Metropolitan Washington Council of Governments

TOUR MODE AND DESTINATION CHOICE MODEL ESTIMATION

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1.0 INTRODUCTION

The National Capital Region Transportation Planning Board (NCRTPB or TPB), staffed by the Metropolitan Washington Council of Governments (MWCOG or COG), is the federally designated metropolitan planning organization (MPO) for metropolitan Washington. COG/TPB staff develops, maintains, applies, and improves, with consultant assistance, the TPB's family of regional travel demand forecasting models, which are used for regional, long-range transportation planning in the metropolitan Washington region. In 2018, COG/TPB set out to develop a next-generation travel demand model. The project team, consisting of RSG and Baseline Mobility Group, recommended that COG transition from its current aggregate, trip-based travel demand model (i.e., Gen2 Model) to a simplified activity-based model (ABM) implemented in the open-source ActivitySim software platform, to be known as the Generation 3, or Gen3, Model.

The model is being implemented in two phases. Phase I is to be a prototype model that can be tested by the COG/TPB staff. Phase II is to be a production-use model that can be used for regional planning work, such as the air quality conformity analysis. In Phase I, a synthetic population for the modeled region was created, and the ActivitySim model system was transferred from the Southeast Michigan Council of Governments (SEMCOG) region (Detroit, Michigan) to MWCOG[1]. The Phase I deployment includes estimation[2] of two models: tour mode choice and tour destination choice (see flowchart in Figure 2). These models play a key role in the ability of the model to replicate the observed behavior of MWCOG residents, and previous research[3] indicates that destination choice models are the least transferable component between regions. We also believe that the household travel survey data in the Washington, D.C. region consists of enough choice transit riders to warrant estimation of mode choice models. After these models are implemented, the models will be "lightly" calibrated and validated to observed data. Along with sensitivity tests, these efforts will inform any model enhancements and subsequent estimation, calibration and validation performed as part of Phase II. This report describes the model estimation process in Phase 1 including ActivitySim's model estimation functionality, data preparation, the models estimated, and model estimation results.

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[1] Note: some model components in the transferred model system were estimated using SEMCOG data, while others were estimated using MTC data

[2] Model estimation is a process in which model parameters are calculated using a statistical algorithm to maximize the goodness-of-fit between estimated and observed choice outcomes for a set of observed data.

[3] Gliebe, J., M. A. Bradley, N. Ferdous, M. Outwater, H. Lin and J. Chen (2014) Transfer of activity-based model parameters from Sacramento, California, to Jacksonville, and to Tampa, Florida, in: 93rd Annual Meeting of the Transportation Research Board, Washington, D.C., January 2014.

2.0 MODEL ESTIMATION IN ACTIVITYSIM

ActivitySim is a disaggregate activity-based travel modeling platform in which a synthetic population is run through each model component. In each model component, the software builds a choice model that is specific to each household and person, taking into account the attributes of the synthetic population, the choice outcomes of previous models in the model system, and logsums[4] from downstream model components. As each model is run, the choice for that model is recorded for the decision-maker before moving on to the next model.

The ActivitySim software was recently enhanced with an “estimation mode.” This feature makes it possible to run a survey population through the software with the same attributes as the synthetic population, in which the observed choices for each decision-maker override the simulated choices from the model. Because the models are constructed for each decision-maker according to their attributes and the observed choices for the decision-maker, the explanatory variables for each model (including logsums from downstream models) can be saved to disk and used to re-estimate the model.

