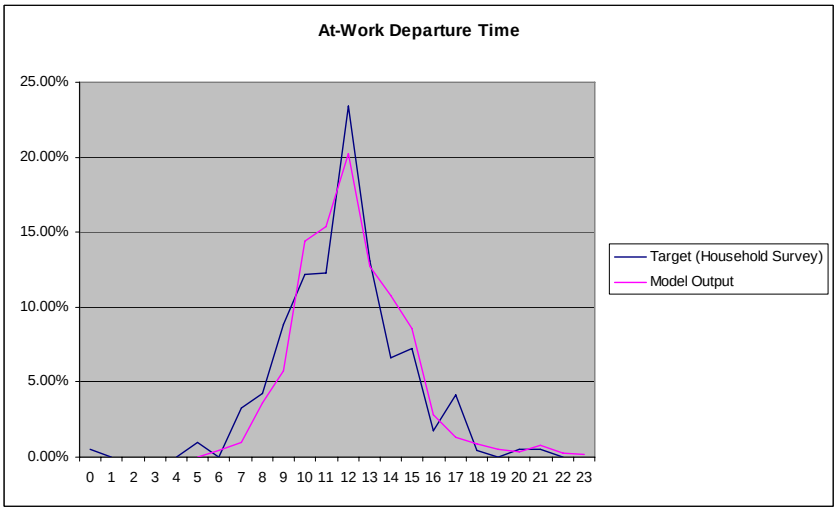


Figure 10.22b Time of day arrival time comparison for work-based tours (Coincidence ratio: 0.70)

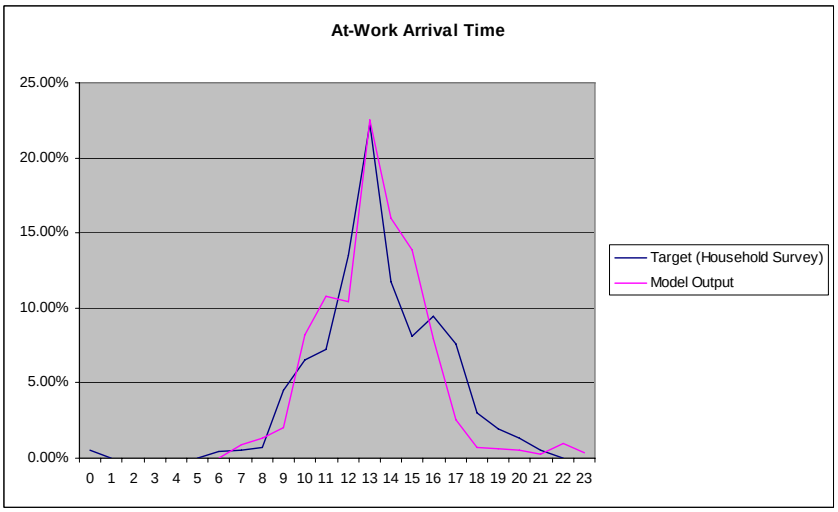
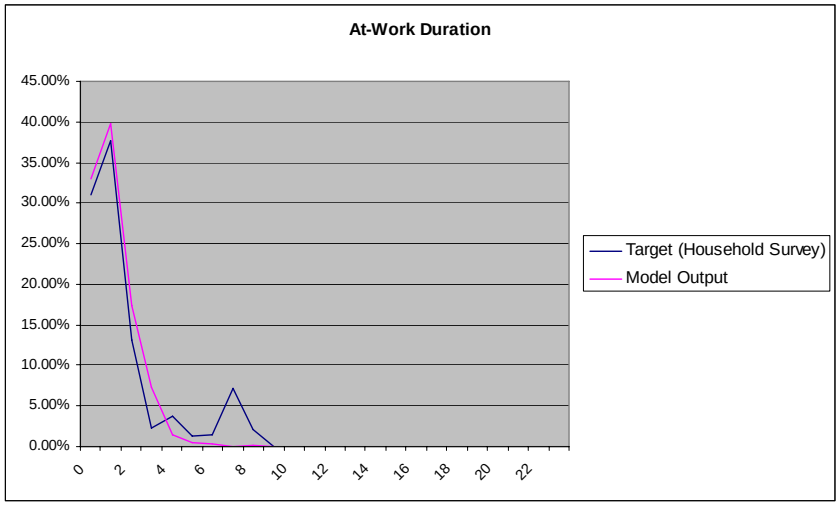


Figure 10.22c Time of day duration comparison for work-based tours (Coincidence ratio: 0.77)



10.6 Mode Choice Sub-model

The mode choice model is a multinomial logit model in which each mode is an alternative. For individual non-mandatory tours, the following alternatives are available:

- Drive alone
- Shared auto
- Walk to transit
- Drive to transit
- Non-motorized

The primary component of the model is travel time, which uses the same coefficient across all modes. For the modes that have costs associated with them (transit has fares, auto modes have operating costs), a value of time factor was estimated; this factor can transfer dollar costs into time, for which a utility can be calculated using the travel time coefficient.

The mode choice model estimation results are presented in the following tables.

Table 10.15 Mode choice estimation results for individual non-mandatory tours

Variable	Drive Alone	Shared Auto	Walk to Transit	Drive to Transit	Non-Motorized
Escort tour	Not Available	0.8200	-6.1780	-6.6070	0.0320
Shop tour	2.1038	0.3000	-0.0144	-4.2904	3.0375
Maintenance tour	1.3500		-0.9970	-0.7260	1.3800
Discretionary tour	3.4000	-1.5000	-1.8970	-3.5260	1.8800
Eat tour	0.7610	-2.5500	-5.7614	-4.4904	1.8880
Time (minutes)	-0.0147				
Value of Time ($/hour) - Worker	6.5300				
Value of Time ($/hour) – Non-worker/Child	3.2650				
Driving Child	-0.8704				
Part Time Worker		0.1632			
Low Income			3.2410		0.4074

Variable	Drive Alone	Shared Auto	Walk to Transit	Drive to Transit	Non-Motorized
High Income	0.2429				-0.7291
Drivers Minus Autos in Household (if positive)	-0.9692		-1.2600		
No autos in household	Not Available				0.7628
Pre-Driving or Preschool Child in Household		0.5479			
Pre-Driving Child	Not Available				
Natural Log of tour distance		0.1642	0.6391		

Table 10.16 Mode choice estimation results for individual work-based tours

Variable	Drive Alone	Shared Auto	Walk to Transit	Drive to Transit	Non-Motorized
Work-related	1.3000	-0.4000	0.7260	Not Available	2.2110
Eat tour	1.3000	0.8790	0.7260	Not Available	3.0200
Other tour	1.4844	-0.4000	0.7260	Not Available	3.0200
Time (minutes)	-0.0205				
Value of Time ($/hour) - Worker	6.5300				
Value of Time ($/hour) – Non-worker/Child	3.2650				
Drive Alone was Work Tour Mode	4.3270	3.2030			
Shared Auto was Work Tour Mode	3.1310	3.8620			
No autos in household	Not Available				0.7628
Pre-Driving Child	Not Available				
Natural Log of tour distance		0.1642	0.6391		

10.7 Mode Choice Sub-model Calibration

To calibrate the mode choice sub-model, the mode choice shares were examined. To perform this analysis, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Figure 10.23: Mode choice share comparisons for escort tours

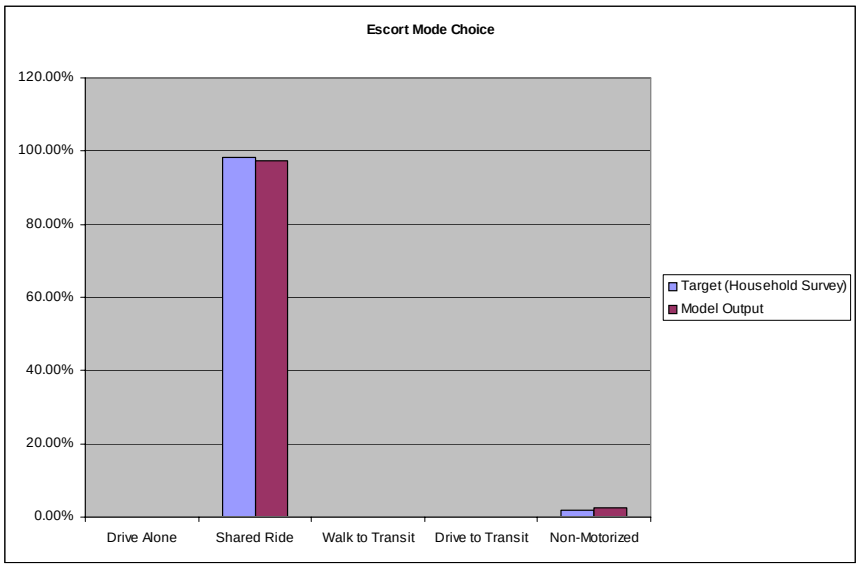


Figure 10.24: Mode choice share comparisons for individual shop tours

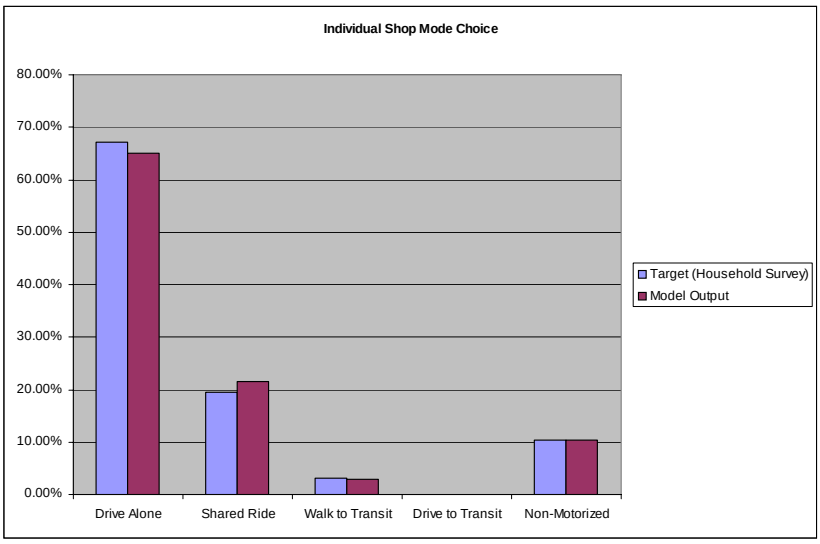


Figure 10.25: Mode choice share comparisons for individual maintenance tours

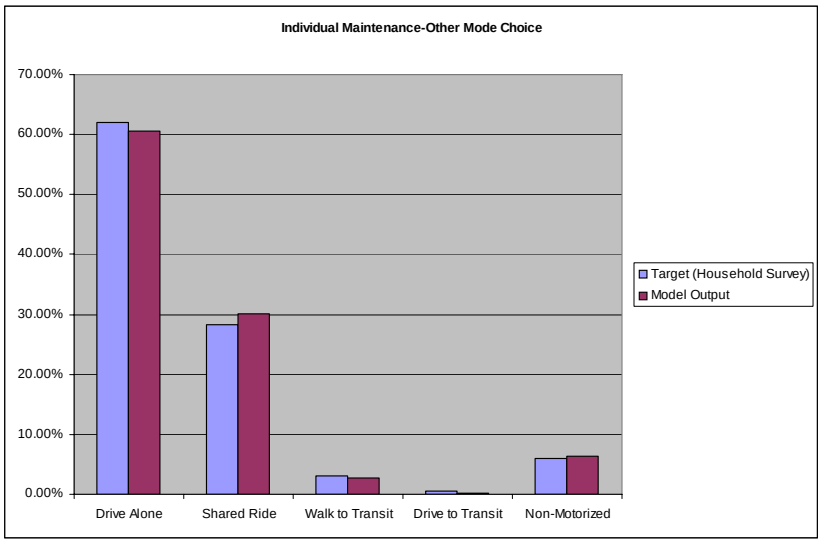


Figure 10.26: Mode choice share comparisons for individual eat tours

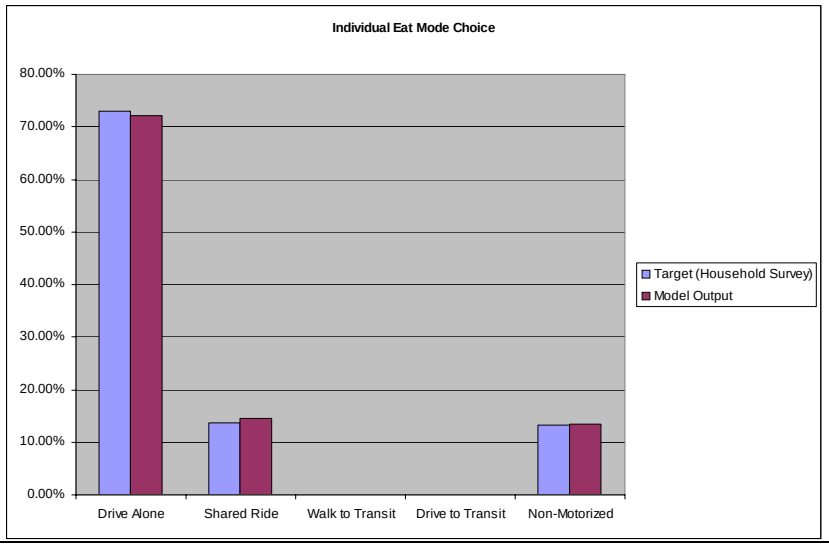


Figure 10.27: Mode choice share comparisons for individual discretionary tours

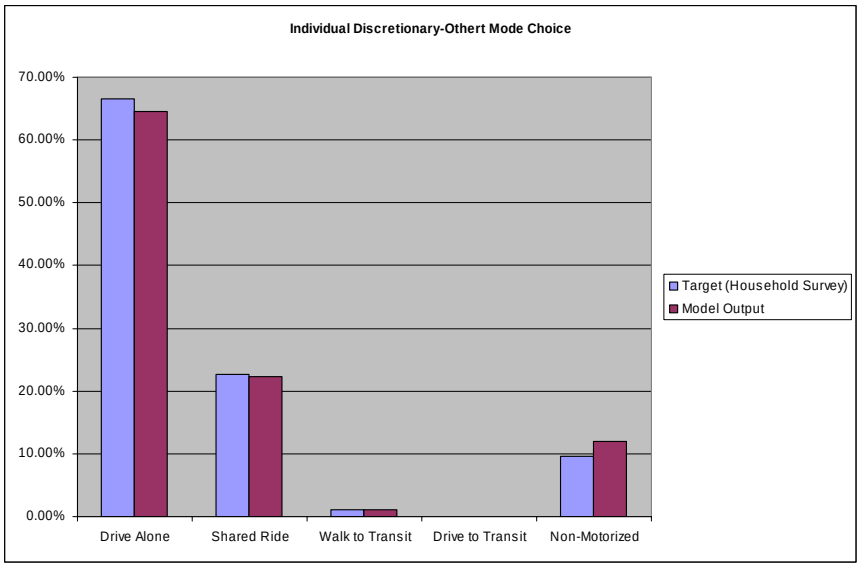
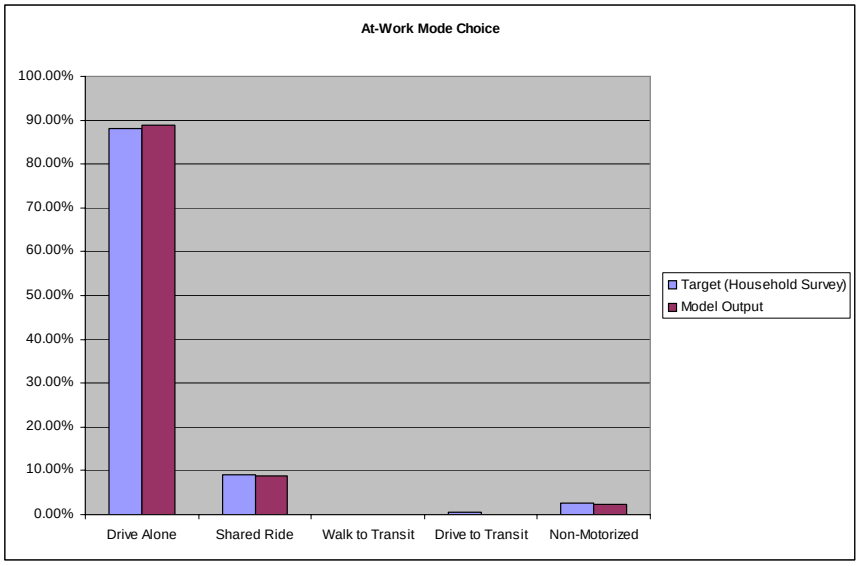


Figure 10.28: Mode choice share comparisons for work-based tours



CHAPTER 11
Stops Model

CHAPTER 11 – STOPS MODEL

11.1 Introduction

In any given tour up to one outbound and one inbound stop is allowed. An outbound stop is one that occurs during the trip to the primary destination, whereas an inbound stop is one that occurs on the way back to the tour origin. Regardless of the tour purpose, the structure of the stops model consists of the following steps:

1. A stops frequency model (how many stops are made)
2. A stop location model (where the stop occurred)
3. A mode choice (how the tour participant(s) traveled to/from the stop)

The structure is similar to those used for the various tour models, only without the time-of-day sub-model (when the stop occurs is fixed by the tour start/end time). In the stops model, each tour is treated as an independent entity, and once the stop frequency is chosen, each stop is treated independently. It is noted that the mode choice model is only necessary to create the correct logic for transit tours; drive or non-motorized tours will use these modes to get to and from the stop.

11.2 Stop Frequency Model

The stop frequency model is a multinomial logit model with four alternatives:

- 0 Stops
- 1 Outbound stop
- 1 Inbound stop
- 1 Outbound and 1 Inbound stop

The model is segmented by tour type. Some of the models include logsums from the stop location model discussed in Section 11.4. The results of the calibrated estimation results for this model are presented in the following tables.

Table 11.1: Stop frequency estimation results for mandatory tours

Variable	No Stops	Outbound Stop	Inbound Stop	Outbound & Inbound Stop
Alternative specific constant - work tour		-2.7760	-1.5550	-3.1290
Alternative specific constant - school tour		-2.4250	-1.0870	-3.1110
Outbound stop location logsum - work tour, high income		0.0165		0.0165
Total joint and non-mandatory tours for person- school tour			-0.1366	-0.1366
Total joint and non-mandatory tours for household- work tour			-0.0691	-0.0691
Tour duration - work tour		0.0468	0.1036	0.1504
School pattern in hh - adult on work tour		0.8043	0.3014	1.1057
Fewer cars than drivers in household		-0.1077	-0.3541	-0.4618
Shared auto mode used		0.5055	0.2202	0.7257
Transit or non-motorized mode used - work tour		-0.1544		-0.1544
Work tour starts before am peak		-0.3344		-0.3344

Table 11.2: Stop frequency estimation results for joint tours

Variable	No Stops	Outbound Stop	Inbound Stop	Outbound & Inbound Stop
Alternative specific constant - adult-only party		-3.0720	-2.8250	-4.8010
Alternative specific constant - mixed party		-2.0920	-2.3420	-3.3020
Inbound stop location logsum - adult-only party			0.1857	0.1857
Inbound stop location logsum - mixed party			0.1324	0.1324
Tour duration - adult-only party		0.1568	-0.2539	-0.0971
Tour duration - mixed party		0.0482	-0.2286	-0.1804
Fewer cars than drivers in household		-0.1077	-0.3541	-0.4618
Shared auto mode used		0.5055	0.2202	0.7257
Adult-only party starts tour after am peak		0.6975		0.6975
Urban origin, urban destination		0.1637		0.1637
Suburban origin, urban destination		0.2256		0.2256
Rural origin, urban destination		0.7727		0.7727
Rural origin, suburban destination		0.3986		0.3986
Destination in external zone - eat tour		4.0000	4.0000	4.0000
Destination in external zone - discretionary tour		0.0000	0.0000	3.0000

Table 11.3: Stop frequency estimation results for individual non-mandatory tours

Variable	No Stops	Outbound Stop	Inbound Stop	Outbound & Inbound Stop
Alternative specific constant - adult		-2.6540	-2.6500	-4.6510
Alternative specific constant - child		-2.1830	-2.7730	-4.8090
Alternative specific constant - escort tour		-5.0000	-1.2500	-5.0000
Inbound stop location logsum - adult			0.1857	0.1857
Inbound stop location logsum - child			0.0595	0.0595
Total joint and non-mandatory tours for adult			-0.1366	-0.1366
Tour duration - adult		0.1568	0.1129	0.2697
Tour duration - child		0.0482	0.2851	0.3333
Mandatory pattern individual adult		-0.2797	-0.4201	-0.6998
Fewer cars than drivers in household		-0.1077	-0.3541	-0.4618
Shared auto mode used		0.5055	0.2202	0.7257
Adult starts tour after am peak		0.6975		0.6975
Urban origin, urban destination		0.1637		0.1637
Suburban origin, urban destination		0.2256		0.2256
Rural origin, urban destination		0.7727		0.7727
Rural origin, suburban destination		0.3986		0.3986
Destination in external zone - discretionary tour		0.0000	0.0000	3.0000

Table 11.4: Stop frequency estimation results for work-based tours

Variable	No Stops	Outbound Stop	Inbound Stop	Outbound & Inbound Stop
Alternative specific constant - work-related sub-tour		-3.0640	-0.6239	-2.7439
Alternative specific constant - eat sub-tour		-0.9530	-1.4689	-1.4540
Alternative specific constant - other sub-tour		-1.2630	-0.2230	-2.6460
Tour duration - work-related sub-tour		-0.1030	-0.1030	-0.2060
Tour duration - eat sub-tour		-1.2000	-1.2000	-2.4000
Two at-work tours		-0.1367	-0.1367	-0.2734
Shared auto mode used		0.3846	0.3846	0.7692
Total joint and non-mandatory tours for person		-0.2830	-0.2830	-0.5660

