SOUTHEAST MICHIGAN COUNCIL OF GOVERNMENTS

MODEL ESTIMATION

Technical Memorandum | April 4, 2022

55 Railroad Row
White River Junction, VT 05001
802.295.4999
www.rsginc.com

PREPARED FOR:
SOUTHEAST MICHIGAN COUNCIL OF GOVERNMENTS

SUBMITTED BY:
RSG

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

This document describes the SEMCOG Activity-Based Model (ABM) estimation procedure and estimation results for auto ownership, tour destination choice, and time-of-day choice. The SEMCOG ABM is built on the ActivitySim framework and can be used to understand transportation demands resulting from changes in land-use, infrastructure, transportation policy, and population characteristics. The process of model estimation relies upon statistical methods to adjust model parameters to maximize goodness-of-fit to observed data for each model component.

This document includes the survey data processing through ActivitySim's estimation mode, the estimation of model parameters using ActivitySim's integration with the Larch[1] estimation package, and the estimation results for auto ownership, tour destination choice, and tour time-of-day choice. Federal research[2] indicates that destination choice models are the least transferable model component across activity-based model implementations. Auto ownership and tour destination choice models were estimated in Phase I model deployment. Tour time-of-day choice models were estimated in Phase II. Other model components in the donor model (developed for the San Francisco Bay Area) were found to match observed data relatively well with calibration and therefore do not require re-estimation. Mode choice models were calibrated to observed data; we did not estimate these models because we believe that there is insufficient variation in cost data (most of the region offers free parking and there are no toll roads) and in transit choice (no fixed-guideway transit outside of the Detroit PeopleMover and the new Qline streetcar which did not open until after the household survey data was collected). Other models were calibrated to observed data in order to focus project resources on improving model specifications with respect to university travel, documented elsewhere.

Tour destination choice models were estimated for mandatory (work and school location) and non-mandatory purposes. Time-of-day choice models were estimated for mandatory (school and work), non-mandatory, and joint tours. University tours were not included in the school estimation model because of the lack of confidence in the survey data for university students. Non-mandatory tours were segmented into six tour purposes: escort, shopping, social, eat out, other maintenance, and other discretionary. Time of day model estimation started with the model specification that was created for the Atlanta Regional Commission (ARC) that includes

---

[1] https://larch.newman.me/

[2] see John Gliebe, Mark Bradley, Nazneen Ferdous, Maren Outwater, Haiyun Lin, and Jason Chen, RSG, Transferability of Activity-Based Model Parameters, Strategic Highway Research Program SHRP2 Report S2-C10A-RW-2, Transportation Research Board, Washington D.C., 2014.

48 half-hour time bins. New terms were not added to the specification, but terms were removed depending on whether they turned out to be significant or not.

2.0 SURVEY DATA PROCESSING AND MODEL ESTIMATION OVERVIEW

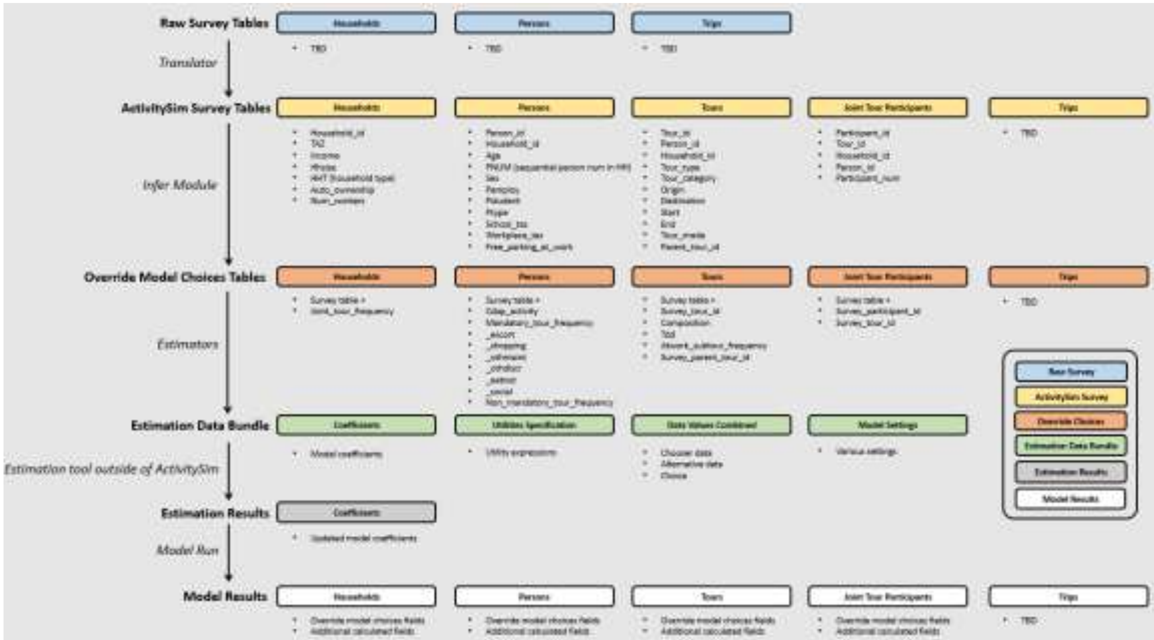
Survey data was first processed into a format compatible with ActivitySim's "estimation mode". This includes formatting the data correctly and removing households, people, and tours that are not valid in the eyes of ActivitySim. Estimation data bundles are produced from ActivitySim's estimation mode and include the inputs needed to estimate the models in Alogit (for destination choice) or Larch (auto ownership and tour time of day choice). Changes were made to the model specifications such that the parameters names and expressions were consistent with each other.

2.1 DATA FORMATTING AND WORKFLOW

ActivitySim estimation mode expects survey input data to be in a specific format with required fields for household, person, tour, and trip level data. Once the minimum level of required information is met, the survey data is run through the *infer* module (a python script named *infer.py*) to do initial pre-checks on the survey data and calculate additional fields including the coordinated daily activity pattern, tour frequencies, joint tour parameters, at-work subtours, and tour departures and durations.

Output from infer.py is the input for ActivitySim estimation mode. Upon completion of ActivitySim estimation mode, the EDBs specified in the *estimation.yaml* configuration file are created and ready for use in model estimation. This workflow can be seen in Figure 1.

FIGURE 1: ACTIVITYSIM ESTIMATION WORKFLOW



When creating ActivitySim tables from the SPA output, most of the changes just involve the re-naming of columns to match the information specified in the above diagram. However, there are a few additional formatting requirements:

- **Unique ID's:** ActivitySim requires unique id's for households, persons, tours, and trips. Only household ids are unique in the SPA output with person, tour, and trip id's restarting for each household. Thus, new unique ids are created for the ActivitySim tables. Additional care is required to ensure that subtours are given their corresponding parent tour id.
- **Joint tour participants file:** SPA creates a unique joint tour file where each row is a joint tour and the columns contain the person ids of participants on that tour. ActivitySim instead expects a joint tour participants file where each row contains a single on the tour. This essentially equates to "melting" the spa unique joint tour file where the columns with person ids become the rows in the joint tour participants ActivitySim file. SPA tours file contains a duplicate of the joint tour for each tour participant, but ActivitySim should only contain a single instance of that tour. Only the first instance of the joint tour from the SPA output is kept in the ActivitySim table.

2.2 HOUSEHOLD TRAVEL SURVEY PROCESSING

The SEMCOG Household Travel Survey (HTS) conducted in 2015 contains roughly 19,000 individuals across 12,000 households. Coding of the HTS was performed using the SEMCOG

Survey Processing Application (SPA) described in the *SEMCOG Survey Processing Memo* and groups trips into linked-trips and tours with the proper modes and purposes to match the SEMCOG ABM. Following SPA processing, further formatting of the data was required before passing the tables to the Infer module.

If the survey data was completely accurate, and ActivitySim fully captured the travel that all individuals make, then we could just run ActivitySim in estimation mode with the formats shown in Figure 1. Unfortunately, survey data is never perfect. There are specific tour patterns that ActivitySim expects, and the survey data can be incomplete or inconsistent leading to ActivitySim crashes. This section contains the cleaning of the SEMCOG household travel survey data to get it into valid ActivitySim data and the assumptions made along the way. Considering the myriad of issues that may accompany survey data, it should be expected that other survey data sets will have issues that are not present in this document.

Households

Processing of household level data in ActivitySim is specified in the *annotate_households.csv* config file, so checking this file for region specific calculations is recommended. The household file for SEMCOG required minimal processing as the region does not contain any special processing requirements. That said, a few modifications were still required:

- **Income:** Household income is kept in a categorical variable in the survey and through the SEMCOG SPA tool. ActivitySim produces and expects actual dollar amounts for income. Income values were randomly generated by sampling from a uniform distribution of the household's income category. Households that were missing income values were assigned a randomly selected income drawn from the distribution of income values in the survey.
- **Household Size:** The household size variable needs to match the actual number of persons in the person file for that household. If persons are removed in subsequent processing steps, this field needs to be updated. No persons were removed in the SEMCOG data.

Persons

Review of the *annotate_persons.csv* config file should be performed prior to processing person level data to understand how student and employment categories are determined and how person type is calculated. For SEMCOG, people are employed when the employment status code (*ESR*) is equal to 1, 2, 4, and 5. Part-time and full-time work is then determined by the usual hours worked per week (*WKHP*) and the number of weeks worked (*WKW*) in the past year. Student status is determined by the person's age and grade level attending (*SCHG*) code.

Certain person and tour level models only run for people that fall within a certain employment, student, or person type category. Thus, when fixing person type issues, special care needs to be taken to ensure the correct variables are being changed in the survey processor so that the persons are annotated correctly in ActivitySim.

- **Age:** In the SEMCOG Household Travel Survey (HTS), there are people who declined to answer the age question which results in a default age value of -8 or -7. Since student status, employment, and person type each have an "age < some number" filter, these missing ages need to be fixed. If a person has a valid school TAZ and a student category less than high school, the assumption used was to set their age 12 to represent non-driving students. Otherwise, they were treated as adults and their age was set to 30. There were 34 people in the SEMCOG HTS that had their age inferred.
- **School TAZ:** Not all people who reported they were students had a school TAZ that had the corresponding enrollment in the land use file. If a school TAZ was not reported, and a school trip was made, that school trip location was assumed to be their school TAZ in a survey pre-processing step. Even with that assumption, 28% of students still had a school TAZ without any corresponding enrollment in the land use file or had a missing school TAZ in the survey and no school trip to infer from.

  If a school TAZ had no enrollment in the land use, ActivitySim would crash in estimation mode because the size term is zero. These people had their school TAZ's replaced with the closest zone (by TAZ centroid distance) with the appropriate level of enrollment. A total of 916 invalid school TAZs were replaced, increasing the total percent of valid school TAZs from 60% to 72%.
- **Workplace TAZ:** Many people who reported as workers did not report a workplace TAZ. If these people made a work tour, the first work tour destination was selected as their workplace TAZ. Workplace TAZs were inferred in this way for 604 people in the SEMCOG data. All internal zones in the SEMCOG land use file contain employment. If another region contains TAZs without employment, additional logic would be needed to ensure a valid workplace TAZ like what was done for school.

  If there was no way to infer the school or workplace TAZ, their values were set to -1 which is ignored in ActivitySim destination choice estimation. Ignoring these values is only acceptable if that person does not make a work or school tour.
- **Person Type:** If a person is not labeled as a worker or a student, but then has a work or school tour, mandatory tour frequency and scheduling models will crash because work and school location choice does not get run for those people and no tour destination is set. Everyone who makes a work or school tour needs to be labeled as a worker or student.

ESR is set to 1 for all persons making a work tour to flag them as employed in the annotate persons step. ActivitySim does not allow full time workers to go to school. If a person takes a work tour and a school tour, the number of working hours and the work hours per week are decreased to fall below the part time threshold so that both school and work tours could be performed. 39 participants of the SEMCOG HTS were changed from full time to part time workers to include their school tours.

There are also several people who reported as non-student workers but perform a school tour and not a work tour. These people are changed from workers to students. Similarly, people who report as non-worker students but only make a work tour and no school tour are changed from students to workers. There were 54 reported workers who were changed to students and 76 reported students who were changed to workers.

Tours

Tour level processing constitutes the bulk of the survey processing code along with determining correct school and workplace TAZs. ActivitySim requires that all tours happen within a 24-hour day and that the number of tours match acceptable tour patterns. The tour frequency is embedded deep within ActivitySim including the association of tour ids with tour numbers and types. Part of the infer.py module includes checking these tour frequencies and assigning ActivitySim tour ids. Thus, most of the debugging effort with tours was in trying to get the tour file to pass the infer.py module.

- **Tour Purpose:** ActivitySim configuration files specify the types of tours allowed. A map between SPA output tour purposes and ActivitySim purposes must be created. Most of the categories map one-to-one with ActvitySim purposes. SPA tour purposes such as "loop" tours are changed to other maintenance or other discretionary purposes for SEMCOG. ActivitySim does not have a university tour type, so university tour types were changed to school.
- **Tour Category:** ActivitySim expects tours to be categorized into mandatory, non-mandatory, joint, and at-work subtours. Only tours that contain multiple members from the household for the entire tour are considered joint tours in ActivitySim (*JOINT_STATUS* = 3 in the SPA tour output).
- **Tour Type:** Atwork subtours contain an additional tour type variable into the ActivitySim categories *business*, *eat*, and *maint*. Work tours are mapped to *business*, eat out tours are mapped to *eat*, and all other atwork subtour purposes are mapped to *maint*. SEMCOG had no *business* atwork subtous in the SPA output.
- **Tour Mode:** Tour modes also need to match the specified tour modes in the ActivitySim configuration files. The numeric tour categories from the SEMCOG SPA had a one-to-

one correspondence with the chosen tour modes in ActivitySim. Other implementations would have to check this step.

- **Tour Locations:** If tour destinations are not within the SEMCOG region or are not reported, those tours do not have a valid start or end TAZ. These tours were removed. SEMCOG HTS removed 1,962 out of 38,872 (5%) of the total tours due to invalid start or end locations.
- **Tour Times:** The *tour_departure_and_duration_alternatives.csv* config file contains the allowed tour start and end times. For SEMCOG, this just includes a full 24-hour day broken down into 48 half-hour time bins starting at 3:00 A.M. Tours were removed if it did not fit this specification. 3,006 tours were removed due to bad start / end times in SEMCOG.
- **Tour Frequencies:** There are configuration files for each of the tour categories that specify the allowed sets of tour frequencies. For SEMCOG, a person can only take two mandatory tours with the following possible combinations: one work, two work, one school, two school, or one work and one school. A much larger set of possible alternatives exists for the non-mandatory purposes (see the config file non_mandatory_tour_frequency_alternatives.csv for a list of all allowed possibilities).

  Code was developed to count the number of tours for each person and each tour category and summarize them up in such a way that matches the ActivitySim tour frequency alternatives files. Tours are then removed if a certain tour exists outside the allowed tour frequencies. For example, if a person were to take 3 eat out tours, but the specification only allows for up to two, then the third eat out tour is removed. Tours are numbered starting at the beginning of the day and the first tours are the ones selected. A slight bias may have been introduced from this sampling method, but comparing the estimation results to survey data that did not remove these tours showed no significant difference. A total of 2,834 tours that did not have an allowed tour frequency were removed from the SEMCOG data.

If a tour was removed for any of the above reasons, all subtours for that parent tour were also removed. Of the 37,180 tours in the SEMCOG HTS, 6,342 tours (17%) were removed due to one of the above conditions.