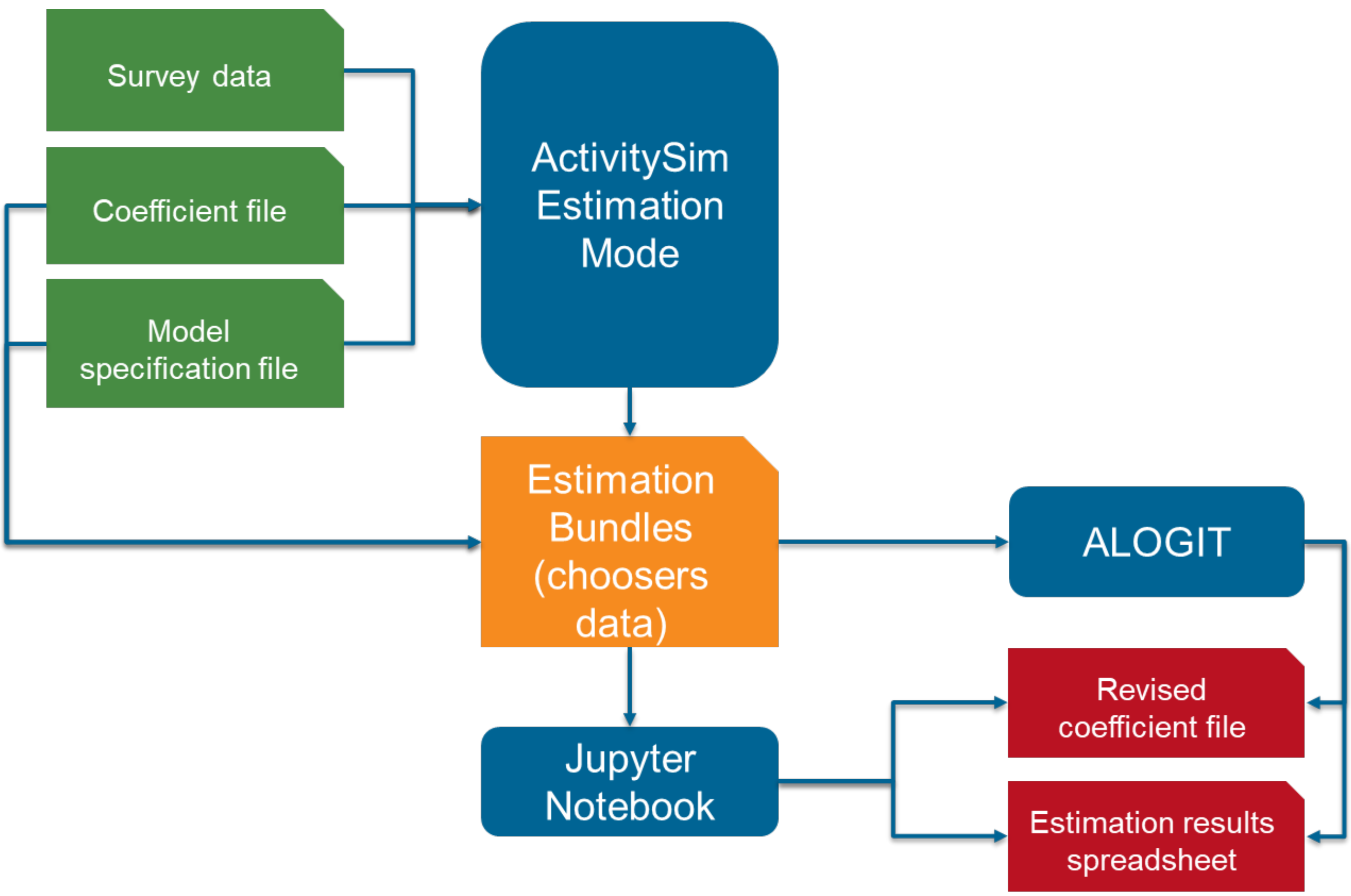
These output files are referred to as “estimation data bundles.” Each estimation data bundle (EDB) consists of a table of data where rows are the unit over which the model is being applied (households, persons, tours, trips, etc.) and columns are data for each alternative to be used in utility equations. This data along with the ActivitySim input coefficient file(s) and model specification file is read by a Jupyter Notebook[5] that re-estimates the model specification in Larch.[6] Larch is a logit model estimation package in Python that is built on top of the Python SciPy[7] package. Alternatively, the EDBs can also be easily post-processed to data formats required by other logit model estimation packages such as ALOGIT[8]. For MWCOG Gen3 Phase I model estimation, Larch was used to estimate tour mode choice models, and ALOGIT was used to estimate tour destination choice models, as described below.

The model estimation process in ActivitySim is shown in Figure 1. Survey data is input to ActivitySim, as a replacement for the synthetic population, and the outputs from any upstream model components run before the component to be estimated. ActivitySim also requires an input coefficient file for each model, as well as an input model specification. When ActivitySim is run in estimation mode, it outputs an estimation data bundle for each model component. The estimation data bundle is read by the Jupyter notebook, along with the input model specification

[4] A logsum is a measure of utility that takes into account multiple alternatives. For example, a mode choice logsum is a utility that considers multiple modes of transportation.
[5] Jupyter, (no date), https://jupyter.org/
[6] Larch Documentation, Ver. 5.4.1, June 5, 2020. https://larch.newman.me/index.html
[7] SciPy, Fundamental algorithms for scientific computing in Python, Ver. 1.7.3, November 24, 2021, https://www.scipy.org/
[8] ALOGIT Model Estimation Package: http://www.alogit.com/index.htm

and coefficient file. The estimation process, run in Jupyter, writes out a new coefficient file in ActivitySim format, with estimated coefficients, as well as an Excel spreadsheet that describes estimation results. When ALOGIT is used for model estimation, the ActivitySim configuration files need to be updated manually as per the updated model specification and coefficients.