11.3 Stop Frequency Model Calibration

To calibrate the destination choice sub-model, the stop frequency shares were analyzed by tour type. To perform the calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Figure 11.1: Stop frequency comparison for work tours

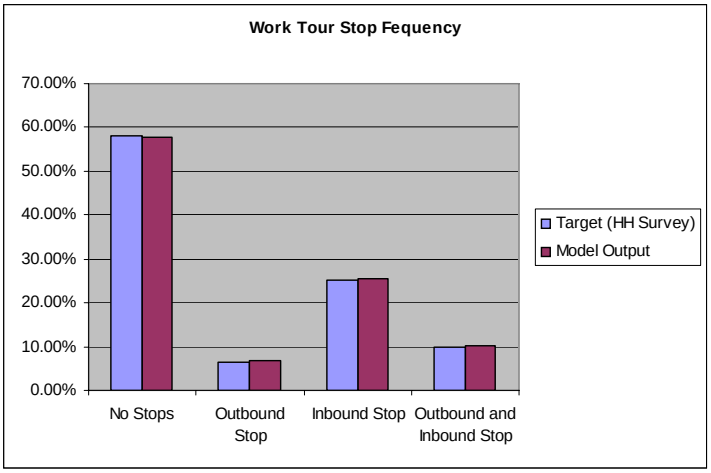


Figure 11.2: Stop frequency comparison for school tours

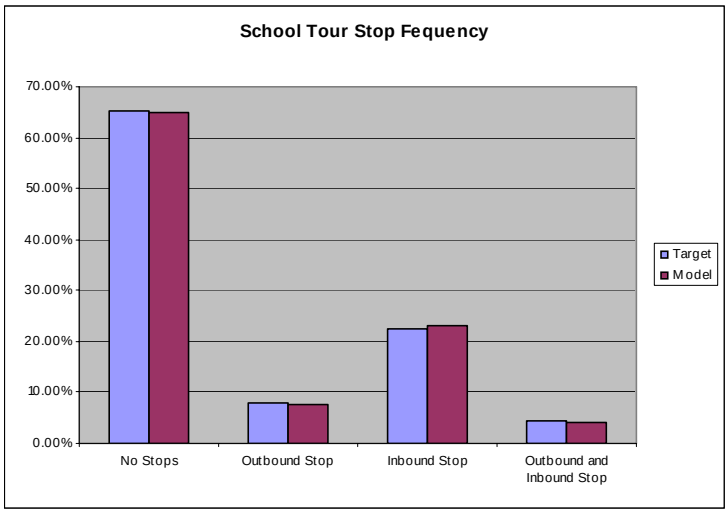


Figure 11.3: Stop frequency comparison for joint tours

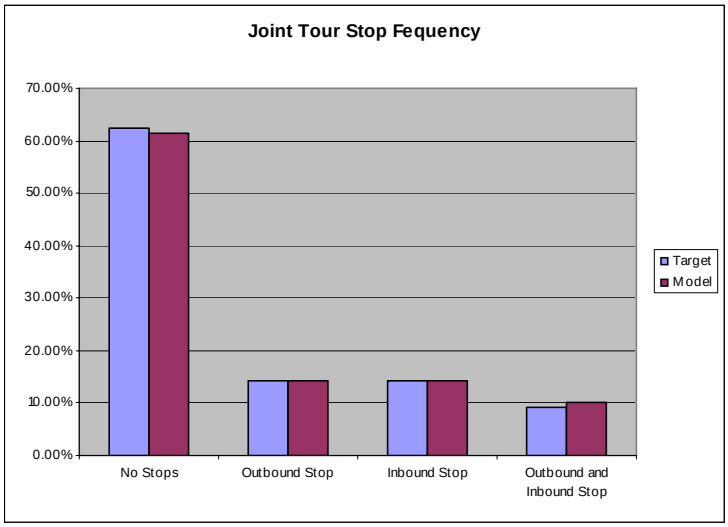


Figure 11.4: Stop frequency comparison for individual non-mandatory tours

Figure 11.5: Stop frequency comparison for escort tours

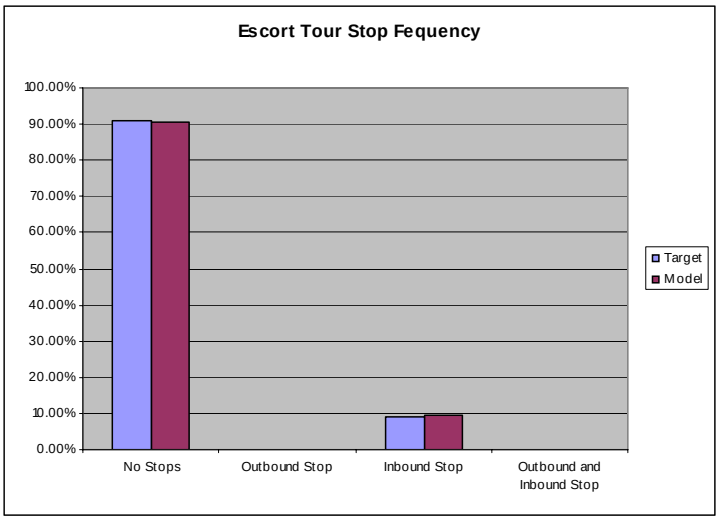


Figure 11.6: Stop frequency comparison for work-based work-related tours

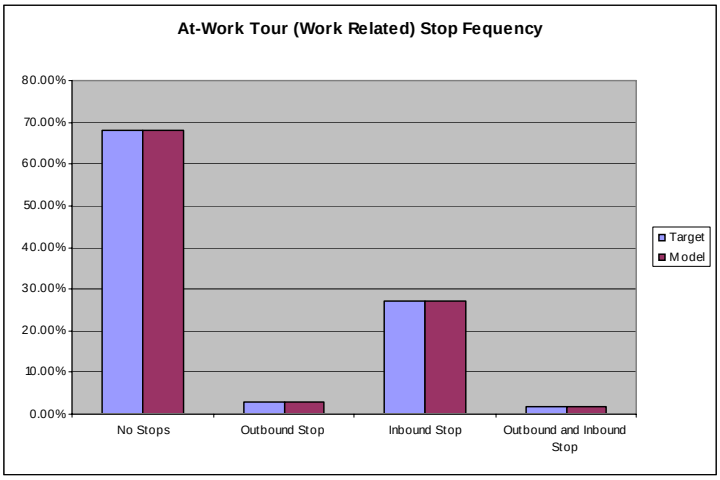


Figure 11.7: Stop frequency comparison for work-based eat tours

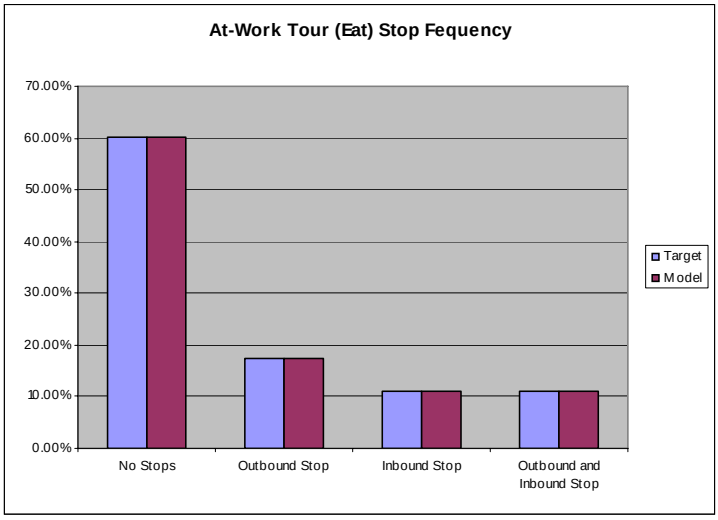
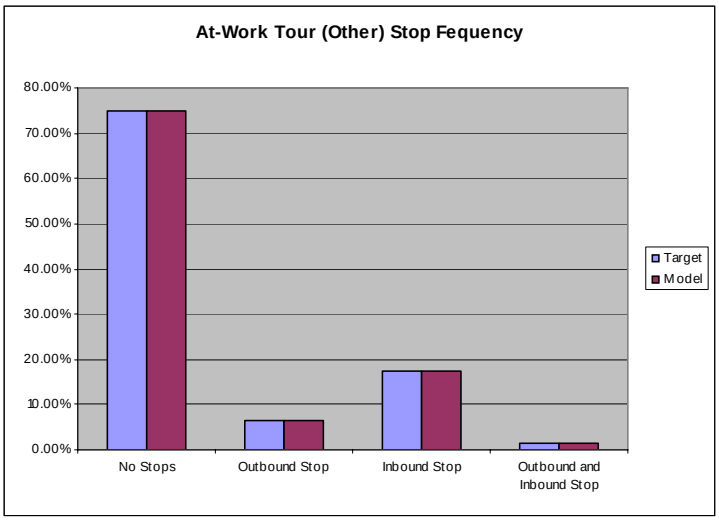


Figure 11.8: Stop frequency comparison for work-based other tours



11.4 Stop Location Model

The stop location choice model is a multinomial logit model in which each potential destination zone is an alternative. The model is stratified by trip type, tour mode, and stop type. Each zone's attractiveness is calculated from a utility function, where the utility consists of both zonal and household specific information. Because the stop is a sub-tour, the distance the stop adds to the tour is used as a distance penalty in the utility. This distance is calculated as either the absolute (actual) difference or relative difference, the latter of which is the absolute difference divided by the distance without the stop.

To provide a measure of a zone's attractiveness based on tour-specific characteristics, a size term is included in the utility expression. The size terms are stratified by individual non-mandatory tour type and are calculated as the natural logarithm of a sum of variables. The following table summarizes the specification (1=variable was used in size term, 0=variable was not used):

Table 11.5: Stop location model size term specification

	Size Term Variable Coefficients						
	Total Occupied Units	Employment					School Enrollment
Tour Type		Retail	Service	Gaming	Recreation	Other	
Work - Outbound	1	0	1	1	1	1	0
Work - Inbound	0	0	0	1	0	1	1
School - Outbound	1	0	1	1	0	0	1
School - Inbound	1	0	0	1	0	0	1
Escort	1	0	0	1	0	1	1
Shop	1	0	0	1	1	0	0
Maintenance-Other	1	0	1	1	1	1	0
Discretionary	1	0	1	1	1	0	0
Eat	1	0	1	1	1	0	1
Work-Based	1	0	1	1	1	1	0

In the Tahoe region, a number of residents actually travel outside of the region to make individual tours. To capture this effect, size terms were assigned to external zones. These size terms are discussed in **Appendix I**. The calibrated stop location choice model estimation results are presented in the following tables.

Table 11.6: Mandatory work tour stop location model estimation results

Variable	Outbound		Inbound	
	Auto	Transit	Auto	Transit
Relative deviation - middle income	-0.2000	-0.2980	-0.0070	-0.0206
Relative deviation - high income				
Absolute deviation - low income	-0.1402	-0.2312	-0.0443	-0.1343
Absolute deviation - middle income	-0.1305	-0.2175	-0.1521	-0.1691
Absolute deviation - high income	-0.0801	-0.1701		
Size term - low income	0.7679		0.9577	
Size term - medium/high income	0.5801		0.7503	
External zone	1.8000		1.3000	
Origin, destination, and stop location within ¼ mile of transit		0.9550		0.9550
No Attractions	Not Available			
No transit access at stop		Not Available		Not Available

Table 11.7: Mandatory school tour stop location model estimation results

Variable	Outbound	Inbound
Absolute deviation - auto	-0.1088	-0.0906
Absolute deviation - transit	-0.2328	-0.2176
Size term	0.9756	0.7971
External zone - auto	-2.0000	3.3000
Origin, destination, and stop location within ¼ mile of transit	0.9550	
No Attractions	Not Available	
No transit access at stop - transit	Not Available	

Table 11.8: Joint tour stop location model estimation results

Variable	Shop		Other-Maintenance		Discretionary		Eat	
	Outbound	Inbound	Outbound	Inbound	Outbound	Inbound	Outbound	Inbound
Absolute deviation - auto	-0.0850	-0.2725	-0.1353	-0.2103	-0.4781	-0.5581	-0.5166	-0.5266
Absolute deviation - transit	-0.2425		-0.2303		-0.2581		-0.4766	
Size term	0.7560		0.7609		0.9833		0.9833	
External zone - auto	1.1300	3.0000	2.3030	3.2000	-4.0000	12.7000	13.0000	11.5000
Origin, destination, and stop location within ¼ mile of transit	0.9550							
No Attractions	Not Available							
No transit access at stop - transit	Not Available							

Table 11.9: Individual non-mandatory tour stop location model estimation results

Variable	Escort		Shop		Other-Maintenance		Discretionary		Eat	
	Outbound	Inbound	Outbound	Inbound	Outbound	Inbound	Outbound	Inbound	Outbound	Inbound
Absolute deviation - auto, adult	-0.3189	-0.4889	-0.3299	-0.5299	-0.2586		-0.2495	-0.2995	-0.4829	-0.3029
Absolute deviation - transit, adult	-0.3189		-0.3799				-0.2495		-0.2929	
Absolute deviation- auto, child	-0.3189	-0.4889	-0.3299	-0.5299			-0.3732		-0.6032	-0.4232
Absolute deviation - transit, child	-0.3189		-0.3799						-0.3732	
Size term - adult	0.8741		0.7651		0.8764		0.6745		0.8967	
Size term - child			0.7914		0.9120		1.0000		1.0000	
External zone - auto		11.5000	1.8000	4.7000	6.6000	4.0000		3.5000	-2.0000	-3.0000
Origin, destination, and stop location within ¼ mile of transit	0.9550									
No Attractions	Not Available									
No transit access at stop - transit	Not Available									

Table 11.10: Work-based tour stop location model estimation results

Variable	Work-Related		Eat		Other	
	Outbound	Inbound	Outbound	Inbound	Outbound	Inbound
Absolute deviation - low income, auto	-1.3276	-0.0276	-0.5467	-0.6467	-0.5575	-0.3275
Absolute deviation - medium income, auto					-0.1825	-0.0925
Absolute deviation - high income, auto	-1.3522	-0.3522	-0.3107	-0.4107		
Absolute deviation - low income, transit	-0.1276		-0.5467		-0.8575	
Absolute deviation - medium income, transit					-0.3925	
Absolute deviation - high income, transit	-0.1522		-0.3107			
Relative deviation - low/medium income, auto	-0.9017	-0.2017				
Relative deviation - low/medium income, transit	-0.3017					
Size term	0.5580		0.4560		0.7767	
No Attractions	Not Available					
No transit access at stop - transit	Not Available					

11.5 Stop Location Model Calibration

To calibrate the destination choice submodel, two primary aspects were examined:

- Tour distance difference (distance with stop minus distance without stop)
- Internal to external flows

To perform the calibration, processed data from the household travel survey was compared with equivalent data processed from the model results. Adjustments to alternative specific constants and selected variable coefficients were made to bring the model results in line with the results of the travel survey.

Table 11.11: Tour distance difference comparison

	Outbound		Inbound	
Tour Type	Target (HH Survey)	Model Output	Target (HH Survey)	Model Output
Work	3.931	3.994	5.600	5.686
School	4.377	4.295	8.597	8.338
Joint Shop	6.081	7.109	2.015	2.556
Joint Maintenance-Other	4.224	4.851	2.974	3.239
Joint Discretionary	1.627	1.506	1.449	1.985
Joint Eat	2.353	1.997	1.813	1.991
Individual Shop	2.430	2.037	1.970	1.788
Individual Maintenance-Other	4.634	3.545	3.060	3.010
Individual Discretionary	2.433	2.382	2.023	2.250
Individual Eat	1.037	1.450	2.337	2.082
Escort	X	3.455	2.862	2.168
At-Work Work Related	0.304	1.322	3.817	4.172
At-Work Eat	18.998	2.580	1.685	2.364
At-Work Other	3.976	3.741	7.683	7.927

Figure 11.9: Outbound stop external location frequency comparison

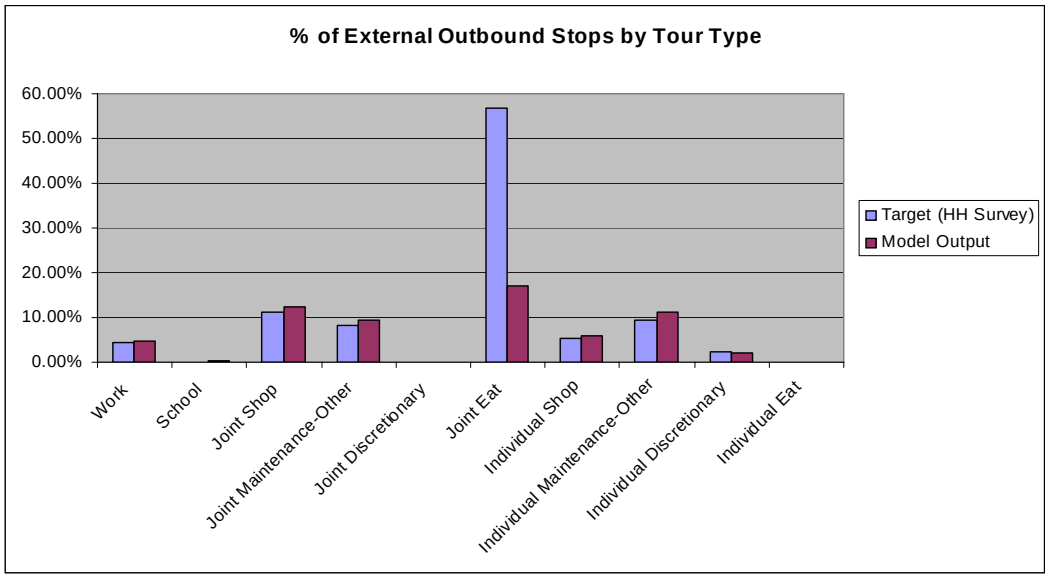


Figure 11.10: Inbound stop external location frequency comparison

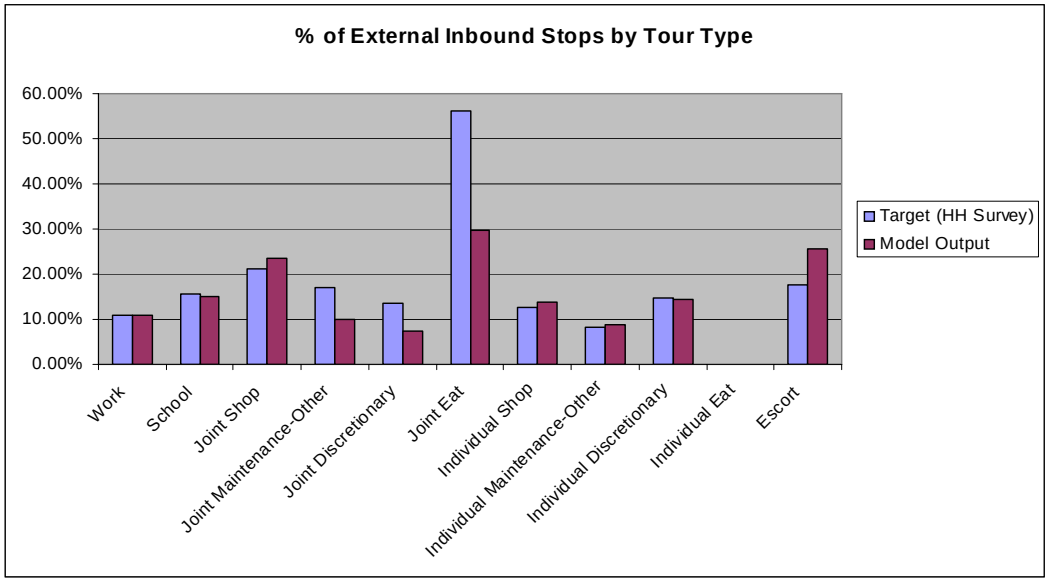
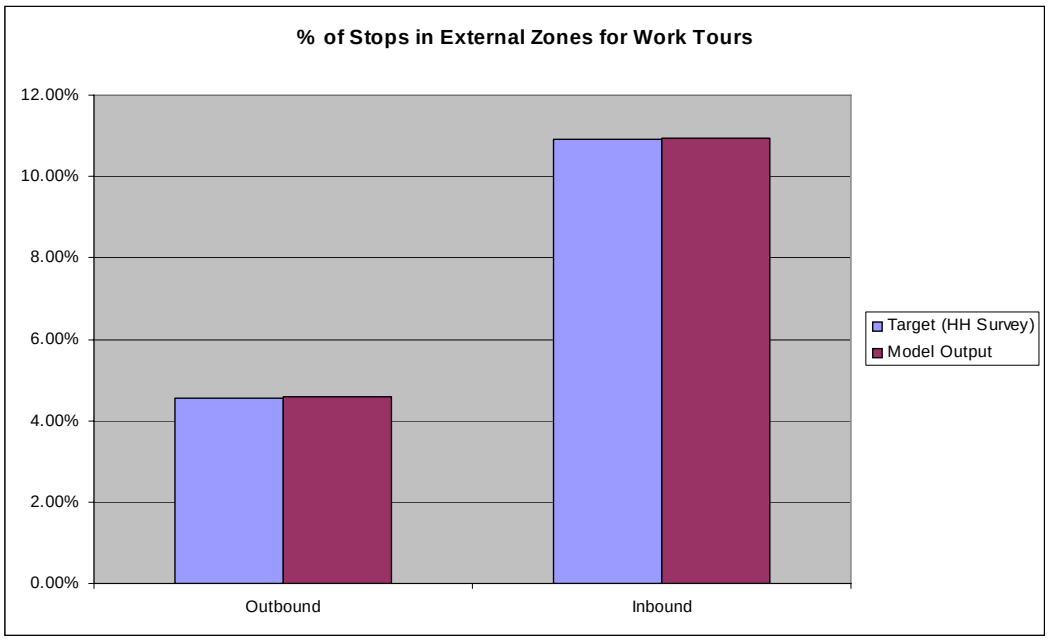


Figure 11.11: Work-based stop external location frequency comparison



11.6 Stop Mode Choice Model

The stop mode choice model is essentially a logical determination if certain tour legs should be non-motorized. This only applies to transit tours, as it is assumed that if the tour mode is drive (alone or shared ride) or non-motorized, then that mode will be used for all trip legs. For a transit tour half (outbound or inbound), the mode choice model takes the shortest leg (to the stop or from the stop) and compares its travel time for the walk to transit and non-motorized (walk) modes. Whichever is shorter is assigned to that leg. For drive to transit trips, only the second leg for outbound trips (from the stop) or the first leg for inbound trips (to the stop) can be walk to transit or non-motorized. The first and last trip must be drive to transit.