Joint Tours

As mentioned in the formatting section, joint tours are handled differently in ActivitySim than in the SPA output. ActivitySim lists joint tours only once in the tours file in contrast with the repeat in the SPA tours file where the tour is listed for each person. Additionally, the joint tour participants file for ActivitySim contains one person per row whereas the SPA output contains one tour per row where the columns contain the tour participants. Besides these formatting changes and the transferrable checks on all tours including locations and start/end times, there are a few additional joint tour checks that need to be made.

- **Joint Tour Type**: ActivitySim does not have an escort joint tour type. The 143 joint escort tours in the SEMCOG data were instead changed to non-mandatory.
- **Joint Tour Frequency:** Joint tours had restrictions on frequency just like non-joint tours. The procedure for removing joint tours that did not fall in the frequency alternatives is the same as for non-joint tours.
- **Joint Tour Participants:** Each joint tour needs to have an adult or child on the tour to determine joint tour composition. This is achieved by ensuring only fully joint tours from the SPA output are treated as joint tours. All of the fully joint tours have participants listed in the joint tour participants file.

After all bad tours are removed and the household and person level data is compliant, the infer.py module is run. This takes the survey tables and appends additional fields to create override tables that are used as input to ActivitySim estimation mode. These override tables are specified as inputs in the *settings.yaml* file in the estimation configs directory.

2.3 RUNNING ACTIVITYSIM IN ESTIMATION MODE

Running ActivitySim in estimation mode works just like running ActivitySim in non-estimation mode except for providing additional estimation config files. An example run command would look like the following:

activitysim run -c configs_estimation -c configs -d data -o output

where the run directory would contain a *configs_estimation* folder with the estimation and run setting yaml files, a normal *config* folder with the typical model configs used in non-estimation mode, a *data* folder containing the override tables from the infer.py module, land use, and skims, and an *output* folder where the estimation data bundles would be written.

In the *configs_estimation* directory should be the *estimation.yaml* file which contains a list for all the models to write estimation data bundles for. For each SEMCOG tour purpose, a separate tour scheduling estimation data bundle was written out.

At the time of this writing, multi-threading is not supported for ActivitySim's estimation mode. Run times for the SEMCOG HTS was about 5 hours to run all the models up to stop frequency.

The cleaning process can be time consuming considering a few fringe cases can cause estimation mode to crash. This means that while using a small sample is useful to test configurations and setup, problems are often not found until running the entire sample.

Debugging typically involves running the entire sample until an error arises. The household(s) that crash can then be traced in a smaller sample to uncover the error. Typically, the error is a result of unclean survey data. The full survey sample is run again after fixing the issue and testing with the traced household with the test sample.

However, the full survey sample must be run from the start since the input data is changing. This means that ActivitySim’s restart functionality cannot be fully taken advantage of for most problems. Without multi-threading and hours long run times to get to later models, this process can be slow. Hopefully the necessary cleaning outlined in this memo transfers well to other scenarios to reduce the time it takes to get estimation data bundles written out for different regions.

3.0 AUTO OWNERSHIP MODEL ESTIMATION

Auto ownership estimation was needed because of the large differences in auto ownership levels between the adopted San Francisco Bay area and the SEMCOG region. The auto ownership model specification was not changed from the initial implementation – only new coefficient values were estimated.

The ActivitySim estimation auto ownership example Jupyter notebook was used to perform the auto ownership estimation[3]. This notebook takes as input the estimation data bundle prepared output from ActivitySim estimation mode and re-estimates the coefficients for the specification provided by the configuration files used to run ActivitySim in estimation mode. Larch estimation software[4] is used in this notebook instead of ALOGIT. Estimation results for auto ownership can be seen in Table 1. Coefficients with a t-statistic of "NA" means that coefficient was constrained in the estimation procedure. This is typically done either because there are too few observations in the data to estimate the parameter or to ensure a reasonable coefficient. The *auto_ownership.csv* ActivitySim configuration file[5] shows exactly how these coefficients are applied.

3 https://github.com/ActivitySim/activitysim/blob/master/activitysim/examples/example_estimation/notebooks/estimating_auto_ownership.ipynb

4 https://larch.newman.me/

5 https://github.com/ActivitySim/activitysim/blob/master/activitysim/examples/example_mtc/configs/auto_ownership.csv

TABLE 1: AUTO OWNERSHIP ESTIMATED COEFFICIENTS

	Parameters					T- Statistic			
Variable	Cars 0	Cars 1	Cars 2	Cars 3	Cars 4+	Cars 1	Cars 2	Cars 3	Cars 4+
util_drivers_1		-0.226	-3.05	-2.97	-2.58	-1.89	-23.34	-18.61	-12.25
util_drivers_2		0.00	0.00	0.00	0.00	NA	NA	NA	NA
util_drivers_3_up		-0.398	-0.530	1.19	1.57	-1.62	-2.16	4.84	6.14
util_persons_16_17		-0.594	-1.41	-1.46	-1.46	-1.82	-4.19	-4.29	-4.29
util_persons_18_24		0.281	-0.237	0.00	0.00	3.44	-3.46	NA	NA
util_persons_25_34		0.00	-0.260	-0.368	-0.368	NA	-4.85	-5.64	-5.64
util_presence_children_0_4		0.00	0.00	-0.468	-0.468	NA	NA	-5.19	-5.19
util_presence_children_5_17		0.365	0.526	0.387	0.387	2.02	2.75	1.95	1.95
util_num_workers_clip_3		-0.389	0.433	0.662	0.929	-2.50	2.76	4.12	5.50
util_hh_income_0_15k		-2.54	-4.08	-4.30	-4.33	-18.61	-24.48	-20.16	-14.70
util_hh_income_15_35k		-1.20	-2.41	-2.77	-3.05	-8.51	-15.43	-15.81	-13.72
util_hh_income_35_50k		0.00	-0.772	-1.07	-1.20	NA	-8.46	-9.00	-7.07
util_hh_income_50_75k		0.00	-0.532	-0.686	-0.719	NA	-6.58	-6.96	-5.52
util_density		0.00	-0.0487	-0.541	-0.800	NA	-1.73	-8.35	-7.92
util_retail_transit		-0.444	-0.715	-0.800	-0.778	-14.06	-17.99	-15.32	-10.93
util_retail_non_motor		0.115	0.00	0.00	0.00	4.51	NA	NA	NA
util_auto_time_saving_per_worker		1.31	0.906	0.900	0.538	5.87	3.88	3.63	1.91
util_constant		3.06	5.44	4.39	3.23	15.00	30.28	22.99	14.76
util_univ_students_GQ		-3.56	-999	-999	-999	NA	NA	NA	NA

4.0 DESTINATION CHOICE MODEL ESTIMATION

This section describes estimation of destination choice models for the SEMCOG region, including the mandatory (work and school) location choice models and the non-mandatory tour destination choice models.

4.1 DESTINATION CHOICE SIZE TERM ESTIMATION

Size terms account for the land use characteristics of the destination zones when performing destination choice; they reflect the quantity of opportunities in each zone to engage in an activity in that zone. The size term in a destination choice model is equivalent to the trip attraction term in a gravity model. The probability of selecting a given destination for a given tour or stop purpose is proportional to its size term, all other things being equal. Any zonal variable expressing the quantity of opportunities in a zone can be used as a size term variable, but they are typically based on employment by type, number of households, and school enrollment by type (K-8, high school, and college/university). Special generator land-uses (hospital beds, casinos, parks and recreation areas, or other variables can also be used.

For the Phase I models, work location choice model size term coefficients were estimated using 2015 1-Year Public Use Microdata Sample (PUMS) data. This data is used instead of household survey data due to the much bigger sample of workers in PUMS. The work location choice model in ActivitySim is segmented by income category; workers have a different set of size term coefficients based on their household income. These size term coefficients represent the distribution of workers by industry in the PUMS data within each income segment. School location choice size terms were asserted to just capture the enrollment corresponding to the school level of the individual making the school tour, and ALOGIT was used to perform size term estimation for non-mandatory tours.

To estimate work location choice size terms, PUMS household and person data for Michigan was downloaded from the Census website and filtered for the Public Use Microdata Areas in the SEMCOG region. Workers were segmented into four categories based on their household income: low income (<$30,000); med income ($30,000-$60,000); high income ($60,000-$100,000); and, very high income (>$100,000). A crosswalk between employment categories in SEMCOG land use data and NAICS industry code was created using information on the NAICS code search website. Workers were assigned an employment category (e.g. e01_nrm) based on their NAICS industry code (e.g. 21). Workers were cross tabulated by income segment and industry (Table 2). For each income segment, the industry with the highest number of workers was identified and set as the base category or reference category. The percentage of workers in each industry compared to the reference is calculated (Table 3) and used as the size term coefficient.

TABLE 2: EXPANDED WORKERS BY INCOME AND INDUSTRY

INDUSTRY	e01	e02	e03	e04	e05	e06	e07	e08	e09	e10
0_30k	0	10563	17179	2923	30873	7335	273	2015	8130	5530
30k_60k	66	20143	52883	8560	49458	14221	1969	5322	16231	21811
60k_100k	375	24030	80983	11993	48062	14383	4014	8873	28753	28354
100k_pl	834	23842	146910	19579	53332	14867	8090	15259	49896	69810

INDUSTRY	e11	e12	e13	e14	e15	e16	e17	e18
0_30k	0	17471	15576	33553	5569	34111	14625	2372
30k_60k	219	19331	28630	56038	10432	37055	19474	11497
60k_100k	563	18495	47570	68253	9983	26730	18444	17279
100k_pl	732	24148	73226	102678	13787	31488	20640	20955

TABLE 3: SIZE TERM COEFFICIENTS

INDUSTRY	e01	e02	e03	e04	e05	e06	e07	e08	e09	e10
0_30k	0.000	0.310	0.504	0.086	0.905	0.215	0.008	0.059	0.238	0.162
30k_60k	0.001	0.359	0.944	0.153	0.883	0.254	0.035	0.095	0.290	0.389
60k_100k	0.005	0.297	1.000	0.148	0.593	0.178	0.050	0.110	0.355	0.350
100k_pl	0.006	0.162	1.000	0.133	0.363	0.101	0.055	0.104	0.340	0.475

INDUSTRY	e11	e12	e13	e14	e15	e16	e17	e18
0_30k	0.000	0.512	0.457	0.984	0.163	1.000	0.429	0.070
30k_60k	0.004	0.345	0.511	1.000	0.186	0.661	0.348	0.205
60k_100k	0.007	0.228	0.587	0.843	0.123	0.330	0.228	0.213
100k_pl	0.005	0.164	0.498	0.699	0.094	0.214	0.140	0.143

4.2 TOUR DESTINATION CHOICE ESTIMATION PROCESS AND RESULTS

After transforming the necessary data into ALOGIT inputs, many different model specifications were created and estimated in ALOGIT to determine the best set of parameters to use for each model. Model specifications started with a coefficient on the mode choice logsum parameter and adding subsequent terms to increase model complexity and hopefully explanatory power of the model. Model parameters that were not statistically significant were removed.

All models containing just a logsum parameter produced a logsum coefficient greater than one. Since having a logsum coefficient greater than one is inconsistent with the derivation of what a logsum represents[6], this model was rejected and a linear distance term was added. Including a linear distance term added enough explanatory power that the estimated logsum coefficient dropped back into its acceptable range between 0 and 1.

Non-linear distance terms were added to better match observed tour length frequency distributions and consisted of squared, cubed, and logged distance terms. The squared and cubed distance terms were capped at 20 miles to restrict these terms from being too greatly affected by outlier tours of very long lengths. This means that even if an alternative was 30 miles away, the squared distance seen by the utility equation is only 20*20 = 400 miles^2 instead of 30*30 = 900 miles^2. The utility as a function of distance must monotonically decrease – it does not make sense for a tour with a farther distance to have a higher utility than a shorter tour based solely on distance. Restricting the polynomial distance terms to 20 miles produces utility functions that satisfy this constraint (Figure 2).

Adding non-linear distance terms stole explanatory power from the logsum parameter and forced the logsum parameter to insignificant values below 0.1. Setting the logsum parameter to the value that was estimated when including just logsum and linear distance keeps the desired explanatory power of the logsum in the model.

After adding non-linear distance terms, household and person characteristics were included by interacting linear distance with a binary variable that turns on the term if the household or person meets the criteria. Person level variables are always off for joint tours. Distance interactions were not kept in the final model specification if their values could not be explained or they were statistically insignificant (T-Statistic of less than 1.5).

Choosing which distance interaction and size terms to try and whether to keep them is not an exact science and relies heavily on the experience of the RSG modeling team to make judgement decisions.

[6] See *A Self Instructing Course in Mode Choice Modeling* by Koppelman and Bhat for more information

To account for the weighting performed in the HTS in the estimation procedure, additional terms were appended to the estimated utility function. First, tours were split into the six bins depending on the distance from their origin to their destination (0-1, 1-3, 3-6, 6-10, 10-15, and 15+ miles). The weighted and unweighted share of the number of tours for a particular purpose were then calculated for each distance bin, and the weighted utility function is given by

$$\mathrm{U}_{\text{weighted}} = \mathrm{U}_{\text{unweighted}} - \ln\left(\frac{\text{weighted share}_{\text{distbin}}}{\text{unweighted share}_{\text{distbin}}}\right)$$

For example, if the raw HTS had 100 unweighted work tours, and 15 of them are between 0 and 1 miles, but 1,000 weighted work tours with 200 between 0 and 1, the new weighted utility for these work tours between 0 and 1 mile is

$$\mathrm{U}_{\text{weighted}} = \mathrm{U}_{\text{unweighted}} - \ln\left(\frac{200/1000}{15/100}\right) = \mathrm{U}_{\text{unweighted}} - .125$$

By changing the utility function as described, the utility function compensates for the under- or over-estimate of the unweighted data.

Mandatory Tour Destination Estimation Results

Mandatory tour estimation results are listed in Table 4: Mandatory Tour Destination ResultsTable 4 and consist of non-university school tours and work tours. University tour destination choice was not estimated due to the unreliable and unrepresentative HTS data for university students in the SEMCOG region.

TABLE 4: MANDATORY TOUR DESTINATION RESULTS

	Work		K-8/9-12 School	
Distance Parameters	**Value**	**T-Stat**	**Value**	**T-Stat**
Mode Choice Logsum	0.25		0.4	
Distance	-0.06334	-22.47	-0.15598	-5.48
Distance^2 (max 20)	0.001294	2.61	-0.01157	-4.45
Distance^3 (max 20)	-6.7E-05	-1.59	0.000475	4.93
Log(Dist + 1) (max 20)	-0.4796	-15.95	-0.93156	-16.35
Distance Interactions				
Low Income < 30K	-0.0294	-7.67		
Medium Income 30K-60K	-0.02486	-8.49		
High Income 60K-100K	-0.01389	-5.81		
Part Time Status	-0.04776	-12.69	-0.09847	-2.77
Full Time Status				
Student Status	-0.02404	-3.34		

Children in HH				
Joint Tour				
Child aged 0 to 5			0.023571	2.03
Child aged 6 to 12			-0.06567	-5.63
Model Statistics	**Value**		**Value**	
Number of Tours	10631		4243	
Log-Likelihood w 0 coeffs	-84409		-27772	
Final Log-Likelihood	-66766		-12041	

As described in the introduction of this chapter, the mode choice logsum was fixed to the estimated value when including just linear distance in the model. A smaller logsum value for work than school indicates that work locations are less sensitive to mode accessibility, especially compared to the logsum values of non-mandatory tours listed in the following section. This makes intuitive sense in that workers must go to work at their designated work location and do not often have much choice on where their workplace is located.