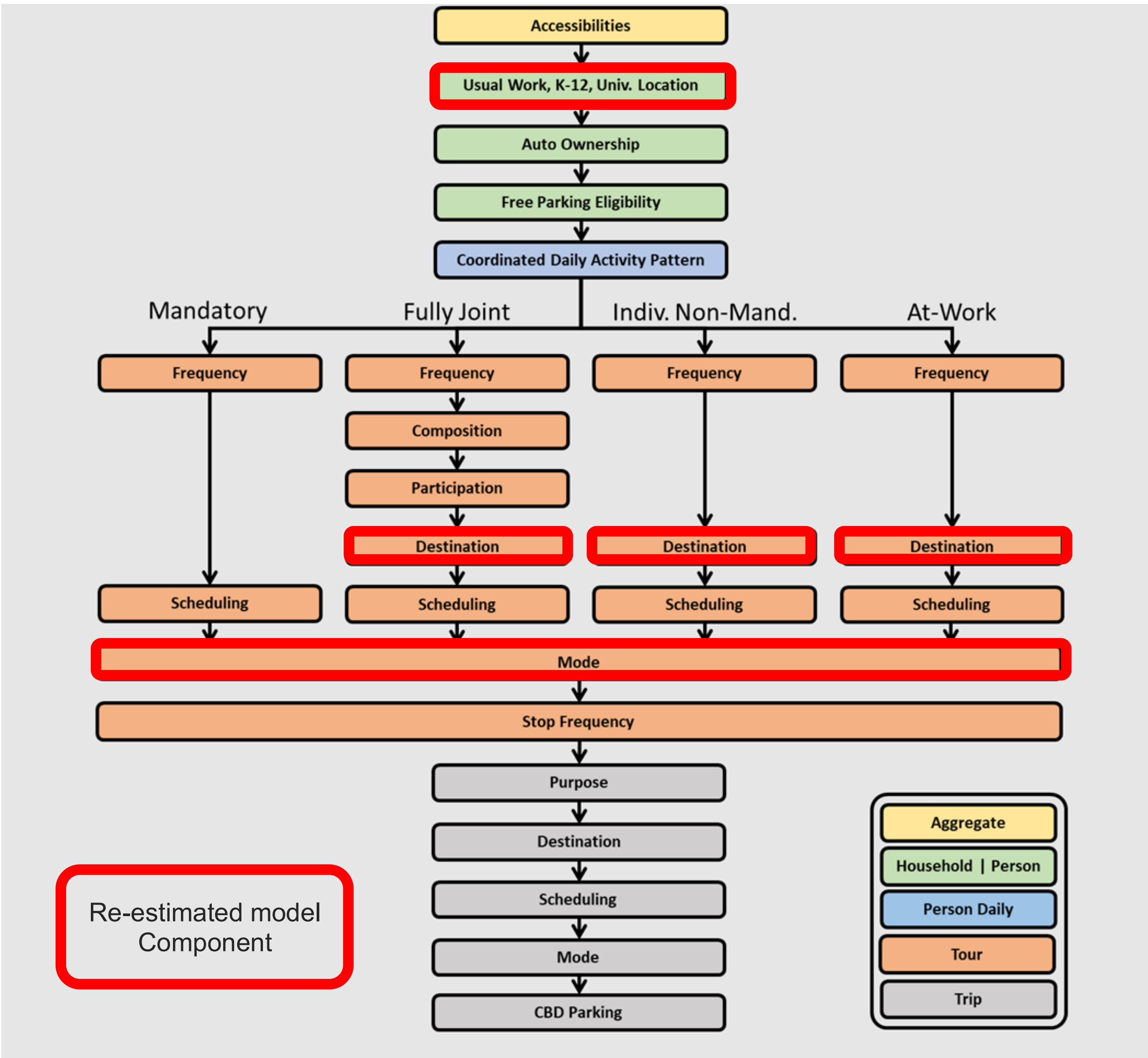
FIGURE 1: ACTIVITYSIM ESTIMATION PROCESS



3.0 MODELS ESTIMATED IN PHASE I

Two model components were estimated in the Gen3 Model, Phase I: tour destination choice models (including usual work and school location choice) and tour mode choice models. These model components are shown in Figure 2. They are described in more detail below, along with the data for estimation and estimation results.

FIGURE 2: ACTIVITYSIM MODEL STRUCTURE AND RE-ESTIMATED MODEL COMPONENTS



3.1 TOUR DESTINATION CHOICE

Destination choice models estimated for Gen3 Phase I model development include work, school, and college/university location choice models (referred to as mandatory location choice) as well as tour destination choice models for non-mandatory tours. These are multinomial logit (MNL) models in which Transportation Analysis Zones (TAZs) are alternatives. The workplace location choice model assigns a usual workplace TAZ for every employed person in the synthetic population. Workplace location choice models are segmented by household income level. The school location choice model assigns a usual school/college/university TAZ for every student in the synthetic population. School location choice models are segmented by grade level: Kindergarten-8, 9-12, and college/university.