CHAPTER 12
External Workers Model

CHAPTER 12 – EXTERNAL WORKERS MODEL

12.1 Introduction

The external workers model concerns itself with people living outside of the Tahoe basin but who work within its boundaries. Partly because of the small size of the basin, and partly because of the economics of living in the region, a significant number of the employment within the basin is filled by persons living outside of the basin ridge. According to the results of the residential travel demand model (which itself is based on the U.S. Census and household travel survey), external workers fill just over 25% of the employment in the basin.

Because the household travel survey only targeted households living within the basin, no information concerning the external workers' characteristics was obtained. Therefore, the formulation, calibration, and validation of the external workers model was carried out using data derived from the following sources:

- The outputs of the residential travel demand model
- The region's socio-economic data
- Count data for the region's external stations
- The North Tahoe/Truckee Employer Commute Survey (2002)

The first two data sources were used to determine how many external workers are in the region on the model day, and where they work. The second two sources were used to determine where the workers originated, and when they made their trips.

The external workers model consists of three steps:

1. A synthesis of the external worker population; determining its size and workplace distribution.
2. An "origin-choice" model (sometimes referred to as a "reverse" destination choice model") which determines which external station each external worker originates from.
3. A time-of-day model which determines when each external worker tour is made.

For simplicity, and because there was little or no data to back up such additions, neither intra-tour stops nor work-based sub-tours were included in the external workers model.

12.2 External Workers Population Synthesis

The external worker population synthesis is a very simple model based on the results of the residential population travel demand model. As discussed in **Chapter 6, Section 4**, the residential mandatory work tour destination choice model used demand constraints (shadow pricing) to ensure that no zone's employment was over-filled (beyond a very small percentage). Because of this, determining the number of external workers required for each zone is just a matter of subtracting the number of residents working in it from its employment:

$$X_i = \max(E_i - R_i, 0)$$

where X_i is the number of external workers working in zone i

E_i is the total employment in zone i

R_i is the number of residents working in zone i

The "max" function is required because there is a small percentage of low-employment zones where employment may be slightly over-filled.

On a given day in the basin region, all of a zone's employment does not necessarily translate into a work trip. This can be due to a multitude of factors, including:

- Part-time workers do not work every weekday
- Some jobs (especially recreation/tourism based ones) may require weekend work and thus the workers' "weekends" may occur during a weekday
- Workers may take vacation, or be sick

In theory, the residential model accounts for such "shrinkage" among the residential population implicitly via the daily activity pattern model. However, just filling up the "unfilled" employment in a zone with external workers will nullify such effects. Thus, in order to account for this, an "unfilled employment factor" is used to ensure that the zonal employment is not completely filled up. This has the effect of slightly shrinking the external worker population. The number used for the unfilled employment factor in the model is 0.005.

The formula for total unfilled employment is determined by:

$$U = E\sigma$$

where U is the unfilled employment in the region
E is the total employment in the region
σ is the unfilled employment factor

Given this, each unfilled employment spot is randomly removed from the external worker population. This removal process is essentially a monte-carlo selection process where every external worker employment spot is equally likely to be removed.

After the unfilled employment procedure, the size of the external worker employment population in each zone is fixed. Given this information, the external worker population is easily synthesized by creating one worker for each employment spot. Each worker essentially has only one defining characteristic: the zone that he/she works in. A summary of the external worker population synthesis, as well as a comparison with the residential population, is presented in **Table 12.1**.

Table 12.1 Summary of external worker synthesized population, and comparison with residential model

Workplace Location (County)	External Worker	Residential Worker	Actual Employment
Washoe	1475	3121	4601
Carson City	0	0	0
Douglas	2325	7241	9484
El Dorado	2040	6670	8877
Placer	1311	2525	3838
Total	7151	19557	26800
Unfilled Employment	92		

12.3 External Workers Origin Choice Model

While most location choice models start with an known origin location (typically "home") and choose a destination (i.e. "workplace"), the external workers location choice model does the exact opposite: the workplace location is known based on the population synthesis, and the origin/home (i.e. external station) is chosen. The origin choice model is a simple multinomial logit choice model where each external zone is an available alternative. The only

variables included in the model are distance, a size term, and a shadow price. The distribution of external worker origins amongst the seven external zones has been determined based on analysis of traffic counts and the North Tahoe/Truckee Employer Commute Survey, which asked a selection of employers in and around the basin region where their employees lived. Because both the survey and counts were seasonal in nature, different distributions for summer and winter were calculated. These distributions are presented in **Table 12.2**.

Table 12.2: External station distribution for external workers

Origin External Station	Summer Distribution	Winter Distribution
Reno	11.68%	12.18%
Carson City	35.32%	35.38%
Kingsbury Grade	24.24%	30.45%
Kirkwood	1.57%	1.07%
Placerville	2.89%	2.86%
Squaw	3.65%	4.81%
Truckee	10.65%	13.25%

From this distribution, a size term is calculated for each external station as the natural log of the number of external workers that should originate in that station (the percentage from Table 12.2 times the total number of external workers). Because of distance variations, the distribution of external workers across external stations will not necessarily be matched, so a shadow price variable is added and the model iteratively run until the distribution is matched within an allowable error. This process is analogous to that described in **Chapter 6, section 4** for the residential mandatory work destination choice model.

The calibrated coefficients used for the external workers origin choice model are presented in **Table 12.3**. The county (destination) to external station (origin) results of the external workers origin choice model are presented in **Table 12.4**. A map presenting these results is show in **Figure 12.1**.

Table 12.3: External workers origin choice model coefficient specification

Variable	Coefficient
Distance (miles)	-0.1680
Size term	1.0000
Size term = 0	Not Available

Table 12.4 External station to county (workplace) flows for the external workers origin choice model

	Workplace Location (County)				
Origin External Station	Washoe	Carson City	Douglas	El Dorado	Placer
Reno	642	0	24	22	241
Carson City	557	0	1167	866	216
Kingsbury Grade	9	0	1056	855	6
Kirkwood	0	0	28	97	0
Placerville	1	0	42	183	4
Squaw	10	0	2	7	273
Truckee	256	0	6	10	571

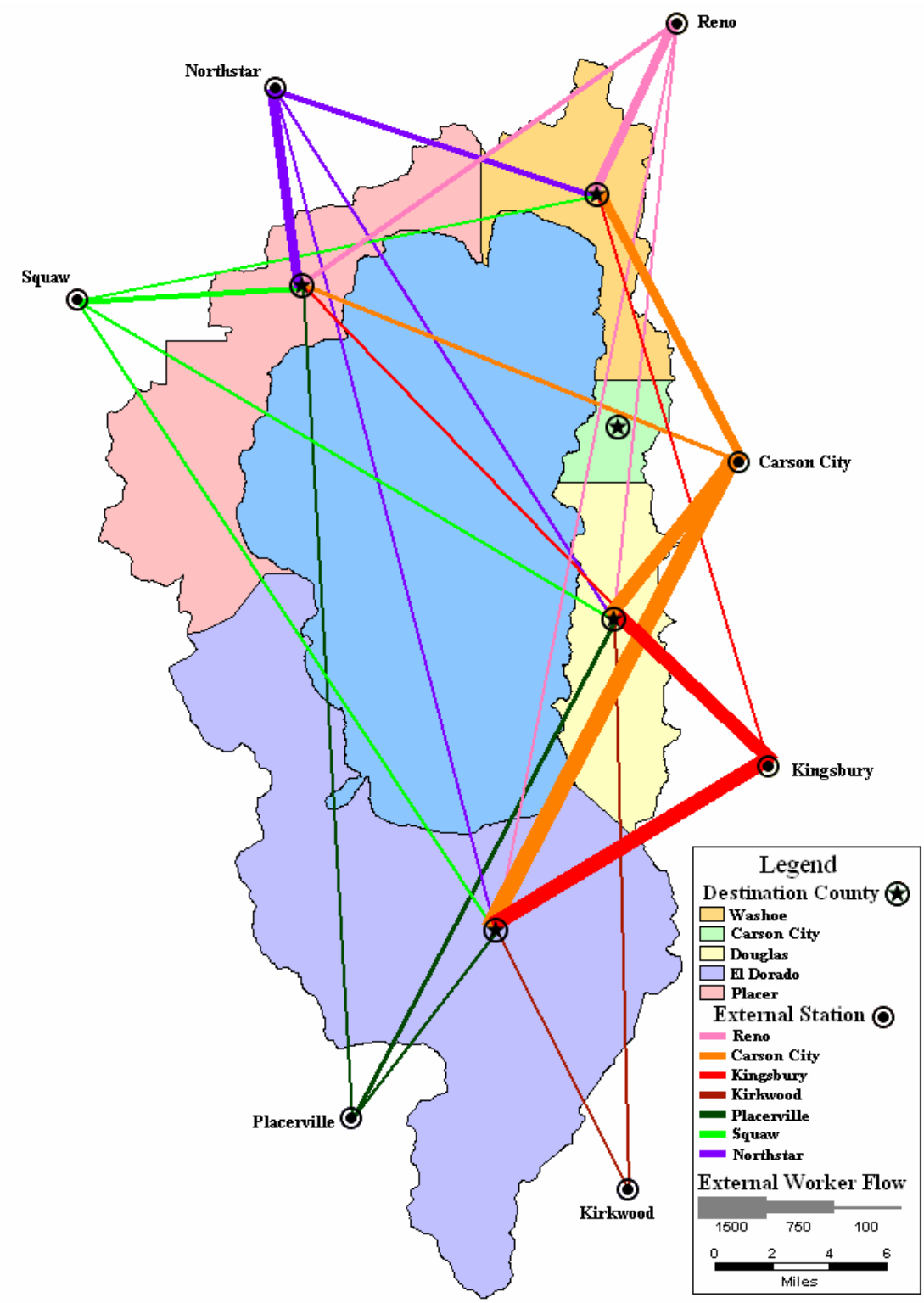


Figure 12.1 External station to county (workplace) flows for external workers origin choice model. Flows of zero have been suppressed. County labels are colored purple, and external stations labels are colored white.

12.4 External Workers Time-Of-Day Choice Model

The external workers time-of-day (TOD) model is a multinomial choice model where each skim period is an available alternative as a start and end of the tour. The skim periods are defined in **Table 12.5**:

Table 12.5: Skim period definitions

Skim Period	Start Time	End Time	Duration
AM Peak (AM)	7:00 AM	10:00 AM	3 hours
Midday (MD)	10:00 AM	4:00 PM	6 hours
PM Peak (PM)	4:00 PM	7:00 PM	3 hours
Late Night (LN)	7:00 PM	7:00 AM	12 hours

Unlike the residential model, one-hour granularity of tour start and end times was not modeled (mainly due to data limitations). Given the four skim periods, there are sixteen available start/end skim period pair permutations. To calibrate coefficients for each of these alternatives, two factors were taken into account:

1. External station count data separated by time period and season
2. Simplifying assumptions due to lack of data

For the first factor, the external station count data was known for each direction and each skim period. Also known was the external station traffic generated by the residential travel demand model. The model was calibrated, concurrently with the visitor model, to match these counts.

One of the difficulties with using the traffic counts was that it was impossible to distinguish the contribution of the external workers versus the visitors to overall external station flows. In order to develop the targets for calibration some assumptions had to be made about the time of day that external workers were entering the region. In particular it was assumed that external workers do not work graveyard shifts and therefore the "startPM, end AM" choice was eliminated. The distribution of the remaining choices is based on the time-of-day results of the residential mandatory work time-of-day choice model. Given this, the calibrated coefficients for the external worker time-of-day choice model are presented in **Tables 12.6a and 12.6b**, and a summary of the model results are presented in **Tables 12.7a and 12.7b**.

Table 12.6a: External worker time-of-day model coefficient specifications, summer

Variable	Coefficient
Start AM, end AM	-2.7895
Start AM, end MD	-1.9590
Start AM, end PM	-1.1833
Start AM, end LN	-2.3755
Start MD, end AM	Not Available
Start MD, end MD	-3.0378
Start MD, end PM	-2.2621
Start MD, end LN	-3.4543
Start PM, end AM	Not Available
Start PM, end MD	Not Available
Start PM, end PM	-2.1650
Start PM, end LN	-3.3572
Start LN, end AM	-3.6468
Start LN, end MD	-2.8162
Start LN, end PM	-2.0405
Start LN, end LN	-3.2327

Table 12.6b: External worker time-of-day model coefficient specifications, winter

Variable	Coefficient
Start AM, end AM	-2.9271
Start AM, end MD	-1.0966
Start AM, end PM	-1.3209
Start AM, end LN	-2.5131
Start MD, end AM	Not Available
Start MD, end MD	-2.8390
Start MD, end PM	-2.0633
Start MD, end LN	-3.2555
Start PM, end AM	Not Available
Start PM, end MD	Not Available
Start PM, end PM	-2.3026
Start PM, end LN	-3.4948
Start LN, end AM	-3.4479
Start LN, end MD	-2.6174
Start LN, end PM	-1.8417
Start LN, end LN	-3 0339

Table 12.7a: External worker time-of-day model results summary, summer

Time Period	Departing	Departing %	Arriving	Arriving %
AM	3595	50.57%	524	7.37%
MD	1139	16.02%	1409	19.82%
PM	900	12.66%	3961	55.72%
LN	1475	20.75%	1215	17.09%

Table 12.7b: External worker time-of-day model results summary, winter

Time Period	Departing	Departing %	Arriving	Arriving %
AM	3196	43.88%	523	7.18%
MD	1393	19.12%	1556	21.36%
PM	796	10.93%	4000	54.91%
LN	1899	26.07%	1205	16.54%

CHAPTER 13
Visitor Model Overview

CHAPTER 13 – VISITOR MODEL OVERVIEW

13.1 Introduction

Understanding and forecasting visitor travel is an important part of modeling travel demand in the Tahoe basin. The visitor models deals with three types of visitors:

- **Overnight-visitors** – those who stay overnight in the region
- **Day-visitors** – those who enter and leave the region during the travel day using the same external station
- **Thru-visitors** – those who enter and leave the region during the travel day using different external stations to enter and exit

Unfortunately visitors to the region are difficult to model not only because data collection is difficult, but also because the number of visitors varies widely depending on the day. During holidays (4th of July, Memorial Day) their numbers may swell to well above "normal", whereas the population might be very small during the "off-season." The goal of the Tahoe visitor model is provide the analyst with a way to specify the population size, populate the region and then model the travel produced by this population accurately.

13.2 Visitor Data Sources and Visitor

The bulk of the visitor data came from the results of overnight and day-visitor travel surveys produced by NuStats (see "Tahoe_report_final_winter[summer].pdf" for more details) These surveys were taken during both the summer and winter seasons, and attempted to capture the travel behavior of non-residents in the region. Seasonal residents, a population that is modeled along with the overnight-visitors, were surveyed during the resident surveys. It was hard to define exactly what constituted a "seasonal resident" since they come in various forms (2nd home-owners, regular visitors, monthly renters, time share owners, etc.). In the end, the surveyors asked the interviewee if he/she considered him/herself a seasonal resident and if so the data was thus marked. The last data source was external station traffic counts, which were used to help determine the flow of visitors into and out of the region during the travel day.

13.3 Visitor Model Flow

The basic unit of visitors is the "travel party." This is a group of people who travel together throughout the day, each enjoying the same activities. Almost all travel decisions are made at the travel party level, and therefore for this model, travel decisions made at a more granular level (e.g. individual or joint tours from the resident model) were not allowed. This simplification was made both because of data limitations and to avoid over complicating the model.

As much as possible, the visitor model was kept consistent with the resident model. It is therefore a micro-simulated, activity-based travel demand model. Due to data availability limitations, the overnight and day-visitor models are more sophisticated and detailed than the thru-visitor model. Furthermore, the survey data for the overnight-visitor model was more detailed than the day-visitor, so a large part of the tour models for the day-visitors was combined with the overnight-visitors to create more robust model estimation results.

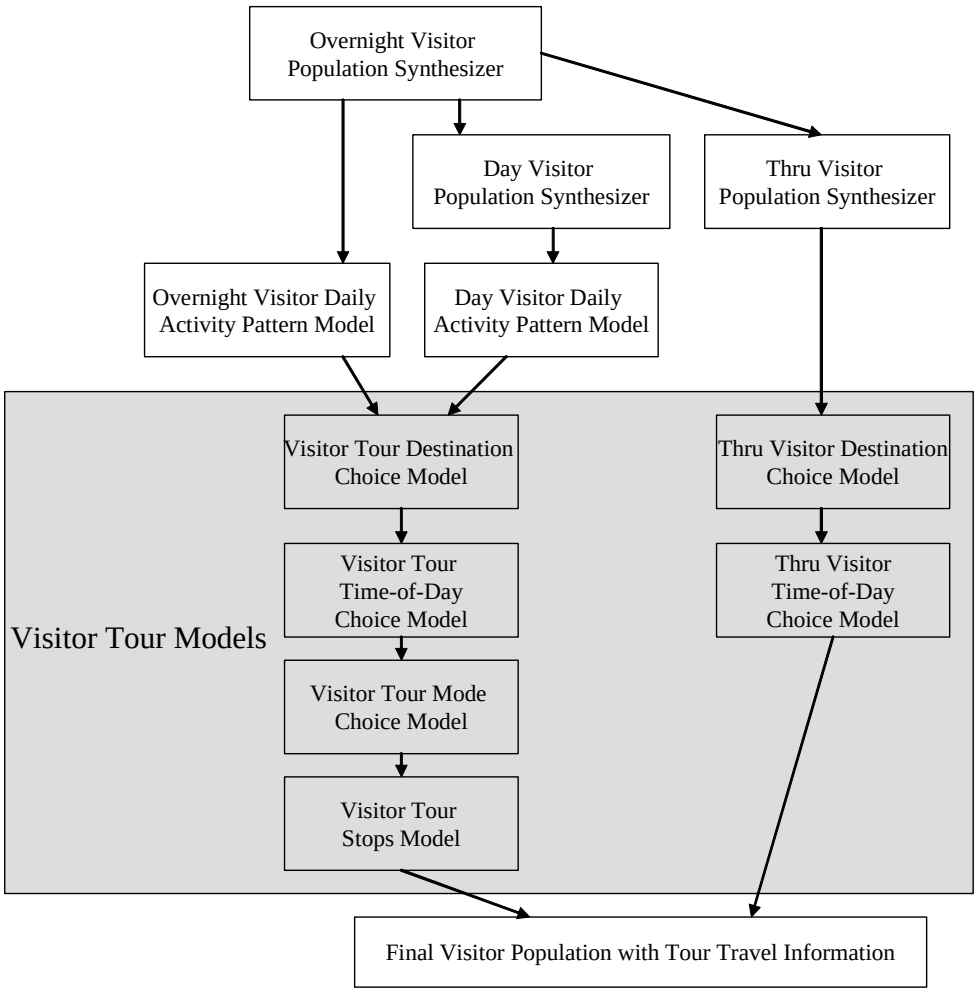
At a general level, the actual flow of the visitor model follows the resident model. The model steps, in order, are as follows:

1. **Overnight-Visitor Population Synthesis** – an overnight-visitor population is micro-simulated from overnight-visitor survey records to match occupancy rates within the region
2. **Day-Visitor Population Synthesis** – a day-visitor population is micro-simulated from day-visitor survey records to match calibrated expansion factors based on the overnight-visitor population

3. **Overnight- and Day-Visitor Daily Activity Pattern Models** – the daily travel behavior for each travel party is determined in these two parallel but separate models
4. **Visitor Tour Destination, Time-of-Day, and Mode Choice Models** – each travel party tour's destination, time, and mode is determined in this single model
5. **Visitor Tour Stop Model** – the location and mode for tour stops is determined in this single model
6. **Thru-Visitor Population Synthesis** – a thru-visitor population is micro-simulated to match calibrated expansion factors based on the overnight visitor population
7. **Thru-Visitor Destination and Time-of-Day Choice Models** – each thru-visitor tour's destination and time is chosen in this model

A graphical representation of this model flow is shown in **Figure 13.1**. It is important to note that the entire model is influenced by the overnight visitor population synthesis. It was decided that the occupancy rates of the various overnight accommodations provide the best information for determining the number of visitors in the region. An assumption is made that days with higher overnight-visitor populations will also have higher day-visitor populations, and that there is a constant linear relationship between the two. This way, the visitor population is sensitive to scenario and policy specific data, and will allow forecasts to account for potential demographic and socio-economic shifts.

Figure 13.1: Tahoe visitor model flow diagram



CHAPTER 14
Overnight-Visitor Synthetic Population

CHAPTER 14 – OVERNIGHT-VISITOR SYNTHETIC POPULATION

14.1 Introduction

The overnight-visitor synthetic population is used to represent persons who visit the Tahoe basin on a non-permanent basis (i.e. are not permanent residents) but who are not just visiting for the day. This population includes not only people who do not claim any residence in the region ("vacationers"), but also seasonal residents, who own or rent a residence in the region and reside in it on a regular, though not permanent, basis. The synthetic population is micro-simulated using occupancy rates (which can vary by scenario) and actual records from the overnight-visitor survey and residential travel survey. The base unit of the synthetic population is the "travel party," which can be considered analogous to the household unit of the residential travel model. The reason overnight-visitors are not referred to as households is two-fold:

1. Often travel parties may consist of multiple households (both within and across families). Thus, referring to the party as a household (as it is used in other parts of this model/documentation) would be misleading.
2. The level of information available for each party is extremely limited: essentially where they stayed and some basic compositional data. The use of the term household – both in terms of the residential model and activity-based models as a whole – implies a deeper level of data than what is known. The use of the more generic and broad sounding "travel party" helps to underline this.