Not all distance terms for work and school are negative – school's cubed distance and work's squared distance terms are positive – but the sum of all distance terms still monotonically decrease as a function of distance, as seen in Figure 2. Positive distance terms are not a problem as long as the overall utility function decreases with distance.

Household income segmentation crossed with linear distance was not statistically significant, but part time work status and child age were. If the individual making the school tour is a part-time worker, there is an additional negative utility as a function of distance compared to non-part-time workers. Considering the increased demand on an individual's schedule to perform work and school, choosing a school location that is closer makes sense.

Child age was split into three categories: 0 to 5 years, 6 to 12 years, and 12 to 18 years, categorizing the children into roughly preschool, grade school, and middle/high school. Including just the 0 to 5-year and 6 to 12-year categories in the model means their estimated coefficients are with respect to the 12 to 18-year-old students. A positive coefficient for preschool aged children means that they are more likely to travel longer distances than high school aged children. This is possibly due to differing structures and pricing among preschools compared to middle/high school. On the other hand, grade school students are more likely to travel shorter distances to school than middle / high school aged students due to the increased abundance of grade schools throughout the SEMCOG region.

Segmenting workers by household income group was statistically significant for work tours. These coefficients listed in Table 4 are with respect to the very high-income group ($100k+ annually). The lower the household income group, the less likely the individual is to travel farther to work. This can be explained by the increased selectivity of workplaces for higher paying jobs. Additionally, the negative coefficient on part-time workers indicates that traveling longer distances for part time work compared to full time work is less likely.

Adding a term crossing distance with part-time work status produced a statistically significant coefficient for workplace location choice compared to the base of full-time workers. These part time workers were more sensitive to longer workplace distances. Including student status in the model was also statistically significant and produced a negative coefficient with respect to non-students, indicating that students are more likely to travel shorter distances to work, as expected.

Non-Mandatory Tour Estimation Results

Non-mandatory tour estimation results are listed in Table 5 and consist of seven non-mandatory tour purposes: escort, shopping, other maintenance, eat out, social, other discretionary, and at-work subtours.

TABLE 5: NON-MANDATORY TOUR DESTINATION ESTIMATION RESULTS

	Escort		Shopping		Eatout		Other Maitenance		Other Discretionary		Social		At Work	
Distance Parameters	Value	T-Stat	Value	T-Stat	Value	T-Stat	Value	T-Stat	Value	T-Stat	Value	T-Stat	Value	T-Stat
Mode Choice logsum	0.43		0.65		0.56		0.38		0.75		0.68		0.79	
Distance	-0.025	-1.41	-0.098	-6.82	-0.039	-3.02	-0.059	-9.59	-0.034	-4.64	-0.071	-8.48	-0.021	-1.08
Distance^2 (max 20)	-0.002	-2.01	-0.020	-11.23	-0.021	-8.10	-0.009	-6.99	-0.012	-8.98			-0.018	-5.52
Distance^3 (max 20)	4E-06	1.75	0.0008	10.06	0.0008	6.57	0.0003	5.19	0.0004	6.49			0.0007	4.78
Log(Dist + 1)	-1.24	-26.35	-0.792	-17.19	-0.68	-9.48	-0.76	-17.71	-0.68	-17.04	-0.67	-12.71	-0.84	-12.52
Distance Interactions														
Low Income < 30K														
Medium Income 30K-60K							-0.007	-1.57	0.037	6.10				
High Income 60K-100K							-0.011	-2.55						
Part Time Status			0.026	2.46			0.021	3.35						
Full Time Status							0.045	10.77			-0.020	-1.70		
Student Status							-0.039	-3.19						
Children in HH	-0.116	-13.29			-0.05976	-4.40			-0.022	-4.40	-0.055	-5.69		
Joint Tour			0.036	4.45					0.012	2.13	0.030	3.32		
Child aged 0 to 5														
Child aged 6 to 12														
Model Statistics	**Value**		**Value**		**Value**		**Value**		**Value**		**Value**		**Value**	
Number of Tours	2600		3492		1381		3859		4328		1194		1002	
Log-Likelihood w 0 coeffs	-20647		-27731		-10967		-30645		-34370		-9482		-7957	
Final Log-Likelihood	-11581		-13946		-6378		-21831		-22262		-6441		-4775	

As was the case for mandatory tours, not all distance terms were negative for non-mandatory tour destination choice, but the sum of all distance terms still produced a utility that monotonically decreases as a function of distance (Figure 2). Social tours stand out from the other purposes in that the squared and cubed distance terms were insignificant and were therefore removed.

All purposes except for escort included both individual and joint tours (escort tours are not allowed to be joint in the ActivitySim framework). If the tour was joint, none of the person level variables crossed with distance were applied. For each of these purposes, a joint tour indicator was tested to determine how the presence of additional household members on the tour influenced the destination choice results. Only shopping and other discretionary tour purposes produced a statistically significant joint tour distance coefficient. Joint tours were less sensitive to distance compared to non-joint tours as denoted by the positive coefficient for both purposes.

Segmenting tours by household income group was also tested for all purposes, but only other maintenance and other discretionary tours had at least one statistically significant income segmentation term.

Full-time and part-time work status variables were only significant for shopping and other maintenance purposes. In both cases, the part-time and full-time coefficients were positive, indicating longer tours. Part-time workers are more likely to go on longer shopping tours due to their more flexible and available schedule compared to full-time workers and students who make up the majority of the non-part-time worker persons. Other maintenance purposes include non-fixed work locations, so part-time and full-time workers attending work-related activities would be expected to travel farther than those not working.

The presence of children in the household was a statistically significant variable for all purposes except for shopping and at work. Children in the household produces shorter tours for all purposes except for other maintenance where one would expect additional children related maintenance appointments with fixed locations like doctor and dentist visits.

At-work subtours did not have any person or household characteristics that were statistically significant, so only distance terms were kept.

Logsum terms varied greatly between the purposes with shopping producing the highest logsum coefficient of 0.75. This implies greater choice in where to perform a shopping tour compared to the lower logsum value of 0.38 for other maintenance tours. Considering the increased abundance of locations for shopping centers compared to typical maintenance facilities like hospitals, these differences in logsum parameters are expected.

Size terms were also estimated for each of the non-mandatory tour purposes. Size terms that were expected to be significant were included in the model, and if the results were statistically insignificant, those size terms were dropped from the final model estimation results. ALOGIT estimates size terms in their non-exponentiated form. Table 6 shows the exponentiated size terms that are applied in utility equations. These exponentiated coefficients are what will be set in the implementation of the new estimated models in the ActivitySim size term coefficients configuration file.

An exponentiated size term of one denotes the chosen base for each purpose. For example, shopping tours often take place at retails stores, so the size term applied to the retail employment category was chosen as the base for shopping tours. Not many other size terms were statistically significant for shopping tours because shopping tours take place almost entirely in retail centers. Those that were statistically significant were still estimated to be small in comparison to retail.

Other maintenance, other discretionary, and at work tours have a wide range of possible destinations and this is indicated in the variety and relatively similar values of the size terms across different employment categories. This contrasts with eat out tours which often occur primarily at leisure facilities.

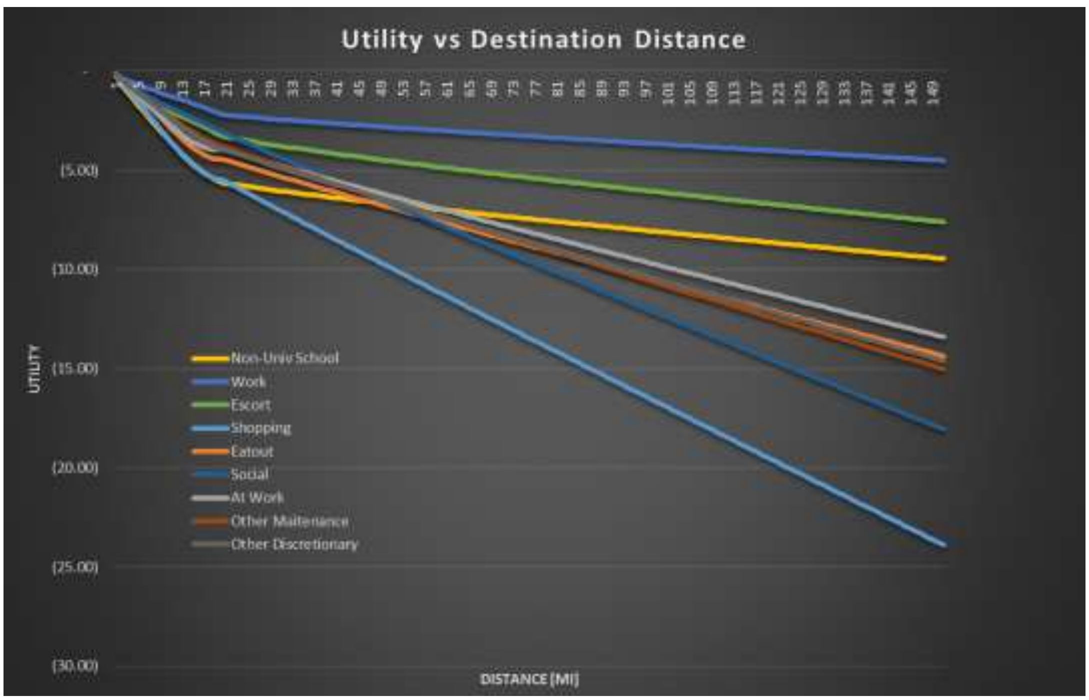
TABLE 6: ESTIMATED SIZE TERMS FOR NON-MANDATORY TOURS

Exponentiated Size Terms	Escort	Shopping	Eat Out	Other Maintenance	Other Discretionary	Social	At Work
e01_nrm							
e02_constr							
e03_manuf							
e04_whole				0.026			0.049
e05_retail	0.188	1.000	0.283	0.587	0.185		1.000
e06_trans							
e07_utility							
e08_infor							
e09_finan				0.268			0.141
e10_pstsvc							
e11_compmgt							
e12_admsvc				0.445			0.482
e13_edusvc				0.161	0.899	0.244	0.048
e14_medfac	0.164			1.000	0.511		0.092
e15_hospit	0.078			0.556	0.004	0.177	0.013
e16_leisure	0.791	0.005	1.000	0.336	1.081	1.000	
e17_othsvc		0.003		0.501	1.000		
e18_pubadm				0.478			0.053
Total Households	0.192		0.004	0.029	0.184	0.487	0.030
K_8_enrollment	1.000						
G9_12_enrollment	0.768						
Univ_enrollment							

4.3 DISCUSSION

Each purpose has a slightly different structure of utility as a function of distance, as shown by Figure 2: Estimated utility as a function of distance. Work tours have the least sensitivity to distance compared to all other tour purposes. This can be explained by the relative lack of workplace choices available to individuals compared to the other purposes. Escort tours are similarly not as sensitive to distance as other non-mandatory tours, likely due to a specific escort destination reducing the available alternatives. Conversely, long shopping tours are particularly discouraged, which is explained by the abundance of available shopping locations.

FIGURE 2: ESTIMATED UTILITY AS A FUNCTION OF DISTANCE



Non-university school location is an interesting case in that it has the highest sensitivity to distance below 20 miles, but then becomes surpassed at larger distances by some non-mandatory tours. Considering schools are strategically located throughout the SEMCOG region to produce short school tours, this high sensitivity at smaller distances is expected. On the other hand, if an individual is travelling longer than 20 miles to school, that individual is likely to have chosen a specific school to attend and is therefore a little less sensitive to distance. University destination choice location was not estimated due to the lack of reliable university tour data in the household travel survey.

The inflection point located around 20 miles for each purpose is primarily due to the distance squared and distance cubed terms being capped at 20 miles. Capping the polynomial distance terms ensured that they were not influenced by outlier tours at very long lengths and would produce a monotonically decreasing utility function with respect to distance. These non-linear distance terms were chosen over binned distance terms to better reproduce trip length frequency distributions while also not causing discontinuities in the utility function at arbitrary distance bins.

5.0 TOUR TIME-OF-DAY CHOICE MODEL ESTIMATION

This section describes the tour time-of-day choice estimation results output from Larch, the process by which model parameters were chosen, and some discussion on the estimated model parameters.

5.1 INTRODUCTION AND ESTIMATION PROCEDURE

Model estimation with Larch was performed using Jupyter notebooks derived from the ActivitySim estimation examples[7]. A new notebook was created for each model purpose. Estimation started with choosing the base departure, arrival, and duration alternative specific constants for each model purpose. Base alternative bins were chosen as the bin with the most survey tours and can be seen in Table 5-1. Bins are broken down into 48 half-hour time periods, with bin number 1 starting at 3:00 AM. For example, bin 9 represents 7:00 to 7:30 AM and a duration of 4 equals 2 to 2.5 hours. Coefficients corresponding to the base alternatives were fixed to zero. These departure, arrival, and duration reference bins were also what the shift calculations were in reference to in the corresponding sociodemographic related expressions.

TABLE 5-1: CHOSEN REFERENCE BINS FOR EACH PURPOSE

TOUR CATEGORY	TOUR PURPOSE	START PERIOD	END PERIOD	START TIME	END TIME	DURATION IN PERIODS
mandatory	school	9	27	7:00 AM - 7:30 AM	4:00 PM- 4:30 PM	16
	work	9	29	7:00 AM - 7:30 AM	5:00 PM - 5:30 PM	20
non mandatory	eatout	31	35	6:00 PM- 6:30 PM	8:00 PM - 8:30 PM	1
	escort	9	11	7:00 AM - 7:30 AM	8:00 AM - 8:30 AM	1
	othdiscr	11	35	8:00 AM -8:30 AM	8:00 PM - 8:30 PM	4
	othmaint	13	29	9:00 AM - 9:30 AM	5:00 PM - 5:30 PM	2
	shopping	15	23	10:00 AM - 10:30 AM	2:00 PM - 2:30 PM	2
	social	31	35	6:00 PM- 6:30 PM	8:00 PM - 8:30 PM	6

7 https://github.com/ActivitySim/activitysim/tree/master/activitysim/examples/example_estimation/notebooks

	eatout	31	35	6:00 PM- 6:30 PM	8:00 PM - 8:30 PM	2
	othdiscr	31	35	6:00 PM- 6:30 PM	8:00 PM - 8:30 PM	3
joint	othmaint	13	25	9:00 AM - 9:30 AM	3:00 PM - 3:30 PM	4
	shopping	15	35	10:00 AM - 10:30 AM	8:00 PM - 8:30 PM	2
	social	29	37	5:00 PM - 5:30 PM	9:00 PM - 9:30 PM	4

After setting the base coefficients, an initial model estimation was performed that included all variables listed in the specification. No additional terms were considered. If the estimated coefficients were not significant, they were fixed to zero and the model was re-estimated without them.

Special attention was paid to the mode choice logsum coefficient. In some cases, the estimated logsum coefficient was estimated to be slightly negative (which is inconsistent with the derivation of what a logsum represents[8]) or very close to zero. Based on the model purpose and the estimated value, some logsum coefficient were fixed at a specific value at the judgement of the modeling team.

The format of estimation results will include the estimated coefficient values, their estimated significance, and a flag on whether they were fixed during estimation or not. Short discussions on each individual model will follow and a global summary of results will be included at the end.