14.2 Population Stratification

The overnight-visitor population is stratified by their "stay-type," or the type of accommodation used during their stay. The reason for this is partly due to the observation that people staying at campgrounds make different travel decisions than people staying in a resort hotel than do people staying in a rental cabin for example.
In addition, stratifying the population provides the user more control over the overnight-visitor population in a specific scenario.

There are six stay-type stratifications for the overnight-visitor population:

- **Seasonal** – For seasonal residents
- **Hotel/Motel** – For visitors staying in a hotel or motel
- **Casino** – For visitors staying in a casino-based hotel
- **Resort** – For visitors staying in a higher-end (non-casino) resort
- **House** – For visitors who are not seasonal residents but who are staying in some type of an attached or detached residence
- **Campground** – For visitors staying at a campsite

For each of these stay-types, the synthetic population model requires the user to specify the number of units that are occupied on the model day for each zone. These "vacancies" are then "filled" by visitor parties during the synthesis procedure. A description of what form the inputs must take and how the information is used to synthesize the population is described below.

For Hotel/Motel, Casino, Resort, and Campground stay-types, the number of available units per zone is a scenario-specific input. The other required input is the occupation percentage, by zone, for each of these stay-types. By multiplying these two values, the number of occupied units is determined. (As a note, the winter Campground occupation rate is globally set to zero, as winter camping rarely, if ever, occurs in the basin).

For the Seasonal and House stay-types, the number of available units is derived from the socio-economic data used in the resident model. That data includes both the number of available housing units and the number of (full-time) occupied units. The difference between these numbers provides the number of units available for the Seasonal and House overnight-visitor stay-types. The user inputs are then the percentages of available units that are filled, and the percentage of those units that are seasonal. From this the number of filled housing units can be determined:

$$R_{i,S} = U_i F_i P_i$$
$$R_{i,H} = U_i F_i (1 - P_i)$$

where $R_{i,S}$ is the number of filled overnight-visitor housing units for Seasonal in zone i

$R_{i,H}$ is the number of filled overnight-visitor housing units for House in zone i

U_i is the number of available overnight-visitor housing units

F_i is the fraction of U_i which are to be filled

P_i is the percentage of the filled units which are Seasonal

14.3 Sample Source

The synthetic population consists of actual travel parties sampled from the overnight-visitor and resident surveys. This is analogous to the use of the PUMS records to generate the resident synthetic population. Because there were two sources for the population, and because the samples would be merged to form the full overnight-visitor population, the data in the sample from each source had to be identical. Furthermore, the day visitor population **(see Chapter 15)** would also be merged with this population later in the model stream, so the limited data collected during the day visitor survey determined what data could be retained/used from all the surveys. The resulting travel party characteristics were used in the models:

- travel party size
- number of children (age < 18) in the party
- presence of an adult female
- stay-type of the party
- season during which the survey was taken (summer, winter, or seasonal for seasonal residents)

For the non-seasonal resident overnight-visitors, the overnight-visitor survey records are sampled. For example, when populating campgrounds with overnight-visitors, the sample set is all surveyed visitors that stayed at a campground. However not all of the stay-types had enough survey records to provide a robust sample set and were therefore combined with other stay-types. For the same reasons, stratification by season or location could not be made. **Table 14.1** summarizes the sample source for each stay-type.

Table 14.1: Non-seasonal overnight-visitor population sample summary

Stay-Type	Available Sample Records	Stay-Types Used for Population Sample
Hotel/Motel	231	Hotel/Motel, Casino, Resort
Casino	224	Hotel/Motel, Casino, Resort
Resort	22	Hotel/Motel, Casino, Resort
House	294	House
Campground	81	Campground

For seasonal-residents, the sample source is the residential household survey. NuStats was able to survey 229 households that self-identified as "seasonal."

14.4 Population Synthesis

Given the number of units to be filled by zone and stay-type, and the sample records corresponding to each stay-type, the population synthesis is a straightforward procedure. For each stay-type unit to be filled in a zone, a travel party is randomly selected from the available population sample records for that stay-type. Along with the sample data described above, the stay location (zone) is recorded and will be used as that travel party's origin/home TAZ.

14.5 Population Synthesis Application Summary

During model development and calibration, the overnight-visitor population synthesis was run for the base year and both summer and winter seasons. **Tables 14.2 through 14.7** give a summary of the base scenario synthesized overnight-visitor population.

Table 14.2a: Summer overnight-visitor stay-type by travel party size summary count

	Travel Party Size					
	1	2	3	4	5+	Total
Seasonal	1684	4330	941	889	365	8209
Hotel/Motel	263	1778	596	892	417	3946
Casino	173	1075	362	560	247	2417
Resort	8	60	15	31	16	130
House	191	720	326	634	512	2383
Campground	142	479	258	525	569	1973
Total	2461	8442	2498	3531	2126	19058

Table 14.2b: Summer overnight-visitor stay-type by travel party size summary percentage

	Travel Party Size					
	1	2	3	4	5+	Total
Seasonal	8.84%	22.72%	4.94%	4.66%	1.92%	43.07%
Hotel/Motel	1.38%	9.33%	3.13%	4.68%	2.19%	20.71%
Casino	0.91%	5.64%	1.90%	2.94%	1.30%	12.68%
Resort	0.04%	0.31%	0.08%	0.16%	0.08%	0.68%
House	1.00%	3.78%	1.71%	3.33%	2.69%	12.50%
Campground	0.75%	2.51%	1.35%	2.75%	2.99%	10.35%
Total	12.91%	44.30%	13.11%	18.53%	11.16%	100.00%

Table 14.3a: Winter overnight-visitor stay-type by travel party size summary count

	Travel Party Size					
	1	2	3	4	5+	Total
Seasonal	1583	4047	890	811	324	7655
Hotel/Motel	360	2411	770	1188	532	5261
Casino	151	1021	326	529	251	2278
Resort	5	110	33	40	15	203
House	147	648	297	610	521	2223
Campground	0	0	0	0	0	0
Total	2246	8237	2316	3178	1643	17620

Table 14.3b: Winter overnight-visitor stay-type by travel party size summary percentage

	Travel Party Size					
	1	2	3	4	5+	Total
Seasonal	8.98%	22.97%	5.05%	4.60%	1.84%	43.44%
Hotel/Motel	2.04%	13.68%	4.37%	6.74%	3.02%	29.86%
Casino	0.86%	5.79%	1.85%	3.00%	1.42%	12.93%
Resort	0.03%	0.62%	0.19%	0.23%	0.09%	1.15%
House	0.83%	3.68%	1.69%	3.46%	2.96%	12.62%
Campground	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	12.75%	46.75%	13.14%	18.04%	9.32%	100.00%

Table 14.4a: Summer overnight-visitor stay-type by presence of children summary

	No Children		Children in Party	
Seasonal	6838	83.30%	1371	16.70%
Hotel/Motel	2667	67.59%	1279	32.41%
Casino	1644	68.02%	773	31.98%
Resort	89	68.46%	41	31.54%
House	1250	52.45%	1133	47.55%
Campground	818	41.46%	1155	58.54%
Total	13306	69.82%	5752	30.18%

Table 14.4b: Winter overnight-visitor stay-type by presence of children summary

	No Children		Children in Party	
Seasonal	6405	83.67%	1250	16.33%
Hotel/Motel	3617	68.75%	1644	31.25%
Casino	1541	67.65%	737	32.35%
Resort	146	71.92%	57	28.08%
House	1107	49.80%	1116	50.20%
Total	12816	72.74%	4804	27.26%

Table 14.5a: Summer overnight-visitor stay-type by presence of adult female summary

	No Female Adult		Female Adult in Party	
Seasonal	813	9.90%	7396	90.10%
Hotel/Motel	499	12.65%	3447	87.35%
Casino	340	14.07%	2077	85.93%
Resort	17	13.08%	113	86.92%
House	292	12.25%	2091	87.75%
Campground	213	10.80%	1760	89.20%
Total	2174	11.41%	16884	88.59%

Table 14.5b: Winter overnight-visitor stay-type by presence of adult female summary

	No Female Adult		Female Adult in Party	
Seasonal	761	9.94%	6894	90.06%
Hotel/Motel	690	13.12%	4571	86.88%
Casino	304	13.35%	1974	86.65%
Resort	24	11.82%	179	88.18%
House	235	10.57%	1988	89.43%
Total	2014	11.43%	15606	88.57%

CHAPTER 15
Day-Visitor Synthetic Population

CHAPTER 15 – DAY-VISITOR SYNTHETIC POPULATION

15.1 Introduction

The day-visitor synthetic population is used to represent persons who visit the Tahoe basin only for the day and do not stay overnight. Technically this population includes thru-visitors, but as these are handled in a separate model **(see Chapter 18)**, further restrictions are made: day-visitors are those described above who also make at least one stop and exit the region using the same external station they entered. Like the overnight-visitor population, the day-visitors are micro-simulated using a sample drawn from the day-visitor survey records, and the base decision making unit is again the "travel party." However, in contrast to the overnight-visitor population, there is no quantity analogous to occupation rates that can accurately constrain the population size. Instead, external station counts (which day-visitors must be a part of) were used to calibrate the day-visitor population size, which was then indexed to the overnight-visitor population.

15.2 Sample Source

As described above, the day-visitor synthetic population consists of a sample of actual travel parties from the day-visitor surveys. This is analogous to the use of the PUMS records to generate the resident synthetic population. As described in **Chapter 14**, the day and overnight-visitor populations are merged later in the visitor model stream, and this forced the requirement that the two populations needed to contain equivalent data. As such, the following variables are included in the day-visitor sample records:

- The travel party size
- The number of children (age < 18) in the party
- The season during which the survey was taken (summer or winter)

As a note, the presence of an adult female in the travel party variable included in the overnight-visitor population was not available from the day-visitor survey. However, this variable is not used once the two populations are merged, and therefore its elimination does not affect the model.

From the day-visitor survey, 597 sample records were put together to form the day-visitor sample.

15.3 Day-visitor Rates

To synthesize the day-visitor population, the number of day-visitors originating at each external station must be known. To determine this, external station counts (in each direction) for the base scenario and mode results from the residential and external worker models are used. Subtracting the residential and external worker trips which use the external stations from the external station counts gives the amount of flow that the day-visitor and thru visitor trips must make up. During validation, the split between the day-visitor and thru visitor trips is determined and, given this, the specific number of day-visitors per external station is known for the base scenario. To make the day-visitors vary correctly with scenarios, two assumptions are made:

1. That the day-visitors rise and fall at the same rate that overnight-visitors do; that is, that day-visitor rates can be linearly modeled from overnight-visitors
2. That the distribution of day-visitors between the external stations is constant across scenarios

Assumption 2 is probably more controversial and less "realistic" than 1, but it is required as there is little to no information as to what drives the day-visitor external station distributions

Given the above assumptions, the number of day-visitors for each external station is calculated using a simple linear formula:

$$D_e = O\sigma_e$$

where D_e is the number of day-visitors coming in through external station e
O is the number of overnight-visitors
σ_e is the day-visitor rate factor for external station e

The values for σ_e are given in **Tables 15.1 and 15.2**. Summing all of the rate factors shows that the number of day-visitors is roughly equal to 78% of the number of overnight-visitors for the summer, and 58% for the winter.

Table 15.1: Day-visitor external station rate factors, summer

External Station	Overnight to Day-visitor Rate Factor
Reno	0.0031
Carson City	0.1100
Kingsbury Grade	1.127E-05
Kirkwood	0.0456
Placerville	0.1986
Squaw	0.3106
Truckee	0.1160

Table 15.2: Day-visitor external station rate factors, winter

External Station	Overnight to Day-visitor Rate Factor
Reno	1.570E-04
Carson City	0.0119
Kingsbury Grade	3.719E-04
Kirkwood	0.0373
Placerville	0.3143
Squaw	0.1883
Truckee	0.0298

15.4 Population Synthesis

Given the number of day-visitor travel parties per external station, and the day-visitor survey sample records, generating the day-visitor synthetic population is a straightforward procedure. Essentially, for each external station, a travel party is randomly selected from the available day-visitor sample records until the required number of parties is achieved. Along with the sample data described above, the external station is recorded and will be used as that travel party's origin/home TAZ.

15.5 Population Synthesis Application Summary

During model development and calibration, the day-visitor population synthesis was run for the base year and both summer and winter seasons. **Tables 15.3 through 15.6** give a summary of the base scenario synthesized overnight-visitor population.

Table 15.3: Summer day-visitor travel party size summary

Travel Party Size	Day-visitor Parties	
1	3466	23.19%
2	5706	38.19%
3	1591	10.65%
4	2483	16.62%
5+	1697	11.36%
Total	14943	100.00%

Table 15.4: Winter day-visitor travel party size summary

Travel Party Size	Day-visitor Parties	
1	2228	23.58%
2	3609	38.19%
3	1003	10.61%
4	1558	16.49%
5+	1051	11.12%
Total	9449	100.00%

Table 15.5: Summer day-visitor presence of child summary

	Day-visitor Parties	
No Children	10315	69.03%
Children in Party	4628	30.97%

Table 15.6: Winter day-visitor presence of child summary

	Day-visitor Parties	
No Children	6561	69.44%
Children in Party	2888	30.56%

CHAPTER 16
Visitor Daily Activity Pattern Models

CHAPTER 16 – VISITOR DAILY ACTIVITY PATTERN MODELS

16.1 Introduction

The daily activity pattern for visitors describes the travel behavior for travel parties. It holds the information concerning how many tours were made, what types the tours were, and how many stops were made. This is in contrast to the resident daily activity pattern model, which only describes the basic travel behavior of residents; the residential tour type and frequency models are not explicitly specified in the visitor travel demand model, but instead are wrapped in the daily activity pattern. The overnight and day-visitor daily activity pattern models are completely separate models, but they share the same overall structure and so are discussed together.

16.2 Daily Activity Pattern Alternatives

For both the day-visitor and overnight-visitor daily activity pattern models, a set of possible daily activity patterns has been specified. These were selected from the patterns found in the overnight and day-visitor surveys. Each pattern begins and ends at the "home" or external station location (H) and can have a most one stop going to and one stop coming from the primary destination. There are 4 main tour types – recreation, gaming, shopping, and other. Each pattern specifies how many tours (H*H*H = 2 tours), the primary purpose and the number of stops that occur in the party's daily travel. For example, the pattern HOHTGH says that the travel party left home to participate in an "other" activity and went back home (HOH). Later the same day the same travel party made a quick stop (T) on the way to a "gaming" activity (G) before returning directly home (H). Because day-visitors are not staying in the region, their daily activity patterns consist of only one tour. The abbreviations used in the patterns for each of the destinations are described in **Table 16.1**. The pattern alternatives are presented in **Tables 16.2 and 16.3**.

Table 16.1: Visitor daily activity pattern destination abbreviations

Symbol	Meaning
H	Home/Origin
R	Recreation tour
G	Gaming tour
S	Shopping tour
O	Other tour
T	Stop

Table 16.2 Overnight-visitor daily activity pattern alternatives

H	HOHSH	HRHSTH	HTGH	HTRTHTGH
HGH	HOHSHRH	HRHTGH	HTGHGH	HTSH
HGHGH	HOHSHSH	HRHTRH	HTGHGTH	HTSHGH
HGHGTH	HOHTGH	HRHTRTH	HTGHOH	HTSHOH
HGHRH	HOHTGTH	HRHTSTH	HTGTH	HTSHTOH
HGHRHOH	HOHTOTH	HRTH	HTGTHGH	HTSHTSTH
HGHTRH	HOHTRH	HRTHGH	HTGTHOH	HTSTH
HGHTRTH	HOHTRTH	HRTHOH	HTGTHTGH	HTSTHOH
HGTH	HOHTSTH	HRTHRH	HTOH	HTSTHRH
HGTHGH	HOTH	HRTHRTH	HTOHRTH	
HGTHOH	HOTHSTH	HRTHTGTH	HTOTH	
HGTHTGH	HOTHTGH	HRTHTRH	HTOTHGH	
HOH	HRH	HSH	HTOTHRH	
HOHGH	HRHGH	HSHOH	HTRH	
HOHOH	HRHGHGH	HSHOHGH	HTRHGH	
HOHOHGH	HRHGTH	HSHOHOH	HTRHGTH	
HOHOHGHGH	HRHOH	HSHRH	HTRHOH	
HOHOHOH	HRHOHGH	HSHRHGH	HTRHOTH	
HOHOHRH	HRHOHOH	HSHRHOH	HTRHRH	
HOHOHRHRHOH	HRHOHRH	HSHRTH	HTRHRTH	
HOHOHSH	HRHRH	HSHSH	HTRHSH	
HOHOTH	HRHRHGH	HSHSTH	HTRHTGH	
HOHRH	HRHRHOH	HSHTRH	HTRHTGTH	
HOHRHGH	HRHRHRH	HSHTRTH	HTRHTRTH	
HOHRHRH	HRHSH	HSTH	HTRTH	
HOHRHSH	HRHSHOH	HSTHGH	HTRTHGH	
HOHRTH	HRHSHOHOH	HSTHOH	HTRTHOH	

Table 16.3 Day-visitor daily activity pattern alternatives.

HGH	HOH	HTRTH	HTRTH
HGTH	HTGH	HTSH	HTRTH
HTGTH	HTGTH	HRH	HRTH
HTGTH	HTGTH	HRTH	HSH
HGTH	HOTH	HRTH	HTGH
HTRH	HTOTH	HRTH	HTGTH
HTRTH	HTRH	HTRTH	HSTH
HGTH	HTRTH	HTRTH	HTRH

16.3 Daily Activity Pattern Models

The daily activity pattern models are multinomial logit models where each pattern is an alternative. Information specific to both the travel parties and the patterns were considered during estimation. The estimation results are presented in **Tables 16.4 and 16.5**.

Table 16.4: Overnight-visitor daily activity pattern model estimation results

Variable	Coefficient
One tour in pattern, seasonal visitor	-1.3448
Two tours in pattern, seasonal visitor	-2.3212
Three or more tours in pattern, seasonal visitor	-2.8592
One tour in pattern, non-seasonal visitor	0.3648
Two tours in pattern, non-seasonal visitor	-1.7402
Three or more tours in pattern, non-seasonal visitor	-3.2094
One outbound stop in pattern	-0.8345
Two outbound stops in pattern	-1.3555
One inbound stop in pattern	-0.4365
Two inbound stops in pattern	-1.3923
Presence of recreation tour, stay-type is resort	-0.7731
Presence of gaming tour, stay-type is house	1.2792
Presence of gaming tour, stay-type is hotel/motel	1.7824
Presence of recreation tour, stay-type is seasonal	-1.8994
Presence of gaming tour, stay-type is casino	2.6565
Presence of recreation tour, children in party	0.7127
Presence of gaming tour, children in party	-0.6724
Presence of shopping tour, adult female in party	0.6791
Presence of a recreation tour before a shopping tour	-1.2033
First tour is recreation	2.4121
First tour is gaming	0.8491
Last tour is recreation	0.6975
Number of recreation tours	-1.1847
Number of gaming tours	-1.5294
Number of shopping tours	-0.7038
Gaming tour and staying on the South Shore	-0.7713

Table 16.5: Day-visitor daily activity pattern model estimation results

Variable	Coefficient
Number of activities in pattern	-3.1
Presence of gaming tour	-0.27
Presence of shopping tour	-1.76
Presence of other tour	-0.44
Outbound stop in pattern	-0.36
Two outbound stops in pattern	2.56
Presence of stops in recreation tour	-0.69
Presence of stops in game tour	-0.88
Presence of stops in shop tour	-0.58
Only recreation tours	0.88
Presence of gaming tour, children in party	-1.96
Presence of recreation tour, children in party	1.15
Presence of recreation tour, more than three adults and no children in party	0.81
Presence of gaming tour, season is winter	0.94
Number of stops on tour, season is summer	0.65

Figures 16.1 through 16.3 show some simple summaries of the overnight and day-visitor pattern models as applied to the base scenario. There are no calibration results, as expansion factors for the surveys cannot be accurately computed. The summer and winter results are nearly identical, so only the summer results are presented. To clarify the terminology, a tour is a string of activities that start and end at "home." For overnight-visitors, each tour may have one, two or no stops, but each stop counts as an activity.

Figure 16.1: Tour count in pattern for summer overnight-visitors

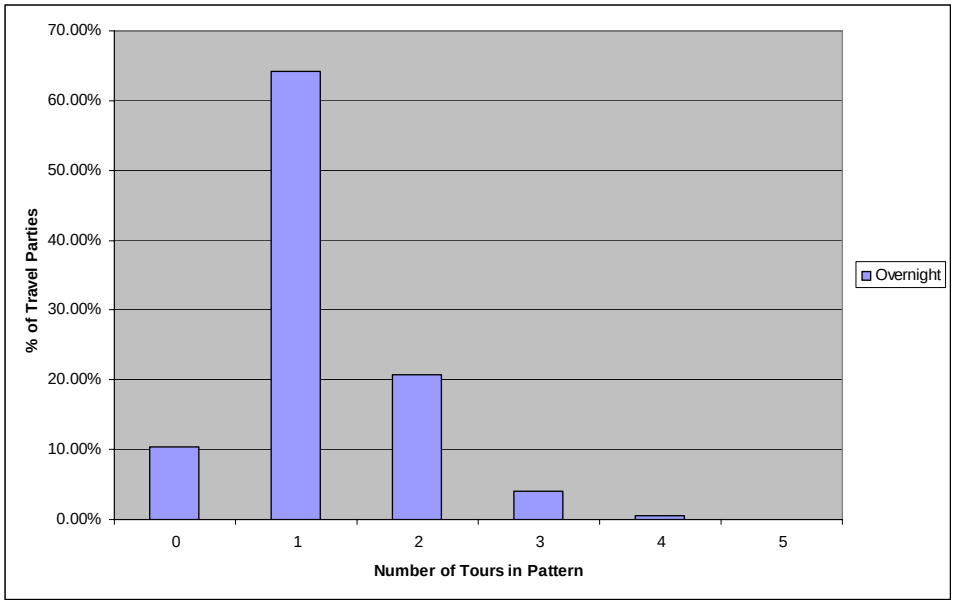


Figure 16.2: Activity count in pattern by visitor type for summer

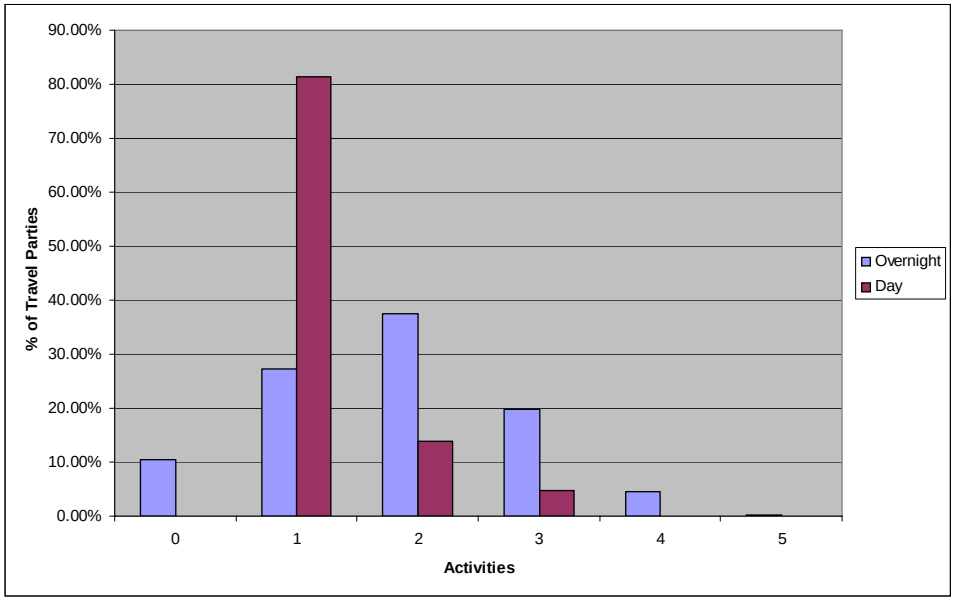
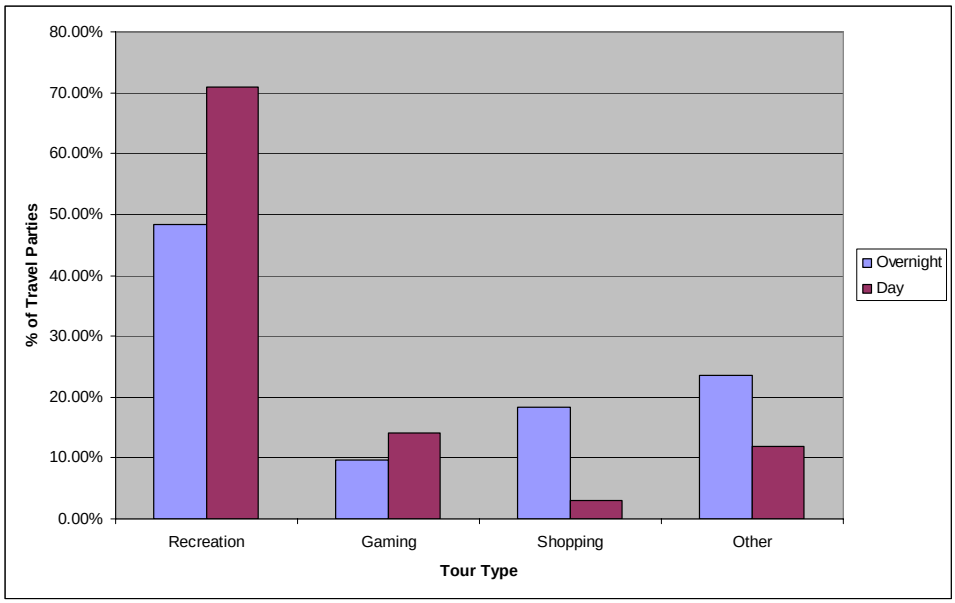


Figure 16.3: Presence of tour type in pattern visitor type for summer



CHAPTER 17
Visitor Tour Destination, Time-of-Day, and Mode Choice Model

CHAPTER 17– VISITOR TOUR DESTINATION, TIME-OF-DAY, AND MODE CHOICE MODEL

17.1 Introduction

For each tour in a travel party's pattern, the visitor tour destination, time-of-day, and mode choice model (DTM) determines where that tour will go (the destination), when the tour will happen (the time-of-day), and how the person will travel during the tour (the mode). When the model is applied, each travel party is treated as a separate and independent decision making unit. The order that the DTM model is applied to each tour in the travel party's daily activity pattern is the same as the order in the pattern.

17.2 Destination Choice Sub-model

The destination choice model is a multinomial logit model in which each potential destination zone is an alternative. Each zone's attractiveness is calculated from a utility function, where the utility consists of variables such as distance, stay-type, and area type. To provide a measure of a zone's attractiveness based on tour-specific characteristics, a size term is included in the utility expression. The size terms are stratified by tour type and are calculated as the natural logarithm of a sum of variables. The visitor DTM model size term specification is summarized in **Table 17.1**.

Also included in the utility expression is the logsum from the mode choice model, which provides an index of accessibilities for a destination zone - the higher the logsum, the more "accessible" (by auto, transit, walking) a zone is. Because the mode-choice model uses time-of-day specific skims, a time-of-day choice must be made before its utility can be evaluated. The actual time-of-day model occurs after the destination choice model, so pre-selected time-of-day choices are used evaluate the mode choice logsums used in the model. These pre-selected choices are based on the expected time-of-day for a given purpose, determined from the visitor travel surveys. For gaming visitor tours, the time-of-day choice used for the logsum calculation is late night peak start, late night end. For all other tours, the midday start, midday end time-of-choice is used.

In the Tahoe region, a number of overnight-visitors actually travel outside of the region for various activities during the day (gaming in Carson City or skiing at North Star for example). To capture this effect, size terms were assigned to external zones. These size terms are discussed in **Appendix I**. In addition to the size terms, each external zone has an alternative specific constant which allowed for further refinement in the calibration phase of the model development.

The calibrated coefficients for the visitor destination choice model are presented in **Table 17.2.**

Table 17.1: Visitor tour destination choice size term specification

	Visitor Tour Type	Employment					Number of Campground Sites	Beach Attractiveness
		Total	Retail	Gaming	Recreation	Other		
Summer	Recreation				2.8672		2.4402	1.0000
	Gaming			1.0000				
	Shop		1.5633			1.0000		
	Other	1.0000						
Winter	Recreation				2.8672			
	Gaming			1.0000				
	Shop		1.5633			1.0000		
	Other	1.0000						

Table 17.2: Visitor tour destination choice model coefficients

	Coefficients			
Variable	Recreation	Gaming	Shop	Other
Distance (miles)	-0.1100	-0.2500	-0.2600	-0.2800
Mode choice logsum	0.0044	0.8000	0.0759	0.6084
Size term	1.0000			
Same origin and destination, casino stay-type		1.4371		
Urban origin, urban destination		2.2450		1.8860
Suburban destination			2.5185	
Rural origin, suburban destination				-1.1953
Suburban origin, urban destination				-0.5936
Rural origin, urban destination				-0.5936
Suburban origin, rural destination, seasonal travel party	-2.3889			
Urban origin, rural destination, winter	1.2346			
Suburban origin, rural destination, winter	1.2346			
Alternative Specific Constant for External Zone 1	-0.0600			
Alternative Specific Constant for External Zone 3	-0.2000			
Bias for External Zone 1 (Winter)	-2.0000			
Bias for External Zone 2 (Winter)	-8.0000			
Bias for External Zone 3 (Winter)	-2.0000			
Bias for External Zone 5 (Winter)	11.0000			
Bias for External Zone 6 (Winter)	-0.5000			
Bias for External Zone 7 (Winter)	-1.0000			
Size term = 0	Not Available			
External zone, day-visitor	Not Available			

17.3 Destination Choice Sub-model Summaries

This section presents some summaries of the destination choice model. In almost all cases, the results are presented only for the summer model, as the winter model's results are somewhat similar. There are no calibration results, as expansion factors for the surveys cannot be accurately computed.

Table 17.3: County to county flows for internal summer overnight-visitor recreation tours

	Washoe	Carson City	Douglas	El Dorado	Placer	Total
Washoe	8.19%	0.00%	0.45%	0.26%	0.76%	9.66%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	1.79%	0.00%	11.66%	7.26%	0.19%	20.89%
El Dorado	4.08%	0.00%	23.08%	25.81%	2.19%	55.16%
Placer	8.00%	0.00%	0.60%	0.75%	4.94%	14.29%
Total	22.06%	0.00%	35.79%	34.07%	8.08%	100.00%

Table 17.4: County to county flows for internal summer overnight-visitor gaming tours

	Washoe	Carson City	Douglas	El Dorado	Placer	Total
Washoe	19.12%	0.00%	0.19%	0.00%	0.00%	19.31%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	26.72%	0.00%	0.00%	26.72%
El Dorado	0.24%	0.00%	31.74%	0.00%	0.00%	31.98%
Placer	19.84%	0.00%	2.15%	0.00%	0.00%	21.99%
Total	39.20%	0.00%	60.80%	0.00%	0.00%	100.00%

Table 17.5: County to county flows for internal summer overnight-visitor shop tours

	Washoe	Carson City	Douglas	El Dorado	Placer	Total
Washoe	11.45%	0.00%	0.02%	0.05%	3.41%	14.93%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.10%	0.00%	5.92%	9.16%	0.05%	15.23%
El Dorado	0.10%	0.00%	6.05%	37.30%	3.26%	46.70%
Placer	2.11%	0.00%	0.00%	0.25%	20.78%	23.14%
Total	13.76%	0.00%	11.99%	46.75%	27.49%	100.00%

Table 17.6: County to county flows for internal summer overnight-visitor other tours

	Washoe	Carson City	Douglas	El Dorado	Placer	Total
Washoe	13.44%	0.00%	0.03%	0.02%	1.78%	15.27%
Carson City	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.07%	0.00%	10.43%	4.52%	0.02%	15.04%
El Dorado	0.07%	0.00%	17.64%	26.67%	2.46%	46.84%
Placer	5.20%	0.00%	0.07%	0.30%	17.29%	22.86%
Total	18.77%	0.00%	28.17%	31.52%	21.54%	100.00%

Figure 17.1: Distance distribution for internal summer overnight-visitor tours

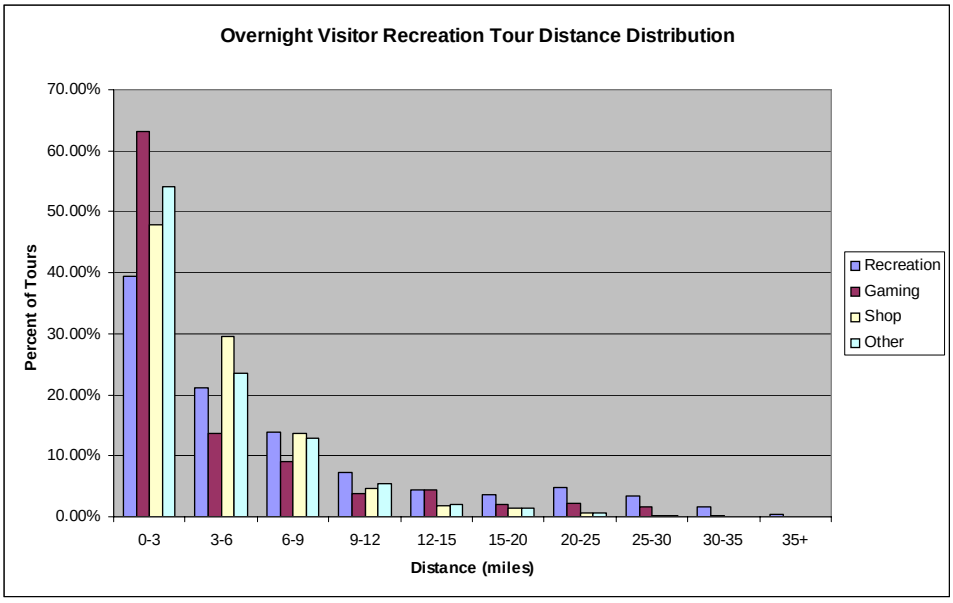


Table 17.7a: External station to external station flows for summer thru-visitor trips

	Reno	Carson City	Kingsbury Grade	Kirkwood	Placerville	Squaw	Truckee	Total
Reno	0.00%	3.08%	1.08%	3.56%	3.47%	2.56%	2.91%	16.66%
Carson City	2.82%	0.00%	1.21%	2.73%	3.73%	3.30%	3.30%	17.09%
Kingsbury Grade	0.09%	0.09%	0.00%	0.13%	0.00%	0.09%	0.09%	0.48%
Kirkwood	2.65%	2.95%	1.00%	0.00%	2.69%	2.78%	3.56%	15.62%
Placerville	3.08%	2.69%	1.08%	3.86%	0.00%	2.52%	3.43%	16.66%
Squaw	3.30%	2.91%	1.21%	2.99%	2.73%	0.00%	3.51%	16.66%
Truckee	2.82%	3.12%	1.43%	3.04%	3.30%	3.12%	0.00%	16.83%
Total	14.75%	14.84%	7.03%	16.31%	15.92%	14.36%	16.79%	100.00%

Table 17.7b: External station to external station flows for winter thru-visitor trips

	Reno	Carson City	Kingsbury Grade	Kirkwood	Placerville	Squaw	Truckee	Total
Reno	0.00%	0.00%	0.00%	0.00%	0.12%	0.12%	0.00%	0.25%
Carson City	0.25%	0.00%	0.49%	5.32%	4.94%	5.56%	5.81%	22.37%
Kingsbury Grade	0.00%	0.12%	0.00%	0.12%	0.25%	0.12%	0.00%	0.62%
Kirkwood	0.37%	2.22%	0.00%	0.00%	3.58%	4.33%	3.09%	13.60%
Placerville	0.87%	6.06%	0.25%	3.71%	0.00%	5.56%	6.30%	22.74%
Squaw	0.62%	4.08%	0.12%	4.70%	5.32%	0.00%	4.94%	19.78%
Truckee	0.25%	4.70%	0.25%	4.08%	5.56%	5.81%	0.00%	20.64%
Total	2.35%	17.18%	1.11%	17.92%	19.78%	21.51%	20.15%	100.00%

17.4 Time-of-Day Choice Sub-model

The time-of-day sub-model is a multinomial logit model in which start/stop hour pairs make up the alternatives. The earliest allowed start/stop time is 5:00 am (corresponding to the 5:00-6:00 hour), and the latest allowed is midnight (corresponding to the 12:00am-1:00am hour). As far as skim periods are concerned, the following definitions are used:

Table 17.8: Skim period definitions

Skim Period	Start Time	End Time	Duration
AM Peak (AM)	7:00 AM	10:00 AM	3 hours
Midday (MD)	10:00 AM	4:00 PM	6 hours
PM Peak (PM)	4:00 PM	7:00 PM	3 hours
Late Night (LN)	7:00 PM	7:00 AM	12 hours

The following tables present the calibrated time-of-day model specification:

Table 17.9: Visitor time-of-day choice model estimation results

	Variable	Coefficient		
		Recreation	Gaming	Shop/Other
First Tour	Start at 6	2.6644		1.7565
	Start at 7	3.6494	1.5876	2.8702
	Start at 8	4.6699	1.5876	2.8702
	Start at 9	4.6699	2.9563	3.7151
	Start at 10	4.6699	2.9563	3.7151
	Start at 11	4.5253	2.098	3.7151
	Start at 12	4.5253	2.098	3.7151
	Start at 13	3.5108	1.6153	3.7151
	Start at 14	3.5108	1.2121	3.145
	Start at 15	3.1033	1.2121	3.145
	Start at 16	3.1033	1.5737	3.145
	Start at 17	2.4467		2.9211
	Start at 18	2.4467	1.18	3.6117
	Start at 19	2.4467	1.18	2.0296
	Start - Winter	-0.2635	0.2333	-0.1673
	Start - Seasonal			-0.1673
	End at 8	0.5643		
	End at 9	0.5643		
	End at 12	0.7026		-0.3192
	End at 13	0.7026		-0.3192
	End at 14	1.2454		-0.3192
	End at 15	1.2454	-1.3561	
	End at 16	2.0878		
	End at 17	1.4701		
	End at 20	-0.6821	-0.9357	
	Endat 21	-0.6821	-0.9357	
	End at 22	-0.6821		
	Duration of 0	1.4801		1.3609
	Duration of 1	1.4801		2.4694
	Duration of 2	2.3093		2.5862
	Duration of 3	2.3093	0.8191	2.5862
	Duration of 4	2.3093		2.0175
	Duration of 5	2.569	0.9262	2.0175
	Duration of 6	2.569		
	Duration of 7	2.569		
	Duration of 8	2.1112		
	Duration of 9	1.325		
	Duration of 10	1.325		
	Duration - Summer	-0.2343	-0.0854	-0.2642
	Duration - Winter	0.1492	0.1479	
	Duration - Seasonal	-2.2001		-3.0551

Table 17.9: Visitor time-of-day choice model estimation results continued

	Variable	Coefficient		
		Recreation	Gaming	Shop/Other
Second or Greater Tour	Start at 11	1.0122		
	Start at 12	1.0122		
	Start at 13	1.0182		
	Start at 14	1.0182		
	Start at 15	1.0182		
	Start at 16	1.4814		
	Start at 17	1.4814		
	Start at 18	2.3369		
	Start at 19	2.3369		
	Start at 20	2.3369		
	Start at 21	1.6652		
	End at 8	2.443		
	End at 9	1.9749		
	End at 10	1.9406		
	End at 11	1.9406		
	End at 12	1.9406		
	End at 13	1.7357		
	End at 14	1.1519		
	End at 15	1.1519		
	End at 16	1.1519		
	End at 17	1.7777		
	End at 18	0.8868		
	End at 19	0.5279		
	End at 20	0.5279		
	Duration of 0	6.1989		
	Duration of 1	6.1989		
	Duration of 2	6.1989		
	Duration of 3	6.1989		
	Duration of 4	4.927		
	Duration of 5	3.5775		
	Duration of 6	3.5775		
	Duration of 7	3.5775		
	Duration - Summer	0.42		
	Duration - Winter	0.6536		
	Duration - Seasonal	-1.3797		

Table 17.9: Visitor time-of-day choice model estimation results continued

Variable	Coefficient		
	Recreation	Gaming	Shop/Other
Start in am, day-visitor	-2.5		
Start in ln, day-visitor	1.2		
End in ln, day-visitor	-0.26		
End in pm, day-visitor	-1.5		
End in am, day-visitor	-0.16		
Start in pm, day-visitor	0.55		
Start in md, day-visitor	-0.4		
Start in am, day-visitor, winter	-0.4		
Start in md, day-visitor, winter	1.33		
End in md, day-visitor, winter	1.33		
Start in pm, day-visitor, winter	2.3		
Start in ln, day-visitor, winter	-2.44		
End in am, day-visitor, winter	0.7		

17.5 Time-of-Day Choice Sub-model Summaries

This section presents some summaries of the time-of-day choice model as applied to the base scenario visitor population. The results are presented only for the summer model, as the winter model's results are somewhat similar.