All coefficients listed in the model configuration files are included in the results tables so the reader can see what coefficients were tried and refer back to the model configuration to see the exact expression used for each coefficient. The exception to this rule is the calibration constants carried over from the previous model implementation. They would cause an overspecification of the alternative specific constants and were therefore fixed to zero at the start of estimation.

5.2 MANDATORY TOUR TIME-OF-DAY ESTIMATION RESULTS

Work

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_2nd_or_later_of_2_plus_mandatory_tour_Departure_after_2_pm	-0.134	-7.22	
coef_2nd_or_later_of_2_plus_mandatory_tour_Departure_before_1_pm	0.00	NA	fixed value
coef_2nd_or_later_of_2_plus_mandatory_tour_Duration_gt_dur_ref	0.527	42.74	
coef_2nd_or_later_of_2_plus_mandatory_tour_Duration_lt_dur_ref	0.458	24.45	
coef_Age_16_to_18_yrs_Departure_After_7_am	0.157	11.51	

[8] See *A Self Instructing Course in Mode Choice Modeling* by Koppelman and Bhat for more information

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_Age_16_to_18_yrs_Departure_Before_7_am	0.00	NA	fixed value
coef_Age_19_to_24_yrs_Arrival_after_6_pm	0.0380	2.53	
coef_Age_19_to_24_yrs_Departure_After_7_am	0.0328	2.83	
coef_Age_25_to_40_yrs_Arrival_before_5_pm	-0.0281	-2.71	
coef_Age_25_to_40_yrs_Departure_Before_7_am	-0.141	-7.27	
coef_Age_56_to_64_yrs_Arrival_after_6_pm	0.00	NA	fixed value
coef_Age_65_plus_yrs_Arrival_after_6_pm	0.00	NA	fixed value
coef_Age_65_plus_yrs_Arrival_before_5_pm	0.00	NA	fixed value
coef_Age_65_plus_yrs_Departure_After_7_am	0.00	NA	fixed value
coef_Arrival_Constant_03_PM_04_PM_26	-0.645	-8.71	
coef_Arrival_Constant_04_PM_04_PM_27	-0.305	-5.15	
coef_Arrival_Constant_04_PM_05_PM_28	-0.189	-3.77	
coef_Arrival_Constant_05_PM_05_PM_29	0.00	NA	fixed value
coef_Arrival_Constant_05_PM_06_PM_30	0.250	6.26	
coef_Arrival_Constant_06_PM_06_PM_31	0.240	5.89	
coef_Arrival_Constant_06_PM_7_PM_32	0.155	3.51	
coef_Arrival_Constant_7_PM_7_PM_33	0.00	NA	fixed value
coef_Arrival_Constant_7_PM_8_PM_34	-0.182	-2.99	
coef_Arrival_Constant_After_08_PM	0.00	NA	fixed value
coef_Arrival_Constant_Before_03_PM	-0.863	-11.15	
coef_Arrival_Constant_Shift_for_every_30_minutes_after_830_pm_Square_root	0.00	NA	fixed value
coef_Arrival_Constant_Shift_for_every_30_minutes_before_3_pm	-0.200	-11.01	
coef_Calibration_constant_Duration_0	-1.21	-6.10	
coef_Departure_Constant_06_AM_06_AM_7	-0.542	-7.88	
coef_Departure_Constant_06_AM_07_AM_8	-0.0815	-1.69	
coef_Departure_Constant_07_AM_07_AM_9	0.00	NA	fixed value
coef_Departure_Constant_07_AM_08_AM_10	-0.125	-3.02	
coef_Departure_Constant_08_AM_08_AM_11	-0.449	-9.63	
coef_Departure_Constant_08_AM_09_AM_12	-0.984	-17.42	
coef_Departure_Constant_After_09_AM	-1.56	-27.25	
coef_Departure_Constant_Before_06_AM	-0.192	-2.38	
coef_Departure_Constant_Shift_for_every_30_minutes_after_9_am_Square_Root	-0.578	-17.59	
coef_Departure_Constant_Shift_for_every_30_minutes_before_6_am	-0.723	-17.92	
coef_Duration_Constant_10_hours	0.00	NA	fixed value
coef_Duration_Constant_10p5_hours	-0.309	-7.30	
coef_Duration_Constant_11_hours	-0.658	-13.52	
coef_Duration_Constant_11p5_hours	-0.873	-16.00	
coef_Duration_Constant_12_hours	-1.36	-20.72	
coef_Duration_Constant_8p5_hours	-0.240	-4.32	
coef_Duration_Constant_9_hours	0.00	NA	fixed value
coef_Duration_Constant_9p5_hours	0.00	NA	fixed value
coef_Duration_Constant_Longer_than_12_hrs	-1.10	-17.15	
coef_Duration_Constant_Shift_for_every_30_minutes_less_than_8p5_hrs	-0.107	-9.20	
coef_Duration_Constant_Shift_for_every_30_minutes_more_than_12_hrs	-0.492	-30.74	
coef_Duration_Constant_Shorter_than_8p5_hrs	0.00	NA	fixed value
coef_Female_Arrival_after_6_pm	-0.0289	-4.70	
coef_Female_Departure_before_7_am	-0.220	-11.72	
coef_Female_with_preschool_child_Arrival_after_6_pm	0.00	NA	fixed value
coef_Female_with_preschool_child_Departure_after_7_am	0.00	NA	fixed value
coef_Female_with_preschool_child_Departure_before_7_am	0.00	NA	fixed value

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_First_of_2_plus_mandatory_tour_Departure_after_7_am	-0.0373	-3.14	
coef_First_of_2_plus_mandatory_tour_Departure_before_7_am	-0.156	-3.48	
coef_First_of_2_plus_mandatory_tour_Duration_gt_dur_ref	0.158	10.68	
coef_First_of_2_plus_mandatory_tour_Duration_lt_dur_ref	0.305	25.02	
coef_Low_income_lt_25000_Arrival_after_6_pm	-0.210	-4.43	
coef_Low_income_lt_25000_Departure_after_7_am	0.0639	7.39	
coef_Low_income_lt_25000_Departure_before_7_am	0.231	6.42	
coef_Med_income_25k_to_60k_Arrival_after_6_pm	0.0308	4.22	
coef_Med_income_25k_to_60k_Departure_before_7_am	0.206	8.12	
coef_Medhigh_income_60k_to_120k_Departure_before_7_am	0.123	5.91	
coef_Mode_Choice_Logsum	0.200	NA	fixed value
coef_Parttime_worker_Arrival_after_6_pm	-0.253	-14.28	
coef_Parttime_worker_Arrival_before_5_pm	0.273	20.84	
coef_Parttime_worker_Departure_after_7_am	0.240	23.01	
coef_Parttime_worker_Departure_before_7_am	-0.465	-7.99	
coef_Presence_of_NonWorking_Adult_in_the_HH_Arrival_before_5_pm	0.00	NA	fixed value
coef_Presence_of_NonWorking_Adult_in_the_HH_Departure_before_7_am	0.00	NA	fixed value
coef_Presence_of_PreDriving_Age_Children_in_the_HH_Arrival_after_6_pm	-0.0429	-5.29	
coef_Presence_of_PreDriving_Age_Children_in_the_HH_Arrival_before_5_pm	0.00	NA	fixed value
coef_Presence_of_PreDriving_Age_Children_in_the_HH_Departure_after_8_am	0.00	NA	fixed value
coef_Presence_of_PreDriving_Age_Children_in_the_HH_Departure_before_7_am	-0.0829	-3.92	
coef_Time_SOV_freeflowto_destination_Arrival_after_6_pm	0.00164	11.58	
coef_Time_SOV_freeflowto_destination_Arrival_before_5_pm	-0.00392	-16.30	
coef_Time_SOV_freeflowto_destination_Departure_after_7_am	-0.00264	-16.93	
coef_Time_SOV_freeflowto_destination_Departure_before_7_am	0.00615	20.09	
coef_University_student_Arrival_after_6_pm	-0.0784	-3.08	
coef_University_student_Arrival_before_5_pm	0.00	NA	fixed value
coef_University_student_Departure_after_7_am	0.107	6.22	
coef_Zero_auto_HH_Arrival_after_6_pm	0.0548	2.79	
coef_Zero_auto_HH_Departure_before_7_am	0.00	NA	fixed value
zero_coef	0.00	NA	fixed value

STATISTIC	AGGREGATE	PER CASE
Number of Cases	8,683	
Log Likelihood at Convergence	-46,766.31	-5.3860
Log Likelihood at Null Parameters	-61,410.29	-7.0725
Rho Squared w.r.t. Null Parameters	0.2385	

The total number of work tours that were included in estimation was 8,683. With more statistics than other purposes, more demographic information could be teased out of the data with significant coefficients compared to other purposes.

Observations from the work time of day estimation include:

- If the work tour is the second or later of two or more mandatory tours for that person, the constants shift the tour away from the reference departure and duration bin.
- If a work tour is the first of two or more mandatory tours, the constants shift the tour towards the reference departure bin.
- High schoolers start work tours after 7am, which is expected as they have school in the morning
- Those aged between 19 and 24 start later and arrive home later
- Those aged between 25 and 40 are less likely to start early and arrive home late, likely due to the presence of children in the household.
- Workers over the age of 65 do not have significant coefficients as they can likely work when they want to and the sample size for those individuals is likely small.
- Low-income workers arrive home earlier and are less likely to start at the reference departure bin.
- Medium income workers start earlier and arrive later than the reference bins.
- The presence of non-working adults in the household was insignificant
- The presence of pre-driving aged children was mostly insignificant except for a decreased likelihood to start early or arrive home late.
- University Students are unlikely to start early and are more likely to work late.
- Zero auto household are more likely to arrive late which could be explained through increased tour lengths from using public transit.
- Work tours that had long distances to and from work started earlier and arrived home later.
- The mode choice logsum coefficient was estimated very close to zero and was instead fixed to 0.2.

School

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_Age_0_to_5_yrs_Departure_Before_730_am	-0.815	-5.66	
coef_Age_0_to_5_yrs_Duration_gt_8hrs	0.242	9.29	
coef_Age_0_to_5_yrs_Duration_lt_8hrs	0.174	12.94	
coef_Age_13_to_15_yrs_Departure_After_800_am	-0.760	-13.53	
coef_Age_13_to_15_yrs_Departure_Before_730_am	0.277	4.18	
coef_Age_13_to_15_yrs_Duration_gt_8hrs	0.596	12.54	
coef_Age_13_to_15_yrs_Duration_lt_8hrs	0.00	NA	fixed value
coef_Age_16_to_17_yrs_Departure_After_800_am	-0.882	-12.60	
coef_Age_16_to_17_yrs_Duration_gt_8hrs	0.696	13.36	
coef_All_adults_in_the_household_are_fulltime_workers_Departure_after_800_am_Linear	-0.147	-5.32	
coef_All_adults_in_the_household_are_fulltime_workers_Departure_before_730_am__Linear	0.00	NA	fixed value

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_All_adults_in_the_household_are_fulltime_workers_arrival_after_ref	0.00	NA	fixed value
coef_All_adults_in_the_household_are_fulltime_workers_arrival_before_ref	-0.166	-9.53	
coef_Arrival_Constant_0230_PM_0300_PM_24_	0.00	NA	fixed value
coef_Arrival_Constant_0300_PM_0330_PM_25_	0.227	4.32	
coef_Arrival_Constant_0330_PM_0400_PM_26_	0.00	NA	fixed value
coef_Arrival_Constant_0400_PM_0430_PM_27_	0.00	NA	fixed value
coef_Arrival_Constant_0430_PM_0500_PM_28_	-1.02	-13.54	
coef_Arrival_Constant_0500_PM_0530_PM_29	-1.44	-15.42	
coef_Arrival_Constant_0530_PM_0600_PM_30_	-1.85	-16.32	
coef_Arrival_Constant_After_0600_PM	-2.33	-18.49	
coef_Arrival_Constant_Before_0230_PM	0.00	NA	fixed value
coef_Arrival_Constant_Shift_for_every_30_minutes_after_630_pm_Linear	-0.685	-16.24	
coef_Departure_Constant_0600_AM_to_0630_AM_7	-2.71	-18.75	
coef_Departure_Constant_0630_AM_to_0700_AM_8	-0.654	-9.14	
coef_Departure_Constant_0700_AM_to_0730_AM_9	0.00	NA	fixed value
coef_Departure_Constant_0730_AM_to_0800_AM_10	-0.483	-8.29	
coef_Departure_Constant_After_0800_AM	1.03	13.12	
coef_Departure_Constant_Before_0600_AM	-8.76	-15.24	
coef_Departure_Constant_Shift_for_every_30_minutes_after_830_am_Linear	0.00	NA	fixed value
coef_Departure_Constant_Shift_for_every_30_minutes_after_830_am_Square_Root	-0.498	-8.32	
coef_Duration_Constant_7_hours	-1.87	-19.24	
coef_Duration_Constant_7p5_hours	-0.382	-6.80	
coef_Duration_Constant_8_hours	0.00	NA	fixed value
coef_Duration_Constant_8p5_hours	-0.274	-4.64	
coef_Duration_Constant_9_hours	-0.818	-9.75	
coef_Duration_Constant_Longer_than_9_hrs	-0.542	-5.69	
coef_Duration_Constant_Shift_for_every_30_minutes_less_than_6p5_hrs_Linear	-0.198	-8.85	
coef_Duration_Constant_Shift_for_every_30_minutes_more_than_9p5_hrs_Linear	0.215	6.40	
coef_Duration_Constant_Shift_for_every_30_minutes_more_than_9p5_hrs_Squared	0.00	NA	fixed value
coef_Duration_Constant_Shorter_than_7_hrs	-3.03	-26.57	
coef_Low_income_lt25000_Departure_after_800_am_Linear	0.00	NA	fixed value
coef_Low_income_lt25000_Departure_before_730_am__Linear	0.00	NA	fixed value
coef_Low_income_lt25000_Duration_gt_8hrs	0.00	NA	fixed value
coef_Low_income_lt25000_Duration_lt_8hrs	0.00	NA	fixed value
coef_Med_income_25k_to_60k_Departure_before_730_am__Linear	0.00	NA	fixed value
coef_Mode_Choice_Logsum	0.00	NA	fixed value
coef_Second_tour_of_two_mandatory_tours_Duration_gt_4_hours	0.00	NA	fixed value
coef_Second_tour_of_two_mandatory_tours_Duration_lt_4_hours	0.00	NA	fixed value
coef_Subsequent_tour_is_school_tour_Departure_after_800_am	0.00	NA	fixed value
coef_Subsequent_tour_is_school_tour_Duration_gt_8_hours	0.00	NA	fixed value
coef_Subsequent_tour_is_school_tour_Duration_lt_8_hours	0.00	NA	fixed value
coef_Subsequent_tour_is_work_tour_Duration_gt_8_hours	0.00	NA	fixed value
coef_Subsequent_tour_is_work_tour_Duration_lt_8_hours	0.00	NA	fixed value
coef_Time_SOV_freeflow_to_destination_Departure_after_800_am_Linear	-0.00851	-7.14	
coef_Time_SOV_freeflow_to_destination_Departure_before_730_am__Linear	0.00454	2.49	
coef_Time_SOV_freeflow_to_destination_arrival_after_ref	0.00214	3.08	
coef_Time_SOV_freeflow_to_destination_arrival_before_ref	-0.00261	-3.92	
zero_coef	0.00	NA	fixed value

STATISTIC	AGGREGATE	PER CASE
Number of Cases	3,596	
Log Likelihood at Convergence	-15,193.61	-4.2251
Log Likelihood at Null Parameters	-25,423.27	-7.0699

Rho Squared w.r.t. Null Parameters	0.4024

School tours include all school ages up through high school -- university students have their own purpose and time-of-day model. The roughly 3,600 school tours included in estimation is less than half the number of work tours estimated, but still has many more tours than some of the non-mandatory purposes.