Figure 17.2: Overnight-visitor tour start time

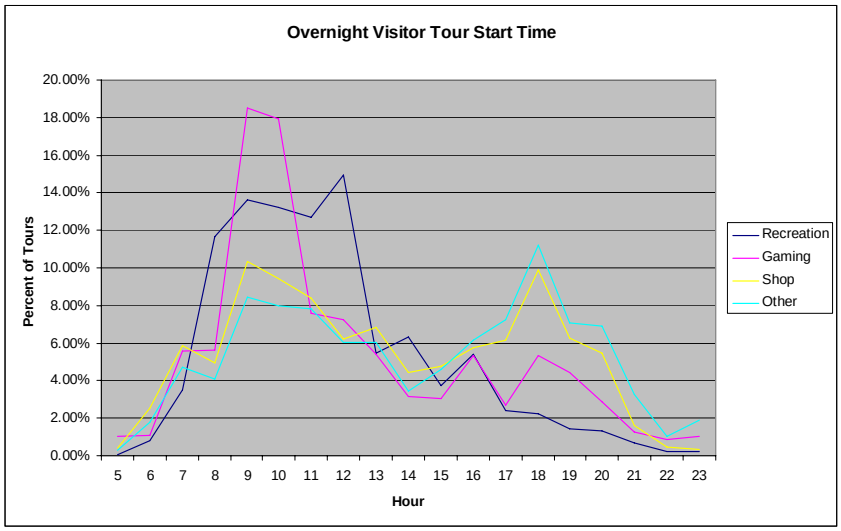


Figure 17.3: Overnight-visitor tour end time

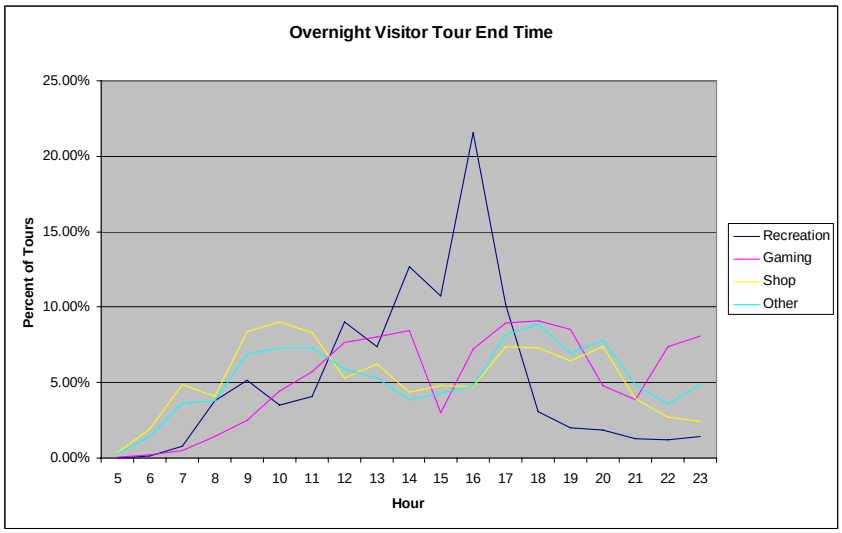


Figure 17.4: Overnight-visitor tour duration

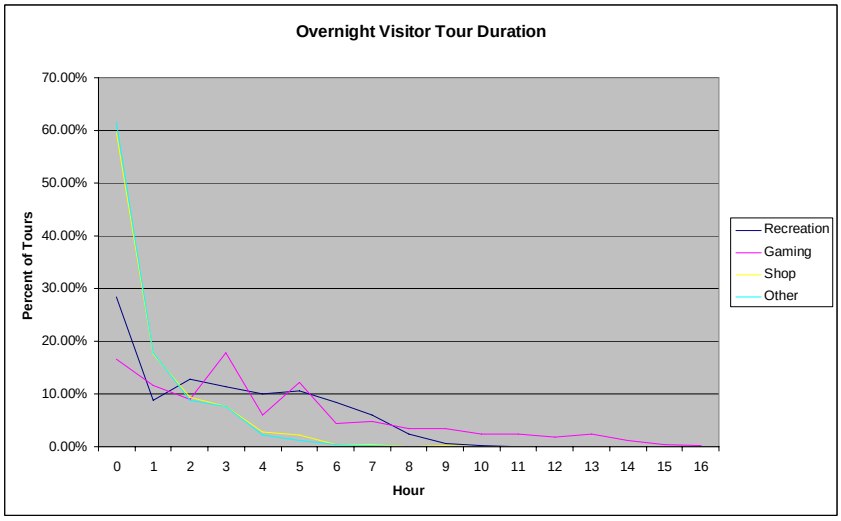


Figure 17.5: Day-visitor tour start time

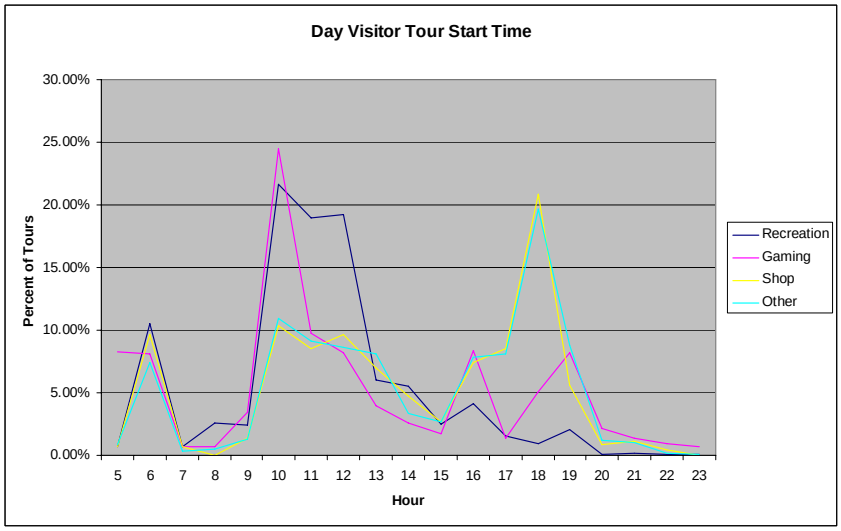


Figure 17.6: Day-visitor tour end time

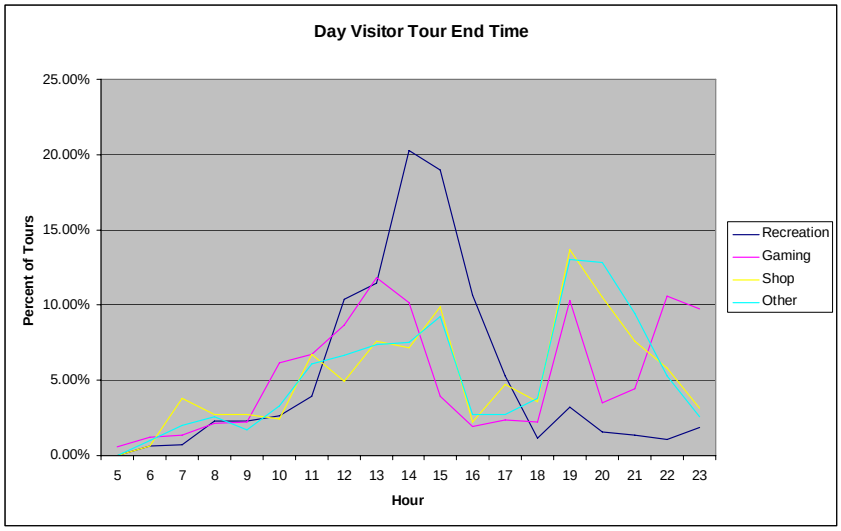
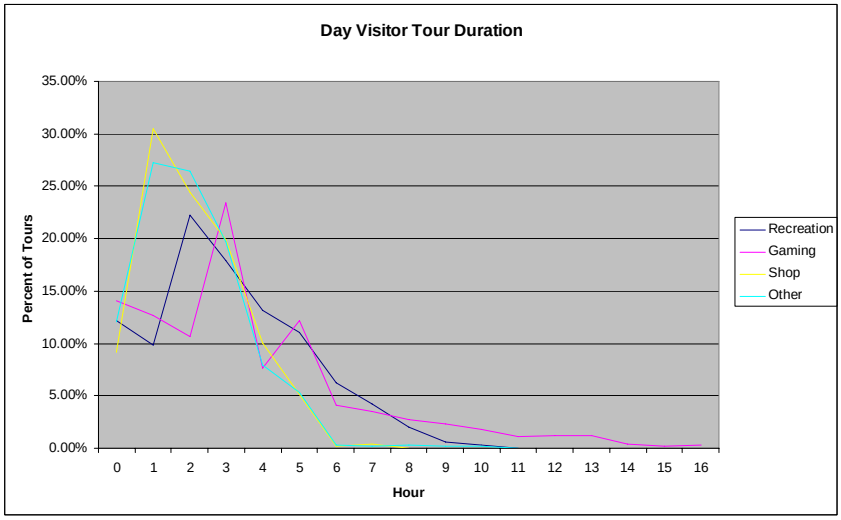


Figure 17.7: Day-visitor tour duration



17.6 Mode Choice Sub-model

The mode choice model is a multinomial logit model in which each mode is an alternative. For overnight tours, the following alternatives are available:

- Drive
- Shuttle
- Walk to transit
- Drive to transit
- Non-motorized

The shuttle mode represents tour buses and commercial shuttles. Day-visitors are forced to use the drive mode. The primary component of the mode choice model is travel time, which uses the same coefficient across all modes. For the modes that have costs associated with them (transit has fares, auto modes have operating costs), a value of

time factor was estimated; this factor can transfer dollar costs into time, for which a utility can be calculated using the travel time coefficient.

The mode choice model estimation results are presented in the following table.

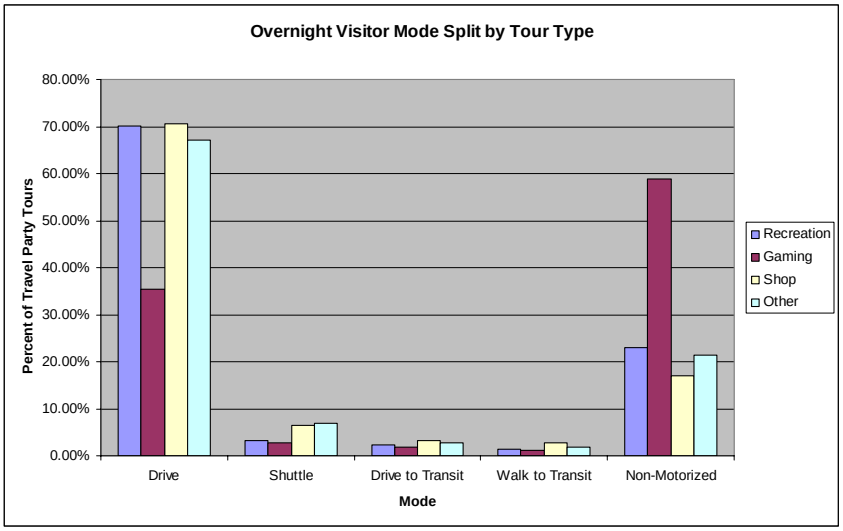
Table 17.10: Visitor mode choice model estimation results

Variable	Drive	Shuttle	Walk to Transit	Drive to Transit	Non-Motorized
Time	-0.0151				
Value of Time ($/hour)	6.53				
Alternative-specific constant – Seasonal Visitor	0.7612		-1.902	-1.587	4.8
Alternative-specific constant - Summer, Non-Seasonal Visitor	-2.2164	-5.255	-1.902	-1.587	
Alternative-specific constant - Winter, Non-Seasonal Visitor	-1.8263	-2.661	-1.902	-1.587	
Travel party all adults	1.118				
Travel party adults and children	1.344				
Gaming tour					3.3
Recreation tour					2.2
Recreation tour, winter			0.5233	0.5233	
Gaming tour, casino stay-type					2.0215
Day-visitor	Not Available				

17.7 Mode Choice Sub-model Summary

This section presents a summary of the mode choice model as applied to the base scenario overnight-visitor population. The chart shows the mode chosen for the various activity types. The day-visitor mode was "drive" for all activity types and therefore the results are not shown.

Figure 17.8: Overnight-visitor tour mode split



CHAPTER 18
Visitor-Stops Model

CHAPTER 18 – VISITOR STOPS MODEL

18.1 Introduction

Each visitor tour may have up to two stops: an outbound stop and an inbound stop.
The determination of whether or not stops are made on a given tour is made in the visitor pattern model: for each tour, the presence of an inbound and/or outbound stop is fixed by the pattern structure. The visitor stops model concerns itself with choosing the location and mode of each tour stop. The time-of-day choice for the stop is pre-determined by the time-of-day choice for the tour that the stop occurs in. The stop location and mode choice models treat each stop independently.

18.2 Stop Location Choice Sub-model

The stop location choice model is a multinomial logit model in which each potential destination zone is an alternative. The model is partially stratified by season. Each zone's attractiveness is calculated from a utility function, where the utility consists of zonal and travel-party specific information. The distance the stop adds to the overall tour distance is used as a penalty in the utility. This penalty is calculated as both the absolute (actual) difference and relative difference, the latter of which is the absolute difference divided by the tour distance without the stop.

To provide a measure of a zone's attractiveness based on tour-specific characteristics, a size term is included in the utility expression. The size terms are stratified by season and are calculated as the natural logarithm of a sum of variables. The following table summarizes the specification:

Table 18.1: Visitor stop location model size term specification

Season	Employment				
	Retail	Service	Gaming	Recreation	Other
Summer	2.9731	1.6243	1.4215	0.2472	2.3037
Winter	1.5394	1.0000	1.1369	0.7072	0.7072

The calibrated visitor stops model results are shown in **Table 18.2**. A simple summary of the results of the model, as applied to the base scenario, is presented in **Table 18.3**.

Table 18.2: Visitor stop-location model estimation results

	Summer		Winter	
Variable	Outbound	Inbound	Outbound	Inbound
Absolute deviation	-0.0660		-0.0848	
Relative deviation	-0.0562			
Size term	1.0000			
Tour and stop destination same	0.9509	1.2972	1.2146	2.2168
Home and stop destination same		1.6306		1.2146
No Attractions	Not Available			
No transit access at stop - transit	Not Available			
Tour destination internal and stop destination external	Not Available			

Table 18.3: Visitor stop-location average distances

	Stop Type			
	Outbound		Inbound	
	Average	Std. Deviation	Average	Std. Deviation
Overnight	4.735	8.639	4.082	8.028
Day	7.908	12.456	7.685	12.109

18.3 Stop Mode Choice Sub-model

The stop mode choice model is used to determine if certain tour legs should be non-motorized. For a tour half (outbound or inbound), the mode choice model takes the shortest leg (to the stop or from the stop) and compares the travel time of the tour mode versus the walk mode. The mode with the shorter travel time is the one assigned to that leg. For tour modes other than non-motorized or walk-to-transit, only the second leg for outbound trips (from the stop) or the first leg for inbound trips (to the stop) can be walk to transit or non-motorized. The first and last trip must be the previously chosen tour mode.

CHAPTER 19
Thru-Visitors

CHAPTER 19 – THRU-VISITORS

19.1 Introduction

Thru-visitors are persons or parties that travel into the Tahoe basin through an external station, they do not stop and they leave through a different external station. These "visitors" include not only recreational travel, but also commercial traffic. Because of their transient nature, very little information about this population is known; its existence can generally only be inferred through traffic count analysis. In spite of these limitations, a simple, disaggregate approach was developed to model the flow of thru-visitors. This was done both for flexibility and to remain consistent with the other population travel demand models. The model flow follows that used for the other models: first a population is synthesized, then a destination is chosen, and finally a time-of-day for the tour/trip is chosen.

19.2 Population Synthesis

The population synthesis for the thru-visitor population is very simple and closely tied to the day-visitor population synthesis **(Chapter 15)**. Essentially, the number of thru-visitors originating at each external station is indexed to the number of overnight-visitors in the region in the scenario. This implies that there is a linear relationship between the number of overnight-visitors and the number of thru-visitors on any given day. The formula for calculating the number of thru-visitors is:

$$T_e = O\lambda_e$$

where T_e is the number of thru-visitors coming in through external station e

O is the number of overnight-visitors

λ_e is the thru-visitor rate factor for external station e

The rate factors were initially set such that the number of thru-visitors equals 2% of overnight-visitors. These factors changed slightly as the model was validated against external counts (in conjunction with the day-visitor population synthesis). Their final values are given in **Tables 19.1a and 19.1b**.

Table 19.1a: Thru-visitor external station rate factors, summer

External Station	Overnight to Thru-Visitor Rate Factor
Reno	0.0201
Carson City	0.0201
Kingsbury Grade	0.0006
Kirkwood	0.0201
Placerville	0.0201
Squaw	0.0201
Truckee	0.0201

Table 19.1b: Thru-visitor external station rate factors, winter

External Station	Overnight to Thru-= Visitor Rate Factor
Reno	0.0001
Carson City	0.0100
Kingsbury Grade	0.0003
Kirkwood	0.0060
Placerville	0.0100
Squaw	0.0100
Truckee	0.0100

Each travel party only contains one identifying characteristic: its origin external station.

19.3: Thru-Visitor Destination Choice Model

The thru-visitor destination choice model is a very simple multinomial logit model where every external station is an alternative. Because so little information concerning the thru-visitors is known, only alternative specific constants were specified for the model. Distance was not included as a variable because there is no indication that a thru-visitor travel party is more inclined to prefer shorter (or longer) trips through the region. **Table 19.2** gives the model specifications. **Tables 19.3a and 19.3b** presents a summary of the results of the destination choice model.

Table 19.2: Thru-visitor destination choice model specifications

Variable	Coefficient
Alternative Specific Constant – Reno (Summer)	1.0000
Alternative Specific Constant – Reno (Winter)	-1.2000
Alternative Specific Constant -Carson City	1.0000
Alternative Specific Constant -Kingsbury Grade (Summer)	0.2000
Alternative Specific Constant -Kingsbury Grade (Winter)	-1.8000
Alternative Specific Constant –Kirkwood	1.0000
Alternative Specific Constant –Placerville	1.0000
Alternative Specific Constant –Squaw	1.0000
Alternative Specific Constant –Truckee	1.0000
Origin and destination station the same	Alternative Unavailable

Table 19.3a: Thru-visitor destination choice model results summary, summer

External Station	Percent of Thru-Visitors Leaving Through Station
Reno	14.75%
Carson City	14.84%
Kingsbury Grade	7.03%
Kirkwood	16.31%
Placerville	15.92%
Squaw	14.36%
Truckee	16.79%

Table 19.3b: Thru-visitor destination choice model results summary, winter

External Station	Percent of Thru-Visitors Leaving Through Station
Reno	2.35%
Carson City	17.18%
Kingsbury Grade	1.11%
Kirkwood	17.92%
Placerville	19.78%
Squaw	21.51%
Truckee	20.15%

19.4 Thru-Visitor Time-of-Day Choice Model

The thru-visitor time-of-day (TOD) choice model is a simple multinomial logit model where each skim period is an alternative. Since a thru-trip has no stops, the TOD choice sets the beginning and end time for the tour. Because so little information concerning the thru-visitors is known, only alternative specific constants were

specified for the model. The skim period alternatives use the same definitions as those from the other models, and are summarized in **Table 19.4**. The TOD choice model specifications are presented in **Table 19.5**. A summary of the TOD choice model results is presented in **Tables 19.6a and 19.6b**.

Table 19.4: Skim period definitions

Skim Period	Start Time	End Time	Duration
AM Peak (AM)	7:00 AM	10:00 AM	3 hours
Midday (MD)	10:00 AM	4:00 PM	6 hours
PM Peak (PM)	4:00 PM	7:00 PM	3 hours
Late Night (LN)	7:00 PM	7:00 AM	12 hours

Table 19.5: Thru-visitor time-of-day choice model specifications

Variable	Coefficient
Alternative Specific Constant –AM (Summer)	1.4000
Alternative Specific Constant –AM (Winter)	1.5500
Alternative Specific Constant -MD	1.0000
Alternative Specific Constant -PM	1.0000
Alternative Specific Constant –LN (Summer)	1.0000
Alternative Specific Constant –LN (Winter)	0.4500

Table 19.6a: Thru-visitor time-of-day choice model results summary, summer

Skim Period	Percent of Thru-Visitors Traveling During Period
AM	35.40%
MD	23.43%
PM	21.30%
LN	19.87%

Table 19.6b Thru-visitor time-of-day choice model results summary, winter.

Skim Period	Percent of Thru-Visitors Traveling During Period
AM	41.90%
MD	20.89%
PM	22.62%
LN	14.59%

CHAPTER 20
Traffic Assignment

CHAPTER 20 – TRAFFIC ASSIGNMENT

20.1 Introduction

Once the resident, external worker, and overnight, day, and thru-visitor models have run, then all of the person tours are transformed into zone-to-zone trip tables that are assigned to the Tahoe highway network. The assignment, performed for each skim period, is done using TransCAD transportation software. The skim periods are defined in the table below.

Table 20.1: Skim period definitions

Skim Period	Start Time	End Time	Duration
AM Peak (AM)	7:00 AM	10:00 AM	3 hours
Midday (MD)	10:00 AM	4:00 PM	6 hours
PM Peak (PM)	4:00 PM	7:00 PM	3 hours
Late Night (LN)	7:00 PM	7:00 AM	12 hours

20.2 Trip Synthesis

After all of the tour models have finished, trips must be synthesized from the individual tours. Each leg of a particular tour counts as one trip from the origin to the destination, unless there was a stop on that leg, in which case there is a trip from the origin to the stop, and a trip from the stop to the destination. The trip information is sorted according to skim period and mode and is stored in separate TransCAD trip tables. When performing the traffic assignment, only the drive-alone and shared auto modes are assigned. The drive-to-transit, walk-to-transit, transit and the non-motorized trips are not assigned to the network because there are so few of them that their impact on traffic totals are negligible.[1]

20.3 Street Network

The street network is built from a TransCAD line and node layer. The node layer is a representation of the street intersections and TAZ nodes, while the line layer is a representation of the streets. The streets are broken into to following functional classifications:

- Principle Arterials
- Minor Arterials
- Collectors
- Centroids

For each of these functional classifications, the following capacity per lane per hour values are assigned:

Table 20.2: Capacity values by functional class

Functional Class	Capacity per Lane per Hour
Principle Arterial	1100
Minor Arterial	800
Collector	500
Centroid	9999

In addition to this, the number of lanes and the speed limit of each link are recorded in the network. From the latter, a free flow travel time is determined for each link by taking the time it takes to traverse the link at its speed

[1] In theory drive-to-transit trips do contribute to traffic totals. However, because it is difficult to determine where the drive leg of the transit trip will end, keeping track of these trips is quite difficult. For Tahoe, the number of drive-to-transit trips is so low that it does not affect the model results.

limit times a "travel-time multiplier." The travel-time multiplier is initially set to one, but was changed for some links during validation to help match observed counts.

Also associated with each link is a volume-delay function (VDF), which is used in the actual traffic assignment procedure. The VDF provides a travel-time for each link given its free-flow travel time, capacity, and assigned volume. The form of the VDF for each link is the standard Bureau of Public Roads (BPR) formula:

$$t_s = t_{ff}\left[1+\alpha\left(\frac{v}{ch_s l}\right)^{\beta}\right]$$

where t_s is the link travel time for skim period s

t_{ff} is the free-flow link travel time

v is the volume assigned to the link

c is the capacity per hour per lane of the link

h_s is the number of hours in skim period s

l is the number of lanes on the link

a, β are calibration parameters

A different value for a and β are used for each link depending on its speed limit, number of lanes, and urban-type location (see **Appendix I** for a discussion of the urban type definitions). These values are summarized in the following table:

Table 20.3: BPR function coefficients specifications

Area Type	Speed Limit	Lanes	α	β
Rural	60	2+	0.09	6
Rural	55	2+	0.08	6
Rural	50	2+	0.07	6
Rural	45	2+	0.07	6
Rural	35	2+	0.92	5
Rural	25	2+	1.10	5
Rural	Any	<2	0.34	4
Suburban	55	Any	0.33	4
Suburban	50	Any	0.34	4
Suburban	45	Any	0.42	5
Suburban	40	Any	0.38	5
Suburban	35	Any	0.96	5
Suburban	30	Any	1.11	5
Suburban	25	Any	1.20	5
Suburban	20	Any	1.25	5
Suburban	15	Any	1.30	5
Urban	50	Any	0.74	5
Urban	45	Any	0.72	5
Urban	40	Any	0.70	5
Urban	35	Any	1.00	5
Urban	30	Any	1.20	5
Urban	25	Any	1.30	5

20.4 Traffic Assignment

A traffic assignment is performed for each skim period, using the trip tables generated during trip synthesis. The assignment type is capacity restraint, meaning that all of the trips between two zones are iteratively assigned to the shortest calculated path by time (all-or-nothing assignment). For each iteration, link volumes are updated by the following (MSA) method:

$$v_{i,n+1} = \left(\frac{n-1}{n}\right)v_{i,n} + \left(\frac{1}{n}\right)v_i$$

where n is the iteration number

$v_{i,n}$ is the volume on link i at iteration n

v_i is the volume on link i calculated from the all-or-nothing assignment

From these link volumes, new link travel times are computed, and the traffic is re-assigned. This procedure is continued until the average change in link volumes becomes very small. This assignment method is guaranteed to converge.

During model development, a convergence criterion of 0.0001 was used, and it was found that a maximum of 50 iterations was needed to reach convergence.

20.5 Skims

Once trips have been assigned to the street network, skims can be produced. Skims are matrices of values giving travel time and cost components between zones for a set of modes. For the Tahoe model, three main sets of skims are produced: highway (street) skims, transit skims, and walk skims. These skims are used throughout the model for such things as calculating accessibilities and destination, time-of-day, and mode choice determinations.

The walk skims are simply a zone-to-zone shortest distance matrix using 3 miles/hour as the walk speed. These do not require the traffic assignment results. For highway skims, the shortest path by time as determined during the traffic assignment results is stored.

Transit skims are somewhat more complicated. For full details, see *Travel Demand Modeling with TransCAD 4.8*. Briefly, the transit skimming procedure determines the shortest path between two zone using transit modes. There is a separate skim for walk-to-transit and drive-to-transit modes. For the former, the access to the transit is by walking from the origin zone to the (usually closest) transit stop; for the latter, the access to the transit is determined by driving to a qualifying transit stop. A qualifying stop is often a park 'n' ride lot but for the Tahoe basin, because of the transit and street layout, all transit stops were considered qualified. In the transit skim, transit transfers are allowed, and access from the final transit station to the destination zone is always made by walking.

For each transit skim, a number of matrices are produced:

- Transit access time (time from origin to transit stop)
- Transit in-vehicle time (time in transit vehicle)
- Transit egress time (time from final transit stop to destination)
- Transit headway wait times
- Transit transfer times
- Transit fare costs

The fare matrix can be translated into time units using an appropriate value of time (which varies across model segments).

20.6 Validation

Validating the Tahoe model to traffic counts is the final measure used to adjust the model to reflect reality as close as possible. Two groups of counts were used to validate the model – internal counts and external station counts. The former were very general and limited, whereas the latter were much more specific and useful. Because of this, and because of the importance of external station flows to the region's traffic, the decision was made to validate to external station counts first, and then adjust the internal counts. Furthermore, the internal counts were limited to the summer season, so internal count validation was only performed for that season, with the winter season using the results of the summer validation.

The summer external station counts were segmented by direction and 15-minute intervals. These were aggregated to the skim-period level so as to match the traffic assignment dimensions. The external station validation was primarily used to validate the day and thru-visitor levels, as their numbers (either absolutely or relatively) were unknown. The validation process resulted in values specified for the number of day and thru-visitors relative to overnight-visitors on both summer and winter days (these values are presented in **Chapter 15 and Chapter 19**). A comparison of the traffic assignment external station volumes to the observed counts is provided in **Tables 20.4a-20.5c**. **Tables 20.6a-20.7c** provide a breakdown of the traffic assignment by resident, external worker, and visitor trips.

Table 20.4a: Summer external station counts by skim period, travel into region

	AM	MD	PM	LN	Total
Reno (1)	705	1606	747	740	3798
Carson City (2)	1433	2986	1373	1894	7686
Kingsbury (3)	834	1139	553	650	3176
Kirkwood (4)	215	710	355	273	1553
Placerville (5)	504	2182	928	944	4558
Squaw (6)	1164	3291	1616	1228	7299
Northstar (7)	760	2222	1394	1217	5593
Total	5615	14136	6966	6946	33663

Table 20.4b: Summer external station assignment volumes by skim period, travel into region

	AM	MD	PM	LN	Total
Reno (1)	764	1040	1136	938	3878
Carson City (2)	1839	2556	1566	1732	7693
Kingsbury (3)	1020	707	756	686	3169
Kirkwood (4)	234	725	272	320	1551
Placerville (5)	422	2676	654	813	4565
Squaw (6)	639	4215	1125	1302	7281
Northstar (7)	787	2367	1331	1132	5617
Total	5739	14190	6782	6980	33691

Table 20.4c: Relative percent difference between summer external station counts and assignment volumes, travel into region

	AM	MD	PM	LN	Total
Reno (1)	8.37%	-35.24%	52.07%	26.76%	2.11%
Carson City (2)	28.33%	-14.40%	14.06%	-8.55%	0.09%
Kingsbury (3)	22.30%	-37.93%	36.71%	5.54%	-0.22%
Kirkwood (4)	8.84%	2.11%	-23.38%	17.22%	-0.13%
Placerville (5)	-16.27%	22.64%	-29.53%	-13.88%	0.15%
Squaw (6)	-45.10%	28.08%	-30.38%	6.03%	-0.25%
Northstar (7)	3.55%	6.53%	-4.52%	-6.98%	0.43%
Total	2.21%	0.38%	-2.64%	0.49%	0.08%

Table 20.5a: Summer external station counts by skim period, travel out of region

	AM	MD	PM	LN	Total
Reno (1)	515	1419	1001	683	3618
Carson City (2)	1035	3221	1974	1437	7667
Kingsbury (3)	418	1074	950	723	3165
Kirkwood (4)	325	700	332	248	1605
Placerville (5)	677	2156	809	845	4487
Squaw (6)	1094	3189	1767	1355	7405
Northstar (7)	1095	2102	1167	1265	5629
Total	5159	13861	8000	6556	33576

Table 20.5b: Summer external station assignment volumes by skim period, travel out of region

	AM	MD	PM	LN	Total
Reno (1)	1156	910	1030	738	3834
Carson City (2)	1193	2550	2332	1566	7641
Kingsbury (3)	611	760	1299	650	3320
Kirkwood (4)	251	694	324	298	1567
Placerville (5)	402	2425	807	914	4548
Squaw (6)	731	3892	1142	1463	7228
Northstar (7)	1016	2301	1221	1078	5616
Total	5331	13458	8191	6711	33691

Table 20.5c: Relative percent difference between summer external station counts and assignment volumes, travel out of region

	AM	MD	PM	LN	Total
Reno (1)	124.47%	-35.87%	2.90%	8.05%	5.97%
Carson City (2)	15.27%	-20.83%	18.14%	8.98%	-0.34%
Kingsbury (3)	46.17%	-29.24%	36.74%	-10.10%	4.90%
Kirkwood (4)	-22.77%	-0.86%	-2.41%	20.16%	-2.37%
Placerville (5)	-40.62%	12.48%	-0.25%	8.17%	1.36%
Squaw (6)	-33.18%	22.04%	-35.37%	7.97%	-2.39%
Northstar (7)	-7.21%	9.47%	4.63%	-14.78%	-0.23%
Total	3.33%	-2.91%	2.39%	2.36%	0.34%

Table 20.6a: Summer resident external station assignment volumes by skim period, travel into region

	AM	MD	PM	LN	Total
Reno (1)	147	662	920	639	2368
Carson City (2)	92	591	770	694	2147
Kingsbury (3)	63	268	458	305	1094
Kirkwood (4)	5	29	75	52	161
Placerville (5)	8	58	49	63	178
Squaw (6)	21	131	252	135	539
Northstar (7)	107	502	723	526	1858
Total	443	2241	3247	2414	8345

Table 20.6b: Summer external worker external station assignment volumes by skim period, travel into region

	AM	MD	PM	LN	Total
Reno (1)	498	153	110	175	936
Carson City (2)	1449	442	357	608	2856
Kingsbury (3)	902	310	241	423	1876
Kirkwood (4)	56	14	19	22	111
Placerville (5)	113	34	21	44	212
Squaw (6)	163	58	35	54	310
Northstar (7)	414	128	117	149	808
Total	3595	1139	900	1475	7109

Table 20.6c: Summer visitor external station assignment volumes by skim period, travel into region

	AM	MD	PM	LN	Total
Reno (1)	141	333	239	132	845
Carson City (2)	362	1338	894	399	2993
Kingsbury (3)	34	117	84	28	263
Kirkwood (4)	184	496	363	200	1243
Placerville (5)	399	1894	1202	456	3951
Squaw (6)	707	3122	1857	746	6432
Northstar (7)	357	1450	919	354	3080
Total	2184	8750	5558	2315	18807

Table 20.7a: Summer resident external station assignment volumes by skim period, travel out of region

	AM	MD	PM	LN	Total
Reno (1)	929	581	386	472	2368
Carson City (2)	672	493	371	611	2147
Kingsbury (3)	356	244	212	282	1094
Kirkwood (4)	63	29	28	41	161
Placerville (5)	49	42	25	62	178
Squaw (6)	211	121	73	134	539
Northstar (7)	621	481	315	441	1858
Total	2901	1991	1410	2043	8345

Table 20.7b: Summer external worker external station assignment volumes by skim period, travel out of region

	AM	MD	PM	LN	Total
Reno (1)	60	185	538	153	936
Carson City (2)	222	578	1567	489	2856
Kingsbury (3)	133	356	1070	317	1876
Kirkwood (4)	13	18	56	24	111
Placerville (5)	11	47	121	33	212
Squaw (6)	26	71	152	61	310
Northstar (7)	59	154	457	138	808
Total	524	1409	3961	1215	7109

Table 20.7c: Summer visitor external station assignment volumes by skim period, travel out of region

	AM	MD	PM	LN	Total
Reno (1)	192	290	162	143	787
Carson City (2)	649	1335	555	409	2948
Kingsbury (3)	117	169	66	53	405
Kirkwood (4)	270	518	269	201	1258
Placerville (5)	729	1837	820	551	3937
Squaw (6)	1303	3045	1183	844	6375
Northstar (7)	629	1446	593	429	3097
Total	3889	8640	3648	2630	18807

For the winter season, full-day external station counts (in both directions) were provided. Count breakdowns by time period were not provided; instead a temporal distribution identical to the summer season was assumed to provide a validation context. Because of this, a greater focus was placed on validating to the aggregate station counts than to the time period counts. A comparison of the assigned volumes to the observed counts is provided in **Tables 20.8a-20.9c**. **Tables 20.10a-20.11c** provide a breakdown of the traffic assignment by resident, external worker, and visitor trips.

Table 20.8a: Winter external station counts by skim period, travel into region

	AM	MD	PM	LN	Total
Reno (1)	328	904	638	435	2305
Carson City (2)	769	2395	1468	1068	5700
Kingsbury (3)	339	872	771	587	2569
Kirkwood (4)	233	502	238	178	1151
Placerville (5)	903	2877	1079	1127	5987
Squaw (6)	766	2232	1237	948	5182
Northstar (7)	750	1441	800	867	3858
Total	4088	11223	6231	5210	26752

Table 20.8b: Winter external station assignment volumes by skim period, travel into region

	AM	MD	PM	LN	Total
Reno (1)	289	634	672	669	2264
Carson City (2)	1652	1359	1086	1736	5833
Kingsbury (3)	566	677	530	766	2539
Kirkwood (4)	133	561	283	176	1153
Placerville (5)	414	4197	1090	297	5998
Squaw (6)	487	2848	1226	638	5199
Northstar (7)	740	1178	943	966	3827
Total	4281	11454	5830	5248	26813

Table 20.8c: Relative percent difference between winter external station counts and assignment volumes, travel into region

	AM	MD	PM	LN	Total
Reno (1)	-11.89%	-29.87%	5.33%	53.79%	-1.78%
Carson City (2)	114.82%	-43.26%	-26.02%	62.55%	2.33%
Kingsbury (3)	66.96%	-22.36%	-31.26%	30.49%	-1.17%
Kirkwood (4)	-42.92%	11.75%	18.91%	-1.12%	0.17%
Placerville (5)	-54.15%	45.88%	1.02%	-73.65%	0.18%
Squaw (6)	-36.42%	27.60%	-0.89%	-32.70%	0.33%
Northstar (7)	-1.33%	-18.25%	17.88%	11.42%	-0.80%
Total	4.72%	2.06%	-6.44%	0.73%	0.23%

Table 20.9a: Winter external station counts by skim period, travel out of region

	AM	MD	PM	LN	Total
Reno (1)	312	861	608	414	2195
Carson City (2)	767	2389	1464	1065	5685
Kingsbury (3)	338	869	769	585	2561
Kirkwood (4)	241	519	246	184	1189
Placerville (5)	889	2832	1062	1109	5893
Squaw (6)	777	2265	1255	962	5258
Northstar (7)	755	1450	805	872	3882
Total	4079	11185	6209	5191	26663

Table 20.9b: Winter external station assignment volumes by skim period, travel out of region

	AM	MD	PM	LN	Total
Reno (1)	858	524	538	361	2281
Carson City (2)	896	1429	2373	1093	5791
Kingsbury (3)	366	750	990	437	2543
Kirkwood (4)	176	525	193	294	1188
Placerville (5)	144	3710	659	1461	5974
Squaw (6)	599	2573	709	1332	5213
Northstar (7)	726	1181	1205	711	3823
Total	3765	10692	6667	5689	26813

Table 20.9c: Relative percent difference between winter external station counts and assignment volumes, travel out of region

	AM	MD	PM	LN	Total
Reno (1)	175.00%	-39.14%	-11.51%	-12.80%	3.92%
Carson City (2)	16.82%	-40.18%	62.09%	2.63%	1.86%
Kingsbury (3)	8.28%	-13.69%	28.74%	-25.30%	-0.70%
Kirkwood (4)	-26.97%	1.16%	-21.54%	59.78%	-0.08%
Placerville (5)	-83.80%	31.00%	-37.95%	31.74%	1.37%
Squaw (6)	-22.91%	13.60%	-43.51%	38.46%	-0.86%
Northstar (7)	-3.84%	-18.55%	49.69%	-18.46%	-1.52%
Total	-7.70%	-4.41%	7.38%	9.59%	0.56%

Table 20.10a: Winter resident external station assignment volumes by skim period, travel into region

	AM	MD	PM	LN	Total
Reno (1)	44	376	564	322	1306
Carson City (2)	87	497	619	675	1878
Kingsbury (3)	47	267	352	230	896
Kirkwood (4)	16	80	129	103	328
Placerville (5)	9	33	38	79	159
Squaw (6)	63	281	594	417	1355
Northstar (7)	95	551	706	557	1909
Total	361	2085	3002	2383	7831

Table 20.10b: Winter external worker external station assignment volumes by skim period, travel into region

	AM	MD	PM	LN	Total
Reno (1)	244	105	60	162	571
Carson City (2)	1487	623	359	843	3312
Kingsbury (3)	513	269	130	317	1229
Kirkwood (4)	52	26	17	36	131
Placerville (5)	128	44	40	60	272
Squaw (6)	222	80	41	118	461
Northstar (7)	550	246	149	363	1308
Total	3196	1393	796	1899	7284

Table 20.10c: Winter visitor external station assignment volumes by skim period, travel into region

	AM	MD	PM	LN	Total
Reno (1)	1	159	41	185	386
Carson City (2)	80	225	112	232	649
Kingsbury (3)	4	174	51	221	450
Kirkwood (4)	60	489	121	31	701
Placerville (5)	293	4153	968	149	5563
Squaw (6)	206	2472	593	104	3375
Northstar (7)	85	389	88	46	608
Total	729	8061	1974	968	11732

Table 20.11a: Winter resident external station assignment volumes by skim period, travel out of region

	AM	MD	PM	LN	Total
Reno (1)	774	162	134	236	1306
Carson City (2)	561	431	383	503	1878
Kingsbury (3)	259	221	205	211	896
Kirkwood (4)	107	76	44	101	328
Placerville (5)	34	34	24	67	159
Squaw (6)	479	269	162	445	1355
Northstar (7)	563	563	387	396	1909
Total	2777	1756	1339	1959	7831

Table 20.11b: Winter external worker external station assignment volumes by skim period, travel out of region

	AM	MD	PM	LN	Total
Reno (1)	47	131	295	98	571
Carson City (2)	240	695	1828	549	3312
Kingsbury (3)	90	282	659	198	1229
Kirkwood (4)	7	29	70	25	131
Placerville (5)	25	55	149	43	272
Squaw (6)	27	90	253	91	461
Northstar (7)	87	274	746	201	1308
Total	523	1556	4000	1205	7284

Table 20.11c: Winter visitor external station assignment volumes by skim period, travel out of region

	AM	MD	PM	LN	Total
Reno (1)	31	242	108	22	403
Carson City (2)	81	315	160	51	607
Kingsbury (3)	22	260	147	25	454
Kirkwood (4)	61	433	77	165	736
Placerville (5)	79	3619	511	1330	5539
Squaw (6)	101	2181	280	827	3389
Northstar (7)	71	357	75	101	604
Total	446	7407	1358	2521	11732

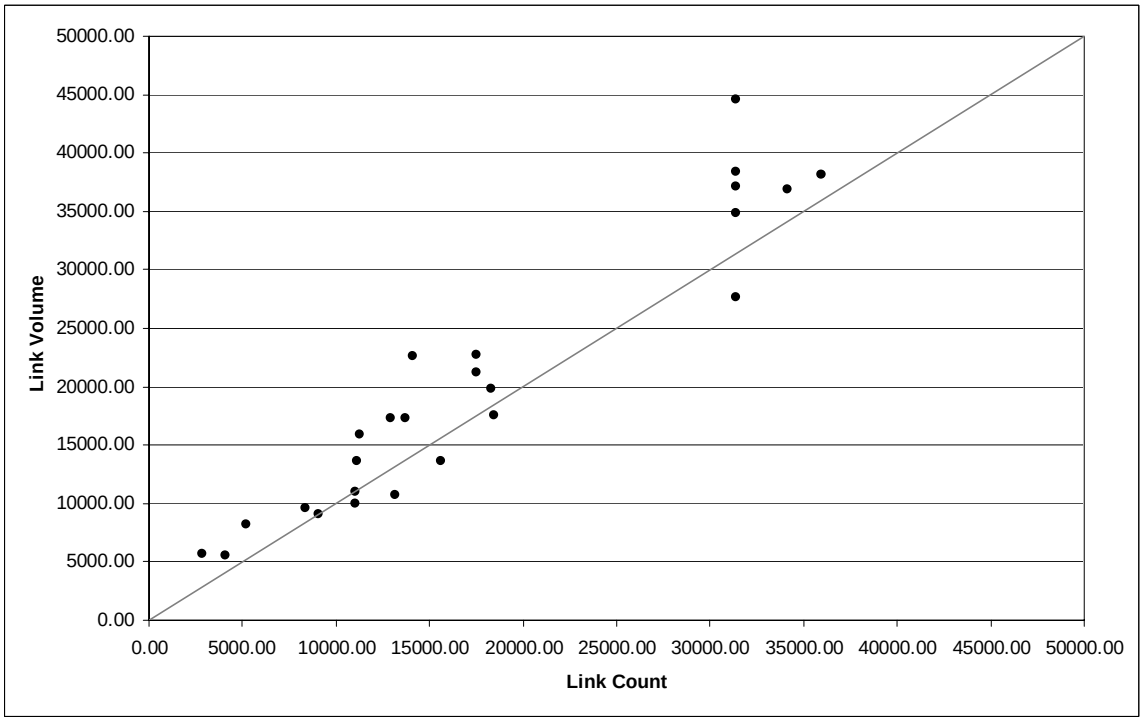
For the internal links, 25 bi-directional full-day counts were provided. The aggregate nature of the counts, as well as their low numbers, limited the amount of (and confidence in the) validation that could be performed with them. However, combining the counts with discussions with the client allowed problem areas to be isolated and resolved through volume-delay function adjustments. After validation, the percent root mean square error of the counts to volume comparison was 25.78%. This value is defined as:

$$\%RMSE = \left[\frac{\sqrt{\frac{\sum_i (volume_i - count_i)^2}{\sum_i -1}}}{\frac{\sum_i count_i}{\sum_i}} \right] \times 100\%$$

for all links *i* with counts.

A summary chart of the count to assigned volume is presented in **Figure 20.1**.

Figure 20.1: Link count to volume comparison chart



CHAPTER 21
Model Convergence and Final Thoughts on Recommended Enhancements

CHAPTER 21: MODEL CONVERGENCE AND FINAL THOUGHTS ON RECOMMENDED ENHANCEMENTS

21.1 Introduction

Up to this point, each of the individual components for the Tahoe regional model has been presented. The final aspect of the overall model performance is the importance of reaching convergence, such that equilibrium has been reached between input and output highway travel times and corresponding speeds.
This chapter will also discuss potential areas of model enhancement and improvement.