Observations from the school time-of-day choice estimation include:

- Preschool children are unlikely to start early and have coefficients that shift away from the reference duration period
- Middle and high school children aged 13 to 17 are likely to start school early and have long school tours, probably due to after school activities.
- Students in households where all the adults are full time workers are likely to leave for school earlier than their counterparts and can be explained by the time constraints of their parents' schedules.
- Income coefficients were not significant.
- Non-linear terms were needed to explain late departures.
- School tours start earlier and arrive later if the distance to school is farther.
- Coefficients that relate to other mandatory tours were insignificant.
- Not all arrival alternative specific constants were significant
- The mode choice logsum was estimated to be negative, and as such needed to be fixed. A value of 0 was chosen with the rationale that school starts at the same time regardless of congestion or mode accessibility.

5.3 NON-MANDATORY TOUR TIME-OF-DAY RESULTS

Non-mandatory tour time-of-day estimation in general has fewer tours to estimate from compared to work and school. The non-mandatory specifications also have fewer demographic terms and even less that are significant compared to mandatory tours. Thus, most of the model prediction comes from the departure, arrival, and duration alternative specific constants. All non-mandatory tours are individual – joint tours were estimated separately and are discussed in the following section.

Eatout

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_eatout_arrival_constant_12_30_pm_to_1_pm	0.00	NA	fixed value
coef_eatout_arrival_constant_1_30_pm_to_2_pm	0.615	3.34	

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_eatout_arrival_constant_1_pm_to_1_30_pm	0.00	NA	fixed value
coef_eatout_arrival_constant_2_30_pm_to_3_pm	0.00	NA	fixed value
coef_eatout_arrival_constant_2_pm_to_2_30_pm	0.00	NA	fixed value
coef_eatout_arrival_constant_6_30_pm_to_7_pm	1.41	6.60	
coef_eatout_arrival_constant_7_30_pm_to_8_pm	0.807	4.31	
coef_eatout_arrival_constant_7_pm_to_7_30_pm	0.581	2.56	
coef_eatout_arrival_constant_8_30_pm_to_9_pm	0.00	NA	fixed value
coef_eatout_arrival_constant_8_pm_to_8_30_pm	0.00	NA	fixed value
coef_eatout_arrival_constant_9_30_am_to_11_am	0.548	3.11	
coef_eatout_arrival_constant_after_9_pm	-0.456	-2.56	
coef_eatout_arrival_constant_before_6_30_pm	0.311	10.95	
coef_eatout_arrival_constant_shift_for_every_30_minutes_after_9_30_pm_linear	-0.554	-12.31	
coef_eatout_arrival_constant_shift_for_every_30_minutes_before_6_pm_linear	1.11	6.09	
coef_eatout_departure_constant_10_30_am_to_11_am	0.900	4.45	
coef_eatout_departure_constant_11_30_am_to_12_pm	1.06	5.86	
coef_eatout_departure_constant_11_am_to_11_30_am	1.05	5.63	
coef_eatout_departure_constant_12_30_pm_to_1_pm	0.551	2.61	
coef_eatout_departure_constant_12_pm_to_12_30_pm	0.00	NA	fixed value
coef_eatout_departure_constant_1_pm_to_1_30_pm	0.00	NA	fixed value
coef_eatout_departure_constant_6_30_pm_to_7_pm	2.02	8.47	
coef_eatout_departure_constant_6_pm_to_6_30_pm	0.00	NA	fixed value
coef_eatout_departure_constant_7_30_am_to_9_am	0.569	3.27	
coef_eatout_departure_constant_7_pm_to_7_30_pm	2.15	8.59	
coef_eatout_departure_constant_after_7_30_pm	2.36	10.53	
coef_eatout_departure_constant_before_6_pm	1.21	5.45	
coef_eatout_departure_constant_shift_for_every_30_minutes_after_8_pm_linear	0.00	NA	fixed value
coef_eatout_departure_constant_shift_for_every_30_minutes_before_5_30_pm_linear	-0.773	-8.20	
coef_eatout_distance_to_destination_duration_greater_than_ref	0.00688	7.92	
coef_eatout_distance_to_destination_duration_less_than_ref	-0.222	-7.76	
coef_eatout_duration_constant_0_hour	7.71	3.88	
coef_eatout_duration_constant_1_hour	0.00	NA	fixed value
coef_eatout_duration_constant_1_hour_30_minutes	1.20	6.60	
coef_eatout_duration_constant_2_hour_30_minutes_or_more	1.46	7.75	
coef_eatout_duration_constant_2_hours	1.33	7.04	
coef_eatout_duration_constant_30_minutes	5.24	5.15	
coef_eatout_duration_constant_shift_for_every_30_minutes_more_than_3_hrs_linear	0.00	NA	fixed value
coef_eatout_female_duration_greater_than_ref	0.0759	3.30	
coef_eatout_female_duration_less_than_ref	0.00	NA	fixed value
coef_eatout_low_income_duration_less_than_ref	0.00	NA	fixed value
coef_eatout_medium_income_duration_less_than_ref	0.00	NA	fixed value
coef_eatout_time_pressure_departure_before_6_30_pm	0.122	4.16	
coef_eatout_time_pressure_duration_less_than_ref	-1.10	-3.23	
coef_eatout_university_student_departure_after_7_pm_linear	0.00	NA	fixed value
coef_eatout_zeroauto_HH_duration_greater_than_ref	0.00	NA	fixed value
coef_mode_choice_logsum	0.200	NA	fixed value

STATISTIC	AGGREGATE	PER CASE
Number of Cases	863	
Log Likelihood at Convergence	-5,137.94	-5.9536
Log Likelihood at Null Parameters	-6,101.30	-7.0699
Rho Squared w.r.t. Null Parameters	0.1579	

Eatout tours often occur during many different time periods with three main peaks corresponding to breakfast, lunch, and dinner. For this reason, there are more departure and arrival constants compared to other models, but not all of them were significant. However, there are shift variables that cover large periods of the day that influence the bin-specific constants. For example, the linear arrival constant shift for every 30 minutes before 6 PM impacts early dinner tours, but also breakfast and lunch tours as well.

Observations from eatout time-of-day estimation include:

- Females are more likely to have longer eatout tours.
- Income coefficients are insignificant
- If the distance to the eatout location is farther away, the tour duration is longer
- Time pressure (the amount of time remaining after scheduling higher-priority activities) variables were significant for early departure and shorter duration
- Mode choice logsum was estimated very close to zero, so a fixed value of 0.2 was chosen.

Escort

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_escort_arrival_constant_2_30_pm_to_3_pm	0.882	4.66	
coef_escort_arrival_constant_3_30_pm_to_4_pm	1.51	7.50	
coef_escort_arrival_constant_3_pm_to_3_30_pm	1.38	7.30	
coef_escort_arrival_constant_4_pm_to_4_30_pm	1.69	7.85	
coef_escort_arrival_constant_7_30_am_to_8_am	2.94	21.69	
coef_escort_arrival_constant_7_am_to_7_30_am	4.18	19.69	
coef_escort_arrival_constant_8_30_am_to_9_am	0.00	NA	fixed value
coef_escort_arrival_constant_8_am_to_8_30_am	0.00	NA	fixed value
coef_escort_arrival_constant_after_4_30_pm	1.27	5.49	
coef_escort_arrival_constant_after_9_am	-0.852	-7.09	
coef_escort_arrival_constant_before_7_am	4.01	14.64	
coef_escort_arrival_constant_shift_for_every_30_minutes_after_5_pm_linear	-0.180	-8.50	
coef_escort_arrival_constant_shift_for_every_30_minutes_after_9_30_am_linear	-0.279	-10.04	
coef_escort_arrival_constant_shift_for_every_30_minutes_before_6_30_am_linear	0.00	NA	fixed value
coef_escort_departure_constant_1_30_pm_to_2_pm	0.00	NA	fixed value
coef_escort_departure_constant_2_30_pm_to_3_pm	1.08	7.25	
coef_escort_departure_constant_2_pm_to_2_30_pm	0.794	5.32	
coef_escort_departure_constant_3_pm_to_3_30_pm	1.33	8.47	
coef_escort_departure_constant_7_30_am_to_8_am	4.12	35.68	
coef_escort_departure_constant_7_am_to_7_30_am	0.00	NA	fixed value
coef_escort_departure_constant_8_30_am_to_9_am	5.12	34.71	
coef_escort_departure_constant_8_am_to_8_30_am	4.84	41.14	
coef_escort_departure_constant_after_3_30_pm	1.19	6.75	
coef_escort_departure_constant_after_9_am	4.28	26.22	
coef_escort_departure_constant_before_7_am	0.732	3.59	
coef_escort_departure_constant_shift_for_every_30_minutes_after_4_pm_linear	0.00	NA	fixed value
coef_escort_departure_constant_shift_for_every_30_minutes_after_9_30_am_linear	0.196	7.97	
coef_escort_departure_constant_shift_for_every_30_minutes_before_6_30_am_linear	-1.24	-12.74	
coef_escort_distance_to_destination_duration_greater_than_30_minutes	0.00857	14.01	

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_escort_distance_to_destination_duration_less_than_30_minutes	-0.473	-12.49	
coef_escort_driving_age_school_child_in_hh_with_mandatory_tour_arrival_after_3_30_pm	0.00	NA	fixed value
coef_escort_driving_age_school_child_in_hh_with_mandatory_tour_arrival_after_8_30_am	0.00	NA	fixed value
coef_escort_driving_age_school_child_in_hh_with_mandatory_tour_departure_after_8_am	0.00	NA	fixed value
coef_escort_driving_age_student_duration_greater_than_30_minutes	0.290	5.02	
coef_escort_driving_age_student_duration_less_than_30_minutes	0.00	NA	fixed value
coef_escort_duration_constant_0_hour	-0.294	-2.56	
coef_escort_duration_constant_1_hour	0.00	NA	fixed value
coef_escort_duration_constant_1_hour_30_minutes	-0.717	-8.49	
coef_escort_duration_constant_2_hours	-1.17	-9.52	
coef_escort_duration_constant_30_minutes	0.00	NA	fixed value
coef_escort_duration_constant_longer_than_2_hours	-1.17	-8.96	
coef_escort_fulltime_worker_departure_after_3_pm_linear	0.103	8.70	
coef_escort_fulltime_worker_departure_after_8_am_linear	0.00	NA	fixed value
coef_escort_fulltime_worker_duration_greater_than_30_minutes	0.0636	3.32	
coef_escort_fulltime_worker_duration_less_than_30_minutes	0.487	3.55	
coef_escort_households_with_no_kids_arrival_after_3_30_pm	0.00	NA	fixed value
coef_escort_households_with_no_kids_arrival_after_8_30_am	0.00	NA	fixed value
coef_escort_households_with_no_kids_arrival_before_3_pm	0.00	NA	fixed value
coef_escort_households_with_no_kids_arrival_before_8_am	0.00	NA	fixed value
coef_escort_households_with_no_kids_departure_after_3_00_pm	0.00	NA	fixed value
coef_escort_households_with_no_kids_departure_after_8_00_am	0.00	NA	fixed value
coef_escort_households_with_no_kids_departure_before_2_30_pm	0.00	NA	fixed value
coef_escort_households_with_no_kids_departure_before_7_30_am	0.00	NA	fixed value
coef_escort_med_high_income_duration_greater_than_30_minutes	0.00	NA	fixed value
coef_escort_mode_choice_logsum	0.200	NA	fixed value
coef_escort_non_driving_age_student_duration_greater_than_30_minutes	0.136	7.32	
coef_escort_number_of_autos_greater_than_number_of_adults_duration_greater_than_30_minutes	0.00	NA	fixed value
coef_escort_number_of_individual_tours_duration_greater_than_30_minutes	-0.0620	-5.89	
coef_escort_number_of_joint_tours_duration_greater_than_30_minutes	0.00	NA	fixed value
coef_escort_pre_school_child_in_hh_with_mandatory_tour_arrival_before_3_pm	0.284	10.48	
coef_escort_pre_school_child_in_hh_with_mandatory_tour_arrival_before_8_am	-1.84	-9.65	
coef_escort_pre_school_child_in_hh_with_mandatory_tour_departure_after_3_pm	-0.337	-8.29	
coef_escort_pre_school_child_in_hh_with_mandatory_tour_departure_after_8_am	0.219	8.14	
coef_escort_pre_school_kid_duration_greater_than_30_minutes	0.00	NA	fixed value
coef_escort_university_student_duration_less_than_30_minutes	0.00	NA	fixed value

STATISTIC	AGGREGATE	PER CASE
Number of Cases	2,630	
Log Likelihood at Convergence	-13,405.87	-5.0973
Log Likelihood at Null Parameters	-18,784.95	-7.1426
Rho Squared w.r.t. Null Parameters	0.2864	

Like eat out tours, escort tours can occur at multiple times throughout the day, typically focused around dropping people off or picking people up from work or school. There are shift variables in the escort specification that also cover large periods of the day like what was seen in eat out tours. A good example is the linear arrival constant shift for every 30 mins after 9:30 AM which has a strong effect on the evening escort tours. These shift expressions interact strongly with the bin specific alternative specific constants, so looking at any one value can be misleading when trying to understand the utility impact.

Observations from escort estimation include:

- Coefficients for driving age students with a mandatory tour were insignificant but driving age students do tend to take longer escort tours.
- Full time workers making escort tours are less likely to take tours between 30 mins and an hour – either the tour is short or long – and are more likely to arrive later than 3 PM.
- Coefficients related to escort tours in households without any children were all insignificant
- If a person has an escort tour in a household with pre-school aged children and they also have a mandatory tour, the escort tour is likely to take place after 8 AM and before 3 PM.
- The mode choice logsum was estimated to be significantly negative, so it was fixed to a value of 0.2 to ensure some sensitivity to congestion.

Shopping

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_mode_choice_logsum	0.200	NA	fixed value
coef_shopping_arrival_constant_12_30_pm_to_3_pm	0.00	NA	fixed value
coef_shopping_arrival_constant_3_30_pm_to_4_pm	-1.37	-12.48	
coef_shopping_arrival_constant_3_pm_to_3_30_pm	-0.970	-9.23	
coef_shopping_arrival_constant_4_30_pm_to_5_pm	-2.52	-18.45	
coef_shopping_arrival_constant_4_pm_to_4_30_pm	-1.87	-15.58	
coef_shopping_arrival_constant_5_30_pm_to_7_pm	-4.39	-27.55	
coef_shopping_arrival_constant_5_pm_to_5_30_pm	-2.95	-20.26	
coef_shopping_arrival_constant_7_pm_to_9_30_pm	-6.57	-29.91	
coef_shopping_arrival_constant_after_9_30_pm	-9.11	-30.28	
coef_shopping_arrival_constant_before_12_30_pm	2.18	26.72	
coef_shopping_arrival_constant_shift_for_every_30_minutes_after_10_pm_linear	-0.823	-14.27	
coef_shopping_arrival_constant_shift_for_every_30_minutes_before_12_pm_linear	0.412	17.76	
coef_shopping_departure_constant_10_30_am_to_11_00_am	1.47	13.98	
coef_shopping_departure_constant_10_am_to_10_30_am	0.00	NA	fixed value
coef_shopping_departure_constant_9_30_am_to_10_am	0.496	4.72	
coef_shopping_departure_constant_9_am_to_9_30_am	0.00	NA	fixed value
coef_shopping_departure_constant_after_11_am	2.17	28.17	
coef_shopping_departure_constant_before_9_am	-0.835	-6.49	
coef_shopping_departure_constant_shift_for_every_30_minutes_after_11_30_am_linear	0.440	28.12	
coef_shopping_departure_constant_shift_for_every_30_minutes_after_11_30_am_squared	-0.00221	-4.57	
coef_shopping_departure_constant_shift_for_every_30_minutes_before_8_30_am_linear	-1.27	-11.75	
coef_shopping_departure_constant_shift_for_every_30_minutes_before_8_30_am_square_root	0.586	2.69	
coef_shopping_distance_duration_greater_than_reference	0.0110	14.03	
coef_shopping_distance_duration_less_than_reference	-0.268	-15.12	
coef_shopping_duration_constant_0_hr	0.00	NA	fixed value
coef_shopping_duration_constant_1_hour_30_minutes	0.00	NA	fixed value
coef_shopping_duration_constant_1_hr	0.00	NA	fixed value
coef_shopping_duration_constant_2_hrs	-0.467	-4.07	

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_shopping_duration_constant_30_minutes	1.19	16.32	
coef_shopping_duration_constant_duration_greater_than_2_hr_30_minutes_linear	-0.428	-6.55	
coef_shopping_duration_constant_duration_greater_than_2_hr_30_minutes_square_root	0.00	NA	fixed value
coef_shopping_duration_constant_longer_than_2_hrs	-1.11	-6.73	
coef_shopping_female_duration_greater_than_reference	0.0612	4.08	
coef_shopping_female_duration_less_than_reference	-0.710	-9.05	
coef_shopping_low_income_duration_greater_than_reference	0.0785	5.48	
coef_shopping_medium_high_income_duration_greater_than_reference	0.00	NA	fixed value
coef_shopping_medium_income_duration_less_than_reference	0.00	NA	fixed value
coef_shopping_number_of_additional_individual_shop_and_maint_tours_duration_greater_than_reference	-0.0734	-3.37	
coef_shopping_number_of_additional_individual_shop_and_maint_tours_duration_less_than_reference	0.00	NA	fixed value
coef_shopping_part_time_worker_duration_greater_than_reference	0.00	NA	fixed value
coef_shopping_retired_duration_greater_than_reference	0.00	NA	fixed value
coef_shopping_retired_duration_less_than_reference	-0.266	-3.03	
coef_shopping_time_pressure_duration_greater_than_reference	0.185	9.11	
coef_shopping_university_student_duration_greater_than_reference	0.00	NA	fixed value
coef_shoppping_driving_age_student_duration_greater_than_reference	0.00	NA	fixed value
coef_shoppping_full_time_worker_duration_greater_than_reference	0.0517	2.90	
coef_shoppping_non_driving_student_duration_greater_than_reference	0.00	NA	fixed value
coef_shoppping_part_time_worker_duration_less_than_reference	0.00	NA	fixed value
coef_shoppping_pre_school_child_duration_less_than_reference	0.00	NA	fixed value

STATISTIC	AGGREGATE	PER CASE
Number of Cases	2,747	
Log Likelihood at Convergence	-15,166.30	-5.5210
Log Likelihood at Null Parameters	-19,450.03	-7.0805
Rho Squared w.r.t. Null Parameters	0.2202	

Observations from shopping estimation include:

- Linear and non-linear shift terms were significant for the departure constants
- If the distance to the shopping location was farther away, the shopping tour was longer
- Females are more likely to take longer shopping tours
- Only one income related variable was significant and it shows a slight preference towards longer shopping trips for low income households
- If there are other shopping and maintenance tours that happen that day, the shopping trip is not likely to last longer than the reference duration
- Part time workers do not have a significant coefficient. This could also be influenced by the fact that part time work status had to be imputed in the survey data.
- Full time workers are more likely to take longer shopping tours
- Retired people are less likely to take short shopping tours

- The mode choice logsum was estimated to be negative, so it was set to a fixed value of 0.2 to ensure some sensitivity to congestion.
- Coefficients relating to children and university students were insignificant.

Social

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_mode_choice_logsum	0.0143	0.24	
coef_social_arrival_constant_10_pm_to_10_30_pm	0.349	1.97	
coef_social_arrival_constant_3_30_pm_to_4_pm	0.00	NA	fixed value
coef_social_arrival_constant_3_pm_to_3_30_pm	0.613	3.68	
coef_social_arrival_constant_4_pm_to_4_30_pm	0.00	NA	fixed value
coef_social_arrival_constant_5_pm_to_6_pm	0.00	NA	fixed value
coef_social_arrival_constant_8_30_pm_to_9_pm	0.373	2.42	
coef_social_arrival_constant_9_30_pm_to_10_pm	0.00	NA	fixed value
coef_social_arrival_constant_9_pm_to_9_30_pm	0.341	2.12	
coef_social_arrival_constant_after_10_30_pm	0.00	NA	fixed value
coef_social_arrival_constant_before_8_30_pm	0.00	NA	fixed value
coef_social_arrival_constant_shift_for_every_30_minutes_after_11_pm_linear	-0.230	-3.56	
coef_social_arrival_constant_shift_for_every_30_minutes_before_8_pm_linear	-0.115	-4.00	
coef_social_auto_distance_duration_greater_than_reference_linear	0.00410	5.18	
coef_social_auto_distance_duration_less_than_reference_linear	-0.0372	-6.93	
coef_social_departure_constant_5_30_pm_to_6_pm	3.40	18.43	
coef_social_departure_constant_6_30_pm_to_7_pm	3.23	17.70	
coef_social_departure_constant_6_pm_to_6_30_pm	0.00	NA	fixed value
coef_social_departure_constant_7_pm_to_7_30_pm	2.96	14.80	
coef_social_departure_constant_9_am_to_9_30_am	0.483	2.92	
coef_social_departure_constant_after_7_30_pm	2.50	12.42	
coef_social_departure_constant_before_5_30_pm	2.92	19.08	
coef_social_departure_constant_before_9_am	0.00	NA	fixed value
coef_social_departure_constant_shift_for_every_30_minutes_after_8_pm_linear	-0.316	-4.26	
coef_social_departure_constant_shift_for_every_30_minutes_before_5_pm_linear	0.106	3.76	
coef_social_departure_constant_shift_for_every_30_minutes_before_8_30_am_linear	-0.350	-9.39	
coef_social_duration_constant_3_hours	0.00	NA	fixed value
coef_social_duration_constant_3_hrs_30_minutes	-0.988	-2.66	
coef_social_duration_constant_4_hours_or_more	-1.97	-2.86	
coef_social_duration_constant_less_than_3_hours	0.00	NA	fixed value
coef_social_duration_constant_shift_for_every_30_minutes_less_than_2_hr_30_minutes_linear	0.00	NA	fixed value
coef_social_duration_constant_shift_for_every_30_minutes_more_than_4_hr_30_minutes_linear	-1.08	-2.98	
coef_social_non_working_senior_or_retiree_duration_less_than_reference_linear	0.00	NA	fixed value
coef_social_number_of_additional_individual_social_and_dicretionary_tours_duration_less_than_reference	0.00	NA	fixed value
coef_social_number_of_auto_more_than_number_of_adults_duration_greater_than_reference_linear	0.00	NA	fixed value
coef_social_number_of_auto_more_than_number_of_adults_duration_less_than_reference_linear	0.00	NA	fixed value
coef_social_person_less_than_18_years_old_duration_greater_than_reference_linear	0.185	9.05	
coef_social_person_less_than_18_years_old_duration_less_than_reference_linear	0.00	NA	fixed value
coef_social_retiree_or_non_working_senior_only_HH_duration_less_than_reference_linear	0.00	NA	fixed value
coef_social_time_pressure_duration_greater_than_reference	0.247	2.15	
coef_social_time_pressure_duration_less_than_reference	0.00	NA	fixed value
coef_social_zero_auto_households_duration_greater_than_reference_linear	0.00	NA	fixed value
coef_social_zero_auto_households_duration_less_than_reference_linear	0.00	NA	fixed value

STATISTIC	AGGREGATE	PER CASE
Number of Cases	971	
Log Likelihood at Convergence	-6,087.33	-6.2691
Log Likelihood at Null Parameters	-6,864.85	-7.0699
Rho Squared w.r.t. Null Parameters	0.1133	

Observations from Social estimation include:

- All sociodemographic variables were insignificant except for children under the age of 18 taking longer social tours. This means almost the entirety of the explanatory power of the model is explained by the alternative specific constants
- Most linear shift constants were significant for departures, arrivals, and durations.
- The mode choice logsum was estimated to be very slightly positive.

Other Maintenance

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_maintenance_arrival_constant_10_30_am_to_11_am	0.00	NA	fixed value
coef_maintenance_arrival_constant_11_30_am_to_1_30_pm	0.00	NA	fixed value
coef_maintenance_arrival_constant_11_am_to_11_30_am	0.00	NA	fixed value
coef_maintenance_arrival_constant_1_30_pm_to_2_30_pm	0.00	NA	fixed value
coef_maintenance_arrival_constant_2_30_pm_to_4_pm	0.00	NA	fixed value
coef_maintenance_arrival_constant_4_pm_to_4_30_pm	0.00	NA	fixed value
coef_maintenance_arrival_constant_after_4_30_pm	0.00	NA	fixed value
coef_maintenance_arrival_constant_before_10_30_am	0.00	NA	fixed value
coef_maintenance_arrival_constant_shift_for_every_30_minutes_after_5_pm_linear	-0.311	-28.47	
coef_maintenance_arrival_constant_shift_for_every_30_minutes_before_10_am_linear	-0.232	-7.54	
coef_maintenance_departure_constant_10_30_am_to_11_am	-0.172	-1.97	
coef_maintenance_departure_constant_10_am_to_10_30_am	0.00	NA	fixed value
coef_maintenance_departure_constant_8_30_am_to_9_00_am	0.00	NA	fixed value
coef_maintenance_departure_constant_8_am_to_8_30_am	-0.149	-1.89	
coef_maintenance_departure_constant_9_30_am_to_10_am	0.00	NA	fixed value
coef_maintenance_departure_constant_9_am_to_9_30_am	0.00	NA	fixed value
coef_maintenance_departure_constant_after_11_am	-0.360	-6.16	
coef_maintenance_departure_constant_before_8_am	-0.560	-6.01	
coef_maintenance_departure_constant_shift_for_every_30_minutes_after_11_30_am_linear	0.0264	3.31	
coef_maintenance_departure_constant_shift_for_every_30_minutes_after_11_30_am_squared	-0.00171	-3.23	
coef_maintenance_departure_constant_shift_for_every_30_minutes_before_7_30_am_linear	-0.899	-12.72	
coef_maintenance_departure_constant_shift_for_every_30_minutes_before_7_30_am_square_root	0.952	6.06	
coef_maintenance_distance_duration_greater_than_reference	0.00429	16.02	
coef_maintenance_distance_duration_less_than_reference	-0.285	-13.75	
coef_maintenance_driving_age_student_duration_greater_than_reference	0.00	NA	fixed value
coef_maintenance_duration_constant_0_hr	5.99	30.27	
coef_maintenance_duration_constant_30_minutes	6.27	40.22	
coef_maintenance_duration_constant_duration_greater_than_1_hr_linear	-0.734	-7.77	
coef_maintenance_duration_constant_duration_greater_than_1_hr_square_root	-0.139	-2.56	

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_maintenance_duration_constant_longer_than_30_minutes	4.90	37.73	
coef_maintenance_female_duration_greater_than_reference	0.00	NA	fixed value
coef_maintenance_female_duration_less_than_reference	-0.336	-3.96	
coef_maintenance_full_time_worker_duration_greater_than_reference	0.135	15.95	
coef_maintenance_low_income_duration_greater_than_reference	0.0401	4.58	
coef_maintenance_medium_high_income_duration_greater_than_reference	0.00	NA	fixed value
coef_maintenance_medium_income_duration_greater_than_reference	0.00	NA	fixed value
coef_maintenance_medium_income_duration_less_than_reference	0.00	NA	fixed value
coef_maintenance_non_driving_student_duration_greater_than_reference	0.00	NA	fixed value
coef_maintenance_number_of_additional_individual_shop_and_maint_tours_duration_greater_than_reference	-0.0386	-2.81	
coef_maintenance_number_of_additional_individual_shop_and_maint_tours_duration_less_than_reference	0.00	NA	fixed value
coef_maintenance_part_time_worker_duration_greater_than_reference	0.00	NA	fixed value
coef_maintenance_part_time_worker_duration_less_than_reference	0.00	NA	fixed value
coef_maintenance_pre_school_child_duration_less_than_reference	-2.16	-2.19	
coef_maintenance_retired_duration_greater_than_reference	-0.0353	-3.34	
coef_maintenance_retired_duration_less_than_reference	0.00	NA	fixed value
coef_maintenance_time_pressure_duration_greater_than_reference	0.215	7.43	
coef_maintenance_university_student_duration_greater_than_reference	0.00	NA	fixed value
coef_mode_choice_logsum	0.239	4.12	

STATISTIC	AGGREGATE	PER CASE
Number of Cases	3,280	
Log Likelihood at Convergence	-19,055.56	-5.8096
Log Likelihood at Null Parameters	-23,189.19	-7.0699
Rho Squared w.r.t. Null Parameters	0.1783	

Other maintenance tours can include activities like a hospital visit, taking your car to the shop, a dentist appointment, etc. Because of the wide range of other maintenance activities, the time-of-day profiles for these tours span a large portion of the day.

Observations from other maintenance estimation include:

- Arrival alternative specific constants were not significant except for the linear shift terms before 10am and after 5pm
- Non-linear duration constants were needed to explain tours longer than an hour
- The only income related coefficient that was significant was that people from low-income households are expected to take longer maintenance tours. Shopping tours also only had one significant income variable for low-income households taking longer shopping tours.
- If there are other non-mandatory tours, the maintenance tour is unlikely to be longer than the reference period
- Retired people are less likely to take long maintenance tours

- The time pressure coefficient is significant for longer duration tours
- The mode choice logsum was estimated to a reasonable value of 0.24.