21.2 Full Model Convergence

The core model runs in the following sequential order:

1. Resident model
2. External worker model
3. Visitor model
4. Traffic assignment

However, the first three models depend on traffic assignment results (i.e. roadway facility speeds), so two considerations must be addressed:

1. Creating initial travel times for each individual link for the model to use
2. Reconciling the fact that the initial travel time/speeds may not be the same as those generated after traffic assignment, and thus the tour models will not be using the most accurate set of travel time for each of the intermediate iterations.

The first requirement is addressed by creating a pre-model assignment from a set of previously developed trip tables. These trip tables are selected as being close to the final values for the forecast year and provide a good "warm start" to the model.

To reconcile the link level travel time/speed differences, the entire core model stream is run multiple times, with the traffic assignment results used to recalculate travel times, which are then fed back to the beginning of the model stream. To determine how many core model iterations should be performed, the full model was run ten times, and the convergence of the traffic assignment results analyzed. It was found that three iterations were enough to get the model to converge and that any additional iterations provided little additional accuracy.

21.3 Running the Model

Running the Tahoe model is done through a TransCAD user interface. This interface not only runs the model, but also acts as a scenario manager and a geographic and mode result analysis tool. Information about and how to use the interface is provided in the *Tahoe Activity-Based Travel Demand Model Users Guide*.

21.4 Recommended Model Enhancements

The Tahoe Activity Based Travel Demand model captures the travel demand complexity of the region in a useful way. Its primary strength lies in its activity-based modeling roots, through which nearly every decision made by travelers can find a behavioral root, and interactions between these decisions are represented. The core of this activity-based modeling effort is the micro-simulated residential model, in which complicated behavioral interactions amongst household members are captured so as to create a detailed and accurate picture of their travel day. Another noteworthy model component is the visitor model – especially the overnight visitor model – in which a micro-simulated activity-based framework has been extended to the non-permanent residents and visitors who make up a significant portion of the daily traffic in the Tahoe Basin region. It is also worth pointing out that although they are simpler, the external worker and thru-visitor models are also essentially activity-based.

Besides demand modeling accuracy, one of the benefits that a micro-simulated activity-based model provides is detailed information about the population and its travel behavior. That means that not only can the final traffic volumes be analyzed, but so too can the behavioral aspects that underlie them. And perhaps the greatest benefit of this framework is that it allows the model to be sensitive to policy changes, and therefore scenarios can be developed and the analyst can have confidence in the results.

There are, however, opportunities for refinement and enhancement. One of the most significant is the day visitor model. The day visitor survey did not capture as much information as would have been helpful for developing a full activity-based model. It was difficult to balance the need to keep the survey short but at the same time get a rich set of data. When the visitor survey is updated suggested improvements to the questionnaire include:

- Identification of which external station the travel party used to enter the region. The survey did ask where the party lived but that did not necessarily equate to where they entered the region. A question such as "Which of the following roads did you use to enter the Tahoe basin?" would be very beneficial.
- It was sometimes unclear whether a travel party did activities together, or if the interviewee's travel behavior was (perhaps incorrectly) attributed to the whole party (which was not interviewed individually).
- Increased information about the specifics of the travel party, especially concerning how many vehicles they traveled in, how they were related, and their specific household characteristics (which might differ across party members).

Expansion of the day visitor survey is particularly challenging as it requires determining the number of visitors on any given day. Perhaps the most appropriate method to address this would be a cordon survey which would accurately disaggregate travelers into their component markets (visitors, residents, workers, etc.).

Another area of possible enhancement would be additional information and travel data regarding the winter travel season. While the residential model had a fair amount of winter-related information from the home-interview travel survey, it was not nearly as extensive as the summer data. The same was true in the visitor survey, where the sampling breadth in the winter season was somewhat smaller than the summer. This data imbalance is primarily due to the fact that data collection is more difficult in the winter season (*e.g.* weather impediments, fewer locations to collect visitor samples).

The last area of recommended model improvement would be to launch a more extensive traffic count program. The nature of the Tahoe region's seasonal and visitor population means that there can be a large deviation in traffic counts across time periods, day of the week and time period (peak and off-peak), . Obtaining link counts that covered a variety of such conditions, which could be averaged and analyzed, would contribute to an even greater confidence in the counts themselves, which would lead to an improved validation of the model. In addition to an expanded traffic count program, a transit on-board rider survey would allow the mode choice component of the model to be verified.

In summary, the Tahoe model is not only a substantial improvement over the region's previous travel demand model, but is also one of the most detailed model of its kind in the country. It should prove to be useful in analyzing a variety of scenarios that are important to the Tahoe Regional Planning Agency as they strive to accomplish their mission of preserving the beauty and clarity of beautiful Lake Tahoe.

APPENDIX I
Zonal Data

APPENDIX I – ZONAL DATA

AI.1 Introduction

Data organized at the zonal (TAZ) level is a core component of the inputs for the Tahoe activity based travel demand model. This data includes geographic, demographic, and socioeconomic data for the region. Understanding this data and how it is organized is especially important for understanding the Tahoe model, especially for creating new scenarios. This appendix will discuss the various zonal files and generated data used by the model. It is split into two major sections: **Fixed and Generated Zonal Data**, and **User-Defined Zonal Data**. The latter section is of exceptional importance for a user working with and creating new scenarios, as it describes the structure and contents of all of the non-GIS files used to define scenarios.

AI.2 Tahoe Basin Zones

The Tahoe Basin region is defined by the ridge of mountains surrounding Lake Tahoe. The region is divided into 289 zones which each of which carry unique socioeconomic, geographic, and demographic characteristics. These zones form the basis for much of the Tahoe model's details, not only from an input file/data perspective, but also in terms of outputs: the traffic assignment which makes up the final stage of the model uses trips from zone to zone as its input. Each zone has a unique id number, ranging from 9 through 297. A picture of the Tahoe basin region zone map is shown in **Figure AI.1**.

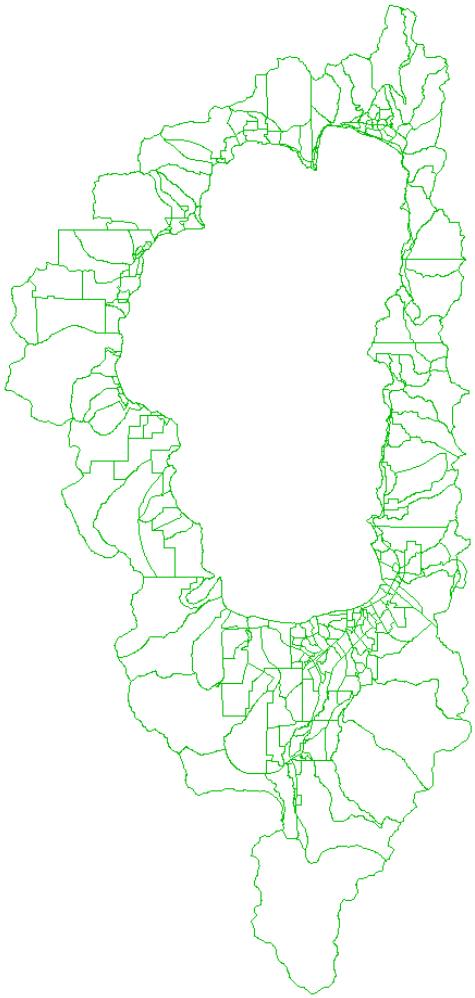


Figure AI.1: The Tahoe Basin regions zone map

In addition to the internal zones, there are seven external "zones" (actually just points/centroids), numbered 1 through 7, which represent the external stations by which persons can enter or exit the regions. **Table AI.1** describes these external zones.

Table AI.1: The Tahoe model external zone description

External Zone Number	Freeway	Common Name	Model Name
1	SR 431	Mt. Rose	Reno
2	US 50	Spooner	Carson City
3	SR 207	Kingsbury Grade	Kingsbury
4	SR 89	Luther Pass	Kirkwood
5	US 50	Echo Summit	Placerville
6	SR 89	Alpine Meadows	Squaw
7	SR 267	Brockway	Northstar

AI.3 Fixed and Generated Zonal Data

This section deals with files and data that the user cannot change and is therefore fixed across scenarios. In the following discussion, the first two files cover geographic data, while the rest involve socioeconomic and demographic data defined and derived for direct use by the model.

AI.3.1 TAZ_District.csv

This file maps the zones to districts. The columns are as follows:

- **taz** – the zone number
- **county_district** – the county the zone sits in, using the following correspondence scheme
  1. Washoe
  2. Carson City
  3. Douglas
  4. El Dorado
  5. Placer
  6. External Zone
- **district** – a custom district system using the following correspondence
  1. North Shore
  2. South Shore
  3. External Zone
- **ext_zone** – an external zone indicator; if the zone is an external zone, the value is the external zone number, otherwise it is zero

AI.3.2 *ZoneMappings.csv*

This file contains geographic information about each zone. The columns are as follows:

- **taz** – the zone number
- **census_tract** – the census tract the zone (mostly) belongs to
- **block_group** – the census block group the zone (mostly) belongs to
- **puma** – the census puma (1%) the zone belongs to
- **county** – the county the zone belongs to
- **county_code** – the FIPS code of the county the zone belongs in
- **state** – the state the zone belongs in

- **state_code** – the FIPS state code the county belongs in
- **full_census_code** – the full census code of the census geography the zone belongs to
- **area_in_sq_miles** – the area of the zone in square miles

AI.3.3 *ExternalZoneSizeCoefficients.csv*

This file contains information for the various external zone size term calculations. The columns are as follows:

- **zone** – the external zone number
- **intWorkSizeCoeffSummer** – the coefficient that will be multiplied by the full internal zonal employment to get an employment figure to use for the summer size term
- **intWorkSizeCoeffWinter** – same as intWorkSizeCoeffSummer, only for the winter season
- **extWorkSizePercentSummer** – the percent of all of the external workers expected to come from each external zone in the summer
- **extWorkSizePercentWinter** – same as extWorkSizePercentSummer, only for the winter season
- **ovDCSizePercentRec** – the percent of the intWorkSizeCoeffSummer/Winter to use for the overnight destination choice size term for recreation tours
- **ovDCSizePercentGam** – same as ovDCSizePercentRec, only for gaming tours
- **ovDCSizePercentShp** – same as ovDCSizePercentRec, only for shopping tours
- **ovDCSizePercentOth** – same as ovDCSizePercentRec, only for other tours
- **ovDCSizePercentOth** – same as ovDCSizePercentRec, only for tour stops

AI.3.4 *DayVisitorZonalData_[Summer/Winter].csv*

This file contains information for the day visitor synthetic population generator. There is a separate file for each season. The columns are as follows:

- **zone** – the external zone number
- **overnight2day** – the percentage of overnight visitor count to use as the day visitor percentage
- **percentThru** – the percentage of day visitors to use as thru-visitors

AI.3.5 Urban Type Model

In order to quantify geographic differences between the various zones, an urban type model was developed. This model maps each zone into one of four urban type categories:

- Rural
- Suburban
- Urban
- External

The latter category is assigned if a zone is an external zone. The other three categories are designated by using the following model structure:

if $WP < 600$ then urban type = Rural
if $600 \leq WP < 7500$ then urban type = Suburban
if $7500 \leq WP$ then urban type = Urban

WP is the sum of the employment and population densities, or:

$$WP_i = \frac{employment_i + population_i}{area_i}$$

where i is a given zone, and the area is measured in square miles

A map of the urban types, as applied to the base 2005 data, is shown in **Figure AI.2**.

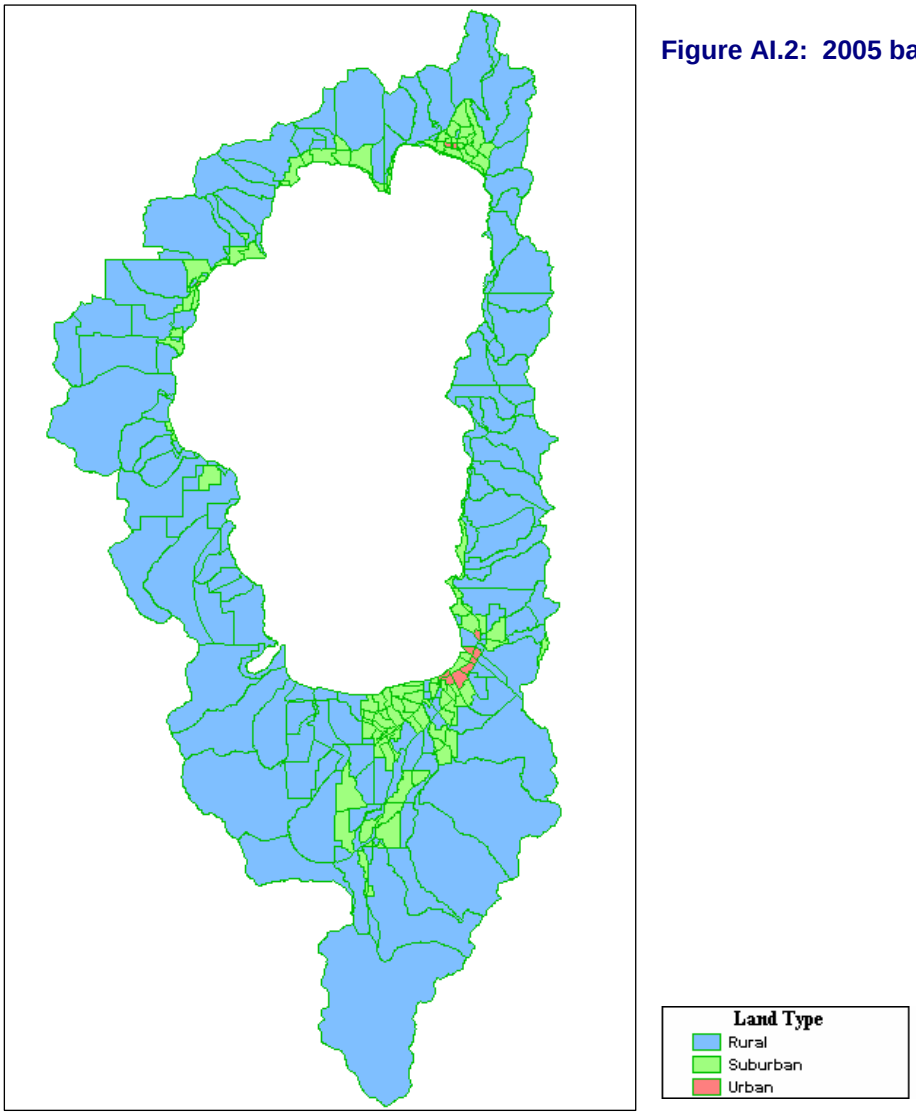


Figure AI.2: 2005 base urban type map

AI.3.6 Accessibility Index Model

Throughout the Tahoe model, accessibility indices are used as a measure of an individual's ability to access various aspects of the Tahoe region. For the model, accessibilities to retail employment and total employment were calculated; these accessibilities were further segmented by a time window and mode dimension. The mode segmentation was walk, transit or auto, while the time window was 20 or 30 minutes.

The accessibility indices are a measure of the relative accessibility from a given zone. To calculate them, mode skims were used to calculate what zones were accessible by a given mode within the time period, and then the appropriate variable (retail or total employment) for those zones was summed. That total was then divided by the variable's total across the entire region, to end with a relative accessibility index.

AI.3.7 Labor Force Model

Though the employment in the Tahoe Basin is contained in the socioeconomic data, the labor force (employed residents) of the region is not. Because there is a significant flow of workers into and out of the region (not to mention amongst zones), the employment information could not be used as a proxy for the labor force of the region. Instead, a labor force model was developed.

The labor force model was estimated as a linear regression model, using U.S. Census CTPP data in the estimation, using only data that was available (or derivable) from the socioeconomic file. The estimation results are shown in **Table AI.2**.

Table AI.2: Labor force submodel estimation results (t-statistics in parentheses)

Variable	Coefficient
Population	0.3534 (7.05)
# Medium Income Households	0.8426 (4.82)
# High Income Households	0.01124 (0.11)
Number of Households in Rural Area	0.07537 (0.5)
Number of Households in Suburban Area	0.1070 (0.72)
Number of Households in Urban Area	0.1391 (0.86)

Statistics	
Sum of Square Regressors	18354870
Sum of Square Errors	195662
R^2	0.9895
Adjusted R^2	0.9887
Number of Observations	91

Using these estimation results, a labor force for a given socioeconomic situation can be calculated. This labor force will be scenario-dynamic and thus sensitive to policy changes. Since it was estimated using 2000 census data, there will be a bias introduced if the relationship between the model variables and the labor force shifts in the region, due to demographic changes. However, such changes will affect many more aspects of the model and cannot be avoided.

AI.4 User-Defined Zonal Data

This section concerns zonal data that varies across scenarios. This data is contained in the *zonal* directory in the scenario folder. Changing this data (as well as possible GIS changes) is what will define a scenario as unique;

these files include information about the socioeconomic makeup of the region, as well as the visitor capacity and occupancy rates. If creating new scenarios, special attention should be paid to preserving their structure (not only the column/row layout, but also their comma-separated values (CSV) file format) so as not to break the model with invalid inputs. It is thus strongly suggested that the initial file generated from the scenario creation interface be edited directly as opposed to attempting to build these input files from scratch.

AI.4.1 *SchoolEnrollment.csv*

This file contains information on the school enrollment for the region. The columns are as follows:

- **taz** – the zone number
- **elementary_school_enrollment** – the elementary school enrollment
- **middle_school_enrollement** – the middle_school_enrollment
- **high_school_enrollment** – the high school enrollment
- **college_enrollment** – the college enrollment, including community colleges and an estimate of the college enrollment of internal residents in external zones

AI.4.2 *SocioEcon_[Summer/Winter].csv*

This file contains the socioeconomic data for the region. There is a separate file for each season. The columns are as follows:

- **taz** – the zone number
- **total_residential_units** – the total housing units (occupied and unoccupied)
- **census_occ_rate** – the residential occupation rate (generally derived from the U.S. Census)
- **total_occ_units** – the total occupied housing units (total_residential_units times census_occ_rate, rounded to nearest unit)
- **occ_units_low_inc** – the total number of housing units occupied by low income households
- **occ_units_med_inc** – the total number of housing units occupied by medium income households
- **occ_units_high_inc** – the total number of housing units occupied by high income households
- **persons_per_occ_unit** – the average number of persons per occupied unit
- **total_persons** – population of the zone (total_occ_units time persons_per_occ_unit, rounded off to nearest person)
- **emp_retail** – the total retail employment
- **emp_srvc** – the total service employment
- **emp_rec** – the total recreation employment
- **emp_game** – the total gaming employment
- **emp_other** – the total other employment

AI.4.3 *OvernightVisitorZonalData_[Summer/Winter].csv*

This file gives information about the overnight visitor capacities; *i.e.* how many overnight visitors each zone could maximally hold. It also contains information concerning the beaches in zones. There is a separate file for each season. The columns are as follows:

- **taz** – the zone number
- **hotelmotel** – the number of hotel/motel (not casino or resort) rooms
- **resort** – the number of resort hotel (not casino) rooms
- **casino** – the number of casino hotel (not resort) rooms
- **campground** – the number of campsites

- **percentHouseSeasonal** – the percentage of unoccupied houses in the zone which are potentially occupied by seasonal residents; the remaining unoccupied houses will potentially be occupied by non-seasonal overnight visitors
- **beach** – the relative attractiveness of beaches in the zone – if a zone has no beaches, this value is zero; since this is a relative attractiveness, the absolute value does not matter (zone A with an attractiveness of 1 and B with an attractiveness of 2 is the same as A with 2 and B with 4)

AI.4.4 *VisitorOccupancyRates_[Summer/Winter].csv*

This file gives information concerning the actual occupancy levels of the overnight visitor stay types. This is used, in conjunction with *OvernightVisitorZonalData_[Summer/Winter].csv* to generate a overnight visitor synthetic population. There is a separate file for each season. The columns are as follows:

- **taz** – the zone number
- **hotelmotel** – the occupancy rate for hotel/motel stay type (not casino or resort)
- **resort** – the occupancy rate for resort hotel (not casino)
- **casino** – the occupancy rate for casino hotel (not resort)
- **campground** – the occupancy rate for campgrounds (should be zero in the winter)
- **house** – the occupancy rate for non-seasonal overnight visitors staying in houses
- **seasonal** – the occupancy rate for seasonal visitors

APPENDIX II
Logit Models

APPENDIX II – LOGIT MODELS

The standard logit formulation can be expressed as:

$$P_i = \frac{e^{U_i}}{\sum_k e^{U_k}}$$

where:

P_i	is the probability of choosing alternative i
U_i	is a linear function of the attributes of alternative i that describe its attractiveness
$\sum_k e^{U_k}$	is the summation of the linear functions of the attributes over all the alternatives (k) for which a choice is feasible

The utility expression for each available alternative (i) is specified as a linear function that incorporates a range of variable types. For example, a mode choice model may include time, cost, location measures, and the socio-economic characteristics of the traveler. For example,

$$U_i = \beta_1 * Time_i + \beta_2 * Cost_i + \beta_3 * Location_{Var} + \beta_4 * SE + \beta_0$$

where:

U_i	is the utility for mode i
β_0	is a constant specific to mode i that captures the overall effect of any significant variables that are missing or unexplained in the expression (e.g., comfort, convenience, safety)
β_1	is a set coefficients describing the level-of-service (in travel time) provided by mode i (e.g., in-vehicle time, wait time, walk time)
β_2	is a set of coefficients describing travel cost, (e.g., transit fare, automobile operating cost, parking costs)
β_3	is a set of coefficients describing the specific attributes of the trip interchange (e.g., CBD destination, park and ride lot use)
β_4	is a set of coefficients describing the influence of each socio-economic characteristic of the traveler (e.g., income group, auto ownership)

The natural logarithm of the composite utilities (the denominator of the logit expression) is also known as the logsum. The logsum can be used as a variable in previous models, thereby providing "vertical feedback" within the decision chain. For example, the logsum from the mode choice model is often used as an impedance measure in the destination choice model. This allows the utility expressions from all modes to be included in determining accessibility within the destination choice model.