Other Discretionary

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_discretionary_arrival_constant_6_30_pm_to_7_pm	-6.43	-24.71	
coef_discretionary_arrival_constant_7_30_pm_to_8_pm	-2.11	-14.84	
coef_discretionary_arrival_constant_7_pm_to_7_30_pm	-4.14	-21.00	
coef_discretionary_arrival_constant_8_30_pm_to_9_pm	2.15	22.45	
coef_discretionary_arrival_constant_8_pm_to_8_30_pm	0.00	NA	fixed value
coef_discretionary_arrival_constant_after_9_pm	3.86	29.67	
coef_discretionary_arrival_constant_before_6_30_pm	-8.32	-26.51	
coef_discretionary_arrival_constant_shift_for_every_30_minutes_after_9_30_pm_linear	1.69	22.99	
coef_discretionary_arrival_constant_shift_for_every_30_minutes_before_6_pm_linear	-1.99	-28.99	
coef_discretionary_auto_distance_duration_greater_than_reference_linear	0.00460	12.01	
coef_discretionary_auto_distance_duration_less_than_reference_linear	-0.0361	-10.02	
coef_discretionary_departure_constant_10_am_to_10_30_am	0.00	NA	fixed value
coef_discretionary_departure_constant_5_30_pm_to_6_pm	7.07	41.89	
coef_discretionary_departure_constant_5_pm_to_5_30_pm	8.81	37.73	
coef_discretionary_departure_constant_6_30_pm_to_7_pm	2.83	28.35	
coef_discretionary_departure_constant_6_pm_to_6_30_pm	4.91	41.23	
coef_discretionary_departure_constant_7_30_am_to_8_am	0.00	NA	fixed value
coef_discretionary_departure_constant_8_30_am_to_9_am	0.00	NA	fixed value
coef_discretionary_departure_constant_8_am_to_8_30_am	0.00	NA	fixed value
coef_discretionary_departure_constant_9_30_am_to_10_am	0.141	1.53	
coef_discretionary_departure_constant_9_am_to_9_30_am	0.337	4.12	
coef_discretionary_departure_constant_after_7_pm	0.00	NA	fixed value
coef_discretionary_departure_constant_before_5_pm	10.1	34.48	
coef_discretionary_departure_constant_before_7_30_am	-0.339	-4.15	
coef_discretionary_departure_constant_shift_for_every_30_minutes_after_7_30_pm_linear	-2.41	-24.01	
coef_discretionary_departure_constant_shift_for_every_30_minutes_before_4_30_pm_linear	2.06	29.89	
coef_discretionary_departure_constant_shift_for_every_30_minutes_before_7_30_pm_linear	-0.610	-21.58	
coef_discretionary_duration_constant_0_hour	0.00	NA	fixed value
coef_discretionary_duration_constant_1_hour	0.00	NA	fixed value
coef_discretionary_duration_constant_1_hr_30_minutes	0.00	NA	fixed value
coef_discretionary_duration_constant_2_hours	0.00	NA	fixed value
coef_discretionary_duration_constant_2_hr_30_minutes	-2.99	-18.53	
coef_discretionary_duration_constant_30_minutes	0.00	NA	fixed value
coef_discretionary_duration_constant_3_hours_or_more	-6.04	-21.16	
coef_discretionary_duration_constant_shift_for_every_30_minutes_more_than_3_hrs_linear	-2.92	-19.66	
coef_discretionary_non_working_senior_retiree_duration_less_than_reference_linear	-0.171	-4.77	
coef_discretionary_number_of_additional_individual_social_and_dicretionary_tours_duration_less_reference	0.0810	2.21	
coef_discretionary_number_of_auto_more_than_number_of_adults_duration_greater_than_reference_linear	0.00	NA	fixed value
coef_discretionary_number_of_auto_more_than_number_of_adults_duration_less_than_reference_linear	0.00	NA	fixed value
coef_discretionary_person_less_than_18_years_old_duration_greater_than_reference_linear	0.00	NA	fixed value
coef_discretionary_person_less_than_18_years_old_duration_less_than_reference_linear	0.0984	2.78	
coef_discretionary_retiree_non_working_senior_only_HH_duration_reference_linear	0.00	NA	fixed value
coef_discretionary_time_pressure_duration_greater_reference	0.254	6.36	
coef_discretionary_time_pressure_duration_less_reference	0.673	28.63	
coef_discretionary_zero_auto_households_duration_greater_than_reference_linear	0.0522	2.98	
coef_discretionary_zero_auto_households_duration_less_than_reference_linear	0.00	NA	fixed value
coef_mode_choice_logsum	0.0634	1.61	

STATISTIC	AGGREGATE	PER CASE
Number of Cases	3,539	
Log Likelihood at Convergence	-20,802.77	-5.8781
Log Likelihood at Null Parameters	-25,020.28	-7.0699
Rho Squared w.r.t. Null Parameters	0.1686	

Like other maintenance, other discretionary tours can cover a wide range of possible activities and will have a spread-out time-of-day profile. In these two purposes, there are a good number of significant alternative specific shift variables to help cover the large range. For example, other discretionary tour estimation includes linear departure variables for before and after 7:30pm.

Other observations from the other discretionary estimation includes:

- If the distance to the tour location is farther away, the tour is likely to last longer
- Retired individuals are less likely to take discretionary tours less than the reference duration
- If the person needs to take other social and discretionary tours, the tour duration is more likely to be shorter.
- The coefficients that relate to the number of autos to adults in the household were not significant, but zero auto households were more likely to take longer duration tours.
- People younger than age 18 are more likely to take shorter discretionary tours
- The time pressure variables for duration both longer and shorter than the reference were significant
- The mode choice logsum was estimated to be a minor 0.06.

5.4 JOINT TOUR TIME-OF-DAY RESULTS

Joint tours were estimated separately from the rest of the non-mandatory purposes due to the model structure of ActivitySim having joint tours separated into its own specific model. (ActivitySim in estimation mode writes out a separate estimation data bundle for joint tours.) However, there are many different tour purposes that can be joint. All joint tours were estimated at the same time from the estimation data bundle, but the coefficients relate only to a specific joint tour purpose. For this reason, there are a lot of coefficients to describe joint tours.

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_disc_Arrival_Constant_6_30_PM_to_7_00_PM	9.78	25.16	
coef_disc_Arrival_Constant_7_00_PM_to_7_30_PM	7.35	25.70	

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_disc_Arrival_Constant_7_30_PM_to_8_00_PM	5.14	26.86	
coef_disc_Arrival_Constant_8_00_PM_to_8_30_PM	2.62	17.23	
coef_disc_Arrival_Constant_8_30_PM_to_9_00_PM	0.00	NA	fixed value
coef_disc_Arrival_Constant_After_9_00_PM	-2.91	-11.94	
coef_disc_Arrival_Constant_Before_6_30_PM	12.1	25.60	
coef_disc_Arrival_Constant_Shift_for_every_30_minutes_after_09_30_pm_Linear	-3.06	-23.82	
coef_disc_Arrival_Constant_Shift_for_every_30_minutes_before_06_00_pm_Linear	2.57	24.30	
coef_disc_Auto_Distance_Duration_gt_1_hrs_Linear	0.00676	6.29	
coef_disc_Auto_Distance_Duration_lt_1_hrs_Linear	-0.321	-7.36	
coef_disc_Departure_Constant_05_00_PM_05_30_PM	-5.57	-17.37	
coef_disc_Departure_Constant_05_30_PM_06_00_PM	-2.67	-11.97	
coef_disc_Departure_Constant_06_00_PM_06_30_PM	0.00	NA	fixed value
coef_disc_Departure_Constant_06_30_PM_07_00_PM	2.37	15.15	
coef_disc_Departure_Constant_10_00_AM_to_10_30_AM	1.40	5.54	
coef_disc_Departure_Constant_7_30_AM_to_8_00_AM	0.00	NA	fixed value
coef_disc_Departure_Constant_8_00_AM_to_8_30_AM	0.635	1.73	
coef_disc_Departure_Constant_8_30_AM_to_9_00_AM	1.71	6.76	
coef_disc_Departure_Constant_9_00_AM_to_9_30_AM	1.48	5.64	
coef_disc_Departure_Constant_9_30_AM_to_10_00_AM	1.38	5.24	
coef_disc_Departure_Constant_After_07_00_PM	4.18	18.45	
coef_disc_Departure_Constant_Before_05_00_PM	-8.34	-20.72	
coef_disc_Departure_Constant_Before_7_30_AM_	0.00	NA	fixed value
coef_disc_Departure_Constant_Shift_for_every_30_minutes_after_07_30_pm_Linear	1.99	12.04	
coef_disc_Departure_Constant_Shift_for_every_30_minutes_before_04_30_pm_Linear	-2.64	-24.85	
coef_disc_Departure_Constant_Shift_for_every_30_minutes_before_07_30_pm_Linear	-0.519	-4.45	
coef_disc_Duration_Constant_0_hours	-8.84	-13.57	
coef_disc_Duration_Constant_0p5_hous	-4.72	-12.83	
coef_disc_Duration_Constant_1_hour	-1.74	-7.27	
coef_disc_Duration_Constant_1p5_hours	0.00	NA	fixed value
coef_disc_Duration_Constant_2_hours	2.44	17.70	
coef_disc_Duration_Constant_2p5_hours_or_more	4.76	24.36	
coef_disc_Duration_Constant_Shift_for_every_30_minutes_more_than_3_hrs_Linear	2.27	20.63	
coef_disc_Joint_Tours_Party_Size_gt_2_Duration_gt_1p5_hr	0.00	NA	fixed value
coef_disc_Kids_in_Joint_Tour_Duration_gt_1p5_hr	0.00	NA	fixed value
coef_disc_Kids_in_Joint_Tour_Duration_lt_1p5_hrs	0.00	NA	fixed value
coef_disc_Number_of_auto_more_that_number_of_adults_Duration_gt_1p5_hrs_Linear	0.00	NA	fixed value
coef_disc_Number_of_auto_more_that_number_of_adults_Duration_lt_1p5_hrs_Linear	0.00	NA	fixed value
coef_disc_Retiree_Nonworking_senior_only_HH_Duration_lt_1p5_hrs_Linear	0.00	NA	fixed value
coef_disc_Zero_auto_households_Duration_gt_1p5_hrs_Linear	0.245	2.62	
coef_disc_Zero_auto_households_Duration_lt_1p5_hrs_Linear	0.00	NA	fixed value
coef_eatout_Arrival_Constant_01_00_PM_to_01_30_PM	1.09	3.48	
coef_eatout_Arrival_Constant_01_30_PM_to_02_00_PM	0.988	3.24	
coef_eatout_Arrival_Constant_02_00_PM_to_02_30_PM	0.00	NA	fixed value
coef_eatout_Arrival_Constant_12_30_PM_to_01_00_PM	0.00	NA	fixed value
coef_eatout_Arrival_Constant_7_00_PM_to_7_30_PM	3.48	14.98	
coef_eatout_Arrival_Constant_7_30_PM_to_8_00_PM	2.91	14.52	
coef_eatout_Arrival_Constant_8_00_PM_to_8_30_PM	0.00	NA	fixed value
coef_eatout_Arrival_Constant_8_30_PM_to_9_00_PM	0.738	3.27	
coef_eatout_Arrival_Constant_After_09_00_PM	0.00	NA	fixed value
coef_eatout_Arrival_Constant_Before_7_00_PM	4.59	22.34	
coef_eatout_Arrival_Constant_Shift_for_every_30_minutes_after_09_30_pm_Linear	-1.32	-11.53	
coef_eatout_Arrival_Constant_Shift_for_every_30_minutes_before_06_30_pm_Linear	0.801	13.18	
coef_eatout_Departure_Constant_05_30_PM_06_00_PM	0.00	NA	fixed value
coef_eatout_Departure_Constant_06_00_PM_06_30_PM	0.00	NA	fixed value
coef_eatout_Departure_Constant_06_30_PM_07_00_PM	1.65	8.11	
coef_eatout_Departure_Constant_07_00_PM_07_30_PM	2.90	13.81	

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_eatout_Departure_Constant_11_00_AM_12_00_PM	0.943	3.63	
coef_eatout_Departure_Constant_12_00_PM_12_30_PM	0.655	1.99	
coef_eatout_Departure_Constant_12_30_PM_to_01_00_PM	0.00	NA	fixed value
coef_eatout_Departure_Constant_After_07_30_PM	2.83	12.13	
coef_eatout_Departure_Constant_Before_05_30_PM	-1.30	-6.48	
coef_eatout_Departure_Constant_Shift_for_every_30_minutes_after_08_00_pm_Linear	0.484	3.56	
coef_eatout_Departure_Constant_Shift_for_every_30_minutes_before_05_00_pm_Linear	-0.968	-16.15	
coef_eatout_Distance_to_destination_Duration_gt_1_hrs	0.0230	12.86	
coef_eatout_Distance_to_destination_Duration_lt_1_hrs	-0.191	-3.97	
coef_eatout_Duration_Constant_0_hours	-2.94	-6.18	
coef_eatout_Duration_Constant_0p5_hous	-0.827	-3.07	
coef_eatout_Duration_Constant_1_hour	0.00	NA	fixed value
coef_eatout_Duration_Constant_1p5_hours	0.547	3.81	
coef_eatout_Duration_Constant_2_hours_or_more	1.65	9.29	
coef_eatout_Duration_Constant_Shift_for_every_30_minutes_more_than_2p5_hrs_Linear	0.00	NA	fixed value
coef_eatout_Duration_Constant_Shift_for_every_30_minutes_more_than_3_hrs_Linear	0.00	NA	fixed value
coef_eatout_Joint_Tours_Party_Size_greater_than_2_Duration_lt_1_hrs	-1.06	-2.96	
coef_eatout_Kids_in_Joint_tour_Duration_lt_1_hrs	1.34	5.21	
coef_eatout_Low_income_lt25000_Duration_lt_1_hrs	0.00	NA	fixed value
coef_eatout_Medium_25k_to_60k_Duration_lt_1_hrs	-1.18	-2.98	
coef_eatout_Zero_auto_HH_Duration_gt_1_hrs	0.00	NA	fixed value
coef_maint_Arrival_Constant_01_30_PM_02_30_PM	1.21	6.89	
coef_maint_Arrival_Constant_02_30_PM_04_00_PM	0.00	NA	fixed value
coef_maint_Arrival_Constant_04_00_PM_04_30_PM	-0.695	-3.02	
coef_maint_Arrival_Constant_10_30_AM_11_00_AM	4.08	14.41	
coef_maint_Arrival_Constant_11_00_AM_11_30_AM	3.89	16.09	
coef_maint_Arrival_Constant_11_30_AM_01_30_PM	2.25	14.49	
coef_maint_Arrival_Constant_After_04_30_PM	-0.890	-4.89	
coef_maint_Arrival_Constant_Before_10_30_AM	4.34	16.50	
coef_maint_Arrival_Constant_Shift_for_every_30_minutes_after_5_00_pm_Linear	-0.696	-25.70	
coef_maint_Arrival_Constant_Shift_for_every_30_minutes_before_10_00_am_Linear	0.00	NA	fixed value
coef_maint_Departure_Constant_08_00_AM_08_30_AM	0.00	NA	fixed value
coef_maint_Departure_Constant_08_30_AM_09_00_AM	0.00	NA	fixed value
coef_maint_Departure_Constant_09_00_AM_09_30_AM	0.00	NA	fixed value
coef_maint_Departure_Constant_09_30_AM_10_00_AM	0.00	NA	fixed value
coef_maint_Departure_Constant_10_00_AM_10_30_AM	0.00	NA	fixed value
coef_maint_Departure_Constant_10_30_AM_11_00_AM	0.00	NA	fixed value
coef_maint_Departure_Constant_After_11_00_AM	0.00	NA	fixed value
coef_maint_Departure_Constant_Before_08_00_AM	0.00	NA	fixed value
coef_maint_Departure_Constant_Shift_for_every_30_minutes_after_11_30_am_Linear	0.00	NA	fixed value
coef_maint_Departure_Constant_Shift_for_every_30_minutes_after_11_30_am_Squared	0.00	NA	fixed value
coef_maint_Departure_Constant_Shift_for_every_30_minutes_before_07_30_am_Linear	0.00	NA	fixed value
coef_maint_Departure_Constant_Shift_for_every_30_minutes_before_07_30_am_Square_Root	0.00	NA	fixed value
coef_maint_Distance_Duration_gt_1p5_hr	0.00762	9.09	
coef_maint_Distance_Duration_lt_1p5_hrs	-0.109	-11.68	
coef_maint_Duration_Constant_0_hrs	0.00	NA	fixed value
coef_maint_Duration_Constant_0p5_hrs	0.00	NA	fixed value
coef_maint_Duration_Constant_Duration_gt_1_hrs_Linear	0.155	6.22	
coef_maint_Duration_Constant_Duration_gt_1_hrs_Square_Root	0.00	NA	fixed value
coef_maint_Duration_Constant_Longer_than_0p5_hrs	0.00	NA	fixed value
coef_maint_Joint_Maintenance_tours_dummy_Departure_after_10_30_AM_Linear	0.416	23.33	
coef_maint_Joint_Maintenance_tours_dummy_Departure_before_10_00_AM_Linear	-0.727	-15.88	
coef_maint_Joint_Tour_with_only_adults_Duration_lt_1p5_hrs	0.00	NA	fixed value
coef_maint_Joint_Tours_Party_Size_gt_2_Duration_gt_1p5_hr	0.00	NA	fixed value
coef_maint_Joint_Tours_Party_Size_gt_2_Duration_lt_1p5_hrs	0.00	NA	fixed value
coef_maint_Kids_in_Joint_Tour_Duration_gt_1p5_hr	0.00	NA	fixed value

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_maint_Kids_in_Joint_Tour_Duration_lt_1p5_hrs	0.00	NA	fixed value
coef_maint_Low_Income_lteq25_000_Duration_gt_1p5_hr	0.00	NA	fixed value
coef_maint_MediumHigh_Income_60_001_to_120_00_Duration_gt_1p5_hr	0.00	NA	fixed value
coef_maint_Medium_Income_25_001_to_60_000_Duration_gt_1p5_hr	0.00	NA	fixed value
coef_maint_Medium_Income_25_001_to_60_000_Duration_lt_1p5_hrs	0.00	NA	fixed value
coef_shop_Arrival_Constant_03_00_PM_03_30_PM	3.01	13.52	
coef_shop_Arrival_Constant_03_30_PM_04_00_PM	2.54	9.60	
coef_shop_Arrival_Constant_04_00_PM_04_30_PM	2.63	10.32	
coef_shop_Arrival_Constant_04_30_PM_05_00_PM	2.81	11.68	
coef_shop_Arrival_Constant_05_00_PM_05_30_PM	2.99	13.40	
coef_shop_Arrival_Constant_05_30_PM_07_00_PM	2.70	17.54	
coef_shop_Arrival_Constant_07_00_PM_09_30_PM	0.00	NA	fixed value
coef_shop_Arrival_Constant_12_30_PM_03_00_PM	2.97	19.19	
coef_shop_Arrival_Constant_After_09_30_PM	1.43	5.53	
coef_shop_Arrival_Constant_Before_12_30_PM	3.14	16.83	
coef_shop_Arrival_Constant_Shift_for_every_30_minutes_after_10_00_pm_Linear	-0.763	-5.30	
coef_shop_Arrival_Constant_Shift_for_every_30_minutes_before_12_00_pm_Linear	-0.174	-3.06	
coef_shop_Departure_Constant_09_00_AM_09_30_AM	0.00	NA	fixed value
coef_shop_Departure_Constant_09_30_AM_10_00_AM	0.00	NA	fixed value
coef_shop_Departure_Constant_10_00_AM_10_30_AM	0.00	NA	fixed value
coef_shop_Departure_Constant_10_30_AM_11_00_AM	0.00	NA	fixed value
coef_shop_Departure_Constant_After_11_00_AM	0.00	NA	fixed value
coef_shop_Departure_Constant_Before_09_00_AM	0.00	NA	fixed value
coef_shop_Departure_Constant_Shift_for_every_30_minutes_after_11_30_am_Linear	0.00	NA	fixed value
coef_shop_Departure_Constant_Shift_for_every_30_minutes_after_11_30_am_Squared	-0.00408	-4.24	
coef_shop_Departure_Constant_Shift_for_every_30_minutes_before_08_30_am_Linear	-1.05	-5.73	
coef_shop_Departure_Constant_Shift_for_every_30_minutes_before_08_30_am_Square_root	0.00	NA	fixed value
coef_shop_Distance_Duration_gt_1p5_hr	0.0175	7.39	
coef_shop_Distance_Duration_lt_1p5_hrs	-0.0286	-2.72	
coef_shop_Duration_Constant_0_hrs	-1.43	-4.90	
coef_shop_Duration_Constant_0p5_hrs	0.00	NA	fixed value
coef_shop_Duration_Constant_1_hrs	0.00	NA	fixed value
coef_shop_Duration_Constant_1p5hrs	0.567	4.81	
coef_shop_Duration_Constant_2_hrs	0.334	2.61	
coef_shop_Duration_Constant_Duration_gt_2p5_hrs_Linear	-0.501	-10.64	
coef_shop_Duration_Constant_Duration_gt_2p5_hrs_Square_root	0.00	NA	fixed value
coef_shop_Duration_Constant_Longer_than_2_hrs	0.00	NA	fixed value
coef_shop_Joint_Shopping_tours_dummy_Departure_after_10_30_AM_Linear	0.00	NA	fixed value
coef_shop_Joint_Shopping_tours_dummy_Departure_before_10_00_AM_Linear	0.00	NA	fixed value
coef_shop_Joint_Tour_with_only_adults_Duration_lt_1p5_hrs	0.00	NA	fixed value
coef_shop_Joint_Tours_Party_Size_gt_2_Duration_gt_1p5_hr	0.00	NA	fixed value
coef_shop_Joint_Tours_Party_Size_gt_2_Duration_lt_1p5_hrs	0.00	NA	fixed value
coef_shop_Kids_in_Joint_Tour_Duration_gt_1p5_hr	0.00	NA	fixed value
coef_shop_Kids_in_Joint_Tour_Duration_lt_1p5_hrs	0.00	NA	fixed value
coef_shop_Low_Income_lteq25_000_Duration_gt_1p5_hr	0.00	NA	fixed value
coef_shop_MediumHigh_Income_60_001_to_120_00_Duration_gt_1p5_hr	0.00	NA	fixed value
coef_shop_Medium_Income_25_001_to_60_000_Duration_lt_1p5_hrs	0.00	NA	fixed value
coef_social_Arrival_Constant_03_00_PM_to_03_30_PM	0.00	NA	fixed value
coef_social_Arrival_Constant_03_30_PM_to_04_00_PM	0.00	NA	fixed value
coef_social_Arrival_Constant_04_00_PM_to_04_30_PM	0.00	NA	fixed value
coef_social_Arrival_Constant_05_00_PM_to_06_00_PM	0.00	NA	fixed value
coef_social_Arrival_Constant_10_00_PM_to_10_30_PM	0.00	NA	fixed value
coef_social_Arrival_Constant_8_30_PM_to_9_00_PM	2.85	8.40	
coef_social_Arrival_Constant_9_00_PM_to_9_30_PM	2.43	8.35	
coef_social_Arrival_Constant_9_30_PM_to10_00_PM	0.00	NA	fixed value
coef_social_Arrival_Constant_After_10_30_PM	-1.55	-2.82	

COEFFICIENT NAME	VALUE	T STAT	FIXED?
coef_social_Arrival_Constant_Before_8_30_PM	3.86	13.44	
coef_social_Arrival_Constant_Shift_for_every_30_minutes_after_11_00_pm_Linear	-1.29	-5.54	
coef_social_Arrival_Constant_Shift_for_every_30_minutes_before_08_00_pm_Linear	0.850	8.72	
coef_social_Auto_Distance_Duration_gt_1_hrs_Linear	0.00703	3.72	
coef_social_Auto_Distance_Duration_lt_1_hrs_Linear	-0.103	-4.54	
coef_social_Departure_Constant_05_30_PM_06_00_PM	-0.985	-2.84	
coef_social_Departure_Constant_06_00_PM_06_30_PM	0.00	NA	fixed value
coef_social_Departure_Constant_06_30_PM_07_00_PM	0.00	NA	fixed value
coef_social_Departure_Constant_07_00_PM_07_30_PM	1.35	3.93	
coef_social_Departure_Constant_09_00_AM_to_09_30_AM	0.00	NA	fixed value
coef_social_Departure_Constant_After_07_30_PM	1.97	5.28	
coef_social_Departure_Constant_Before_05_30_PM	-2.67	-7.15	
coef_social_Departure_Constant_Before_09_00_AM	0.00	NA	fixed value
coef_social_Departure_Constant_Shift_for_every_30_minutes_after_08_00_pm_Linear	0.00	NA	fixed value
coef_social_Departure_Constant_Shift_for_every_30_minutes_before_05_00_pm_Linear	-0.856	-8.78	
coef_social_Departure_Constant_Shift_for_every_30_minutes_before_08_30_am_Linear	-1.26	-3.66	
coef_social_Duration_Constant_2_hours	0.00	NA	fixed value
coef_social_Duration_Constant_2p5_hours	1.27	5.24	
coef_social_Duration_Constant_3_hours_or_more	1.90	7.49	
coef_social_Duration_Constant_Less_than_2_hours	0.00	NA	fixed value
coef_social_Duration_Constant_Shift_for_every_30_minutes_less_than_1p5_hrs_Linear	-1.10	-6.13	
coef_social_Duration_Constant_Shift_for_every_30_minutes_more_than_3p5_hrs_Linear	0.584	5.34	
coef_social_Joint_Tours_Party_Size_gt_2_Duration_gt_1p5_hr	0.00	NA	fixed value
coef_social_Kids_in_Joint_Tour_Duration_gt_1p5_hr	0.00	NA	fixed value
coef_social_Kids_in_Joint_Tour_Duration_lt_1p5_hrs	0.00	NA	fixed value
coef_social_Number_of_auto_more_that_number_of_adults_Duration_gt_1p5_hrs_Linear	0.00	NA	fixed value
coef_social_Number_of_auto_more_that_number_of_adults_Duration_lt_1p5_hrs_Linear	0.00	NA	fixed value
coef_social_Retiree_Nonworking_senior_only_HH_Duration_lt_1p5_hrs_Linear	0.00	NA	fixed value
coef_social_Zero_auto_households_Duration_gt_1p5_hrs_Linear	0.00	NA	fixed value
coef_social_Zero_auto_households_Duration_lt_1p5_hrs_Linear	0.00	NA	fixed value

STATISTIC	AGGREGATE	PER CASE
Number of Cases	3,044	
Log Likelihood at Convergence	-17,406.03	-5.7181
Log Likelihood at Null Parameters	-21,520.70	-7.0699
Rho Squared w.r.t. Null Parameters	0.1912	

A large portion of the coefficients fit in estimation were insignificant. The only sociodemographic coefficients to be found significant was in eat out joint tours where medium income households or the presence of children leads to shorter tours. All other explanatory power of the models lies within the alternative specific constants and the linear (and some non-linear) shift variables.

5.5 DISCUSSION

All estimated purposes found a large portion of coefficients to be insignificant, particularly for sociodemographic variables. In some sense, this is to be expected considering people generally take tours at similar times throughout the day.

A few trends stood out across the different purposes. First, coefficients that relate to the distance of the tour from home were significant and always pointed to longer duration tours the farther away the tour destination. During the estimation process, if the purpose had a logsum value that was nonsensical or very small, these distance coefficients were turned off to see if the logsum would compensate, but no major change in the logsum value was observed when removing these coefficients.

Coefficients relating to time pressure of other scheduled tours were usually found to be significant. Most purposes had linear shift constants used to primarily explain tours that were not included in the bin-specific alternative constants. These linear shift constants could be applied to duration, departure, or arrival times. A few of the purposes also had significant non-linear effects as well, but these were more likely to be insignificant.

Only a few income-specific constants were found to be significant, and they often related to the low-income group taking longer tours. This could be explained by these households being less likely to own a car and therefore take longer tours using alternative modes. It is hard to draw many other patterns for sociodemographic coefficients as they tend to be pretty purpose specific.

Mode choice logsum coefficients were often estimated to be very close to zero or negative. Some of the lack of significance in the mode choice logsum coefficients can be attributed to having only five skim periods. For a given origin and destination pair, the mode choice logsum only changes when the tour departure or arrival moves into a different skim period. So, unless there are people willing to change their tour times by an amount significant enough to change time periods, the mode choice logsum is too coarse to be estimated appropriately. The SEMCOG region does not have significant enough congestion to see a shift in the tour start times for most of the purposes leading to a bad estimate for the logsum coefficient. However, the mode choice logsum is still an important indicator for potential congestion scenarios, so it was asserted (usually to a value of 0.2) for most of the purposes.

Running ActivitySim with the newly estimated tour time-of-day configuration files shows generally good agreement between the model output and the survey data. The school and work purposes follow the survey distributions almost exactly, but some of the other non-mandatory purposes see a little bit more deviation. Calibration constants will be added to future versions to help further match the time-of-day distributions from the model to the survey data.

6.0 CONCLUSIONS

SEMCOG's household travel survey was processed into a format readable by ActivitySim's estimation mode functionality. This involved significant cleaning of the survey data to impute missing data where possible or remove instances where the survey data could not be fit into the ActivitySim framework. ActivitySim produced estimation data bundles that contained the necessary information for auto ownership, tour destination choice, and mandatory and non-mandatory tour time-of-day choice estimation.

ALOGIT input was constructed from the ActivitySim estimation mode output for tour destination choice models and many different model specifications were tried for each of the tour purposes. Size terms for work location choice were estimated from PUMS data. School location choice size terms were asserted based on the corresponding level of school, and non-mandatory size terms were estimated in ALOGIT. Logsum values were fixed to their predicted value when including just logsum and linear distance to keep their explanatory power when adding additional model parameters. Non-linear distance terms were capped at 20 miles to produce monotonically decreasing utilities as a function of distance. Person and household level variables were crossed with distance to capture their effects on the utility function, and the utility function was modified to account for the weights in the survey data.

All estimated models and their size terms are implemented in their respective AcitivitySim configuration files. The existing university tour specification will remain unchanged since only non-university school tours were included in the model estimation. Auto ownership coefficients were re-estimated according to their original specification using the ActivitySim estimation example notebooks. Validation summaries will be re-created upon integration of the new models into ActivitySim.

Tour time-of-day choice estimation started with the previously used specification from the ARC implementation of half-hour time periods. Updated reference bins for tour departure, arrival, and duration were set in the specification and the corresponding "base" coefficients were set to 0. After estimating the model, if coefficients were found to be insignificant, they were subsequently set to a fixed value of zero and the model was re-estimated. Many of the coefficients that were in the original specification were determined to be insignificant, particularly those related to sociodemographic variables. Re-estimation was also performed if the mode choice logsum coefficient needed to be fixed to a more reasonable value.

The result of the estimation procedure is the output of new ActivitySim configuration files for the tour scheduling models. These updated configs were then used in the ActivitySim model run and generally good agreement was observed between the survey time-of-day distributions and the ActivitySim output.

the science of insight

55 Railroad Row
White River Junction, VT 05001
802.295.4999
www.rsginc.com

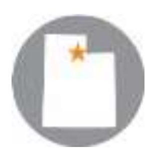
White River Junction & Burlington, VT

Arlington, VA

Chicago, IL

Evansville, IN

Portland, OR



Salt Lake City, UT

San Diego, CA

RSG promotes sustainable business practices that minimize negative impacts on the environment. We print all proposals and reports on recycled paper that utilizes a minimum of 30% post-consumer waste.

RSG also encourages recycling of printed materials (including this document) whenever practicable.
For more information on RSG's sustainability practices, please visit www.rsginc.com.