Tour destination choice models assign a primary destination TAZ for each non-mandatory tour (mandatory tour destination locations are determined via the work and school location choice models described above). Non-mandatory tour purposes include escort (pick-up/drop-off of household members at non-home locations), shopping, other maintenance, eating out, social/recreational, other discretionary, and all at-work subtours, regardless of purpose. The primary destination of the tour is defined as the primary or main purpose of the tour according to a scoring mechanism (for tours with more than one out-of-home activity).[9]

The systematic utility (U_{ijn}) of choosing a work destination (*j*) for an individual (*n*) in the zone (*i*) is given by

$$U_{ijn} = S_j + \alpha \times L_{ij} + \sum \beta^k \times D_{ij}^k + \sum \beta^k \times D_{ij}^k\, N_n^k + C_{jn}$$

Where, S_j is the size variable for destination zone *j*, L_{ij} is the tour mode choice logsum between zone pair *ij*, D_{ij}^k represents the various distance terms (linear, log, squared, cubed, and square root), N_n^k represents the person or household characteristics for individual *n* and is used for creating interaction variables with distance terms, $C_{jn}$is a correction term to compensate for the sampling bias in the model estimation (i.e., represent the difference between the sampling probability and final estimated probability for each alternative), and α and β^k are model paramaters. Explanatory variables are described in more detail below:

- Size terms (S_j): A set of terms reflecting the quantity of activities in the destination zone. These terms are equivalent to a trip attraction equation in a gravity model. The variables

[9] For more details on the scoring mechanism and other data processing issues, see RSG “Gen3 Data Development.” Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, October 6, 2021.

associated with the destination include households, employment by type, and/or active acres of park space.

- Tour mode choice logsum (L_{ij}): The natural log of the denominator of the tour mode choice model for the alternative destinations TAZ j. The tour mode choice model is run for the chooser, but since the model is run before time-of-day choice, a representative time period is used instead of the actual time period chosen for the tour.
- Distance terms (D_{ij}^{k}): A set of distance terms is used to fit the estimated tour length distribution to observed data, as experience has shown that the tour mode choice logsum term alone is inadequate to match the observed distribution.
- Household and or person variables (N_{n}^{k}): A set of household and/or person variables are interacted with distance to reflect differences in tour length with respect to attributes of the decision-maker (other than, or in addition to, those reflected in the tour mode choice logsum)

In application, importance sampling is used to construct a choice set of 30 TAZs from the full set of alternative zones. This choice set is selected using Monte Carlo simulation according to a simple destination choice model with only distance terms and the size term from the full model (e.g., not including a mode choice logsum or household/person variables). This is done because the calculation of the mode choice logsum to each alternative TAZ for every worker/student and tour would be prohibitively computationally expensive. Importance sampling is used in order to create a sample of alternatives which is efficient; that is, the distribution of utilities of the sample replicates the distribution of utilities from the full choice set.

In model estimation, sampling is not used; the alternatives used in estimation include all TAZs in the MWCOG region. Although this increases the time required for model estimation, it eliminates the need to calculate utility correction factors (C_{jn}), which account for the probability of inclusion of the choice set in the utility of the sampled alternative. The calculation of correction factors is described in more detail in Section 6.0 (Appendix).

Because tour mode choice logsums are used in destination choice, the destination and mode choice models can be thought of as nested logit models where tour mode is nested under destination choice. In other words, the cross-elasticity of mode choice is greater than the cross-elasticity of destination choice. The mode choice logsum coefficient must be greater than zero and less than or equal to one. A logsum parameter of exactly one means that the choice of destination and mode is multinomial; in other words, exactly equal cross-elasticities between destinations and modes. The smaller the logsum parameter, the less the mode choice logsum contributes to the destination choice model, all else being equal. This structure imposes an order to model estimation: tour mode choice models must be estimated and implemented prior to destination choice, so that tour mode choice logsums are generally consistent with the model in application.

3.2 TOUR MODE CHOICE

The tour mode choice model determines the main tour mode used to get from the origin to the primary destination and back. The tour-based modeling approach requires a certain reconsideration of the conventional mode choice structure. Instead of a single mode choice model pertinent to a four-step structure, there are two different levels where the mode choice decision is modeled:

- The tour mode level (upper-level choice),
- The trip mode level (lower-level choice conditional upon the upper-level choice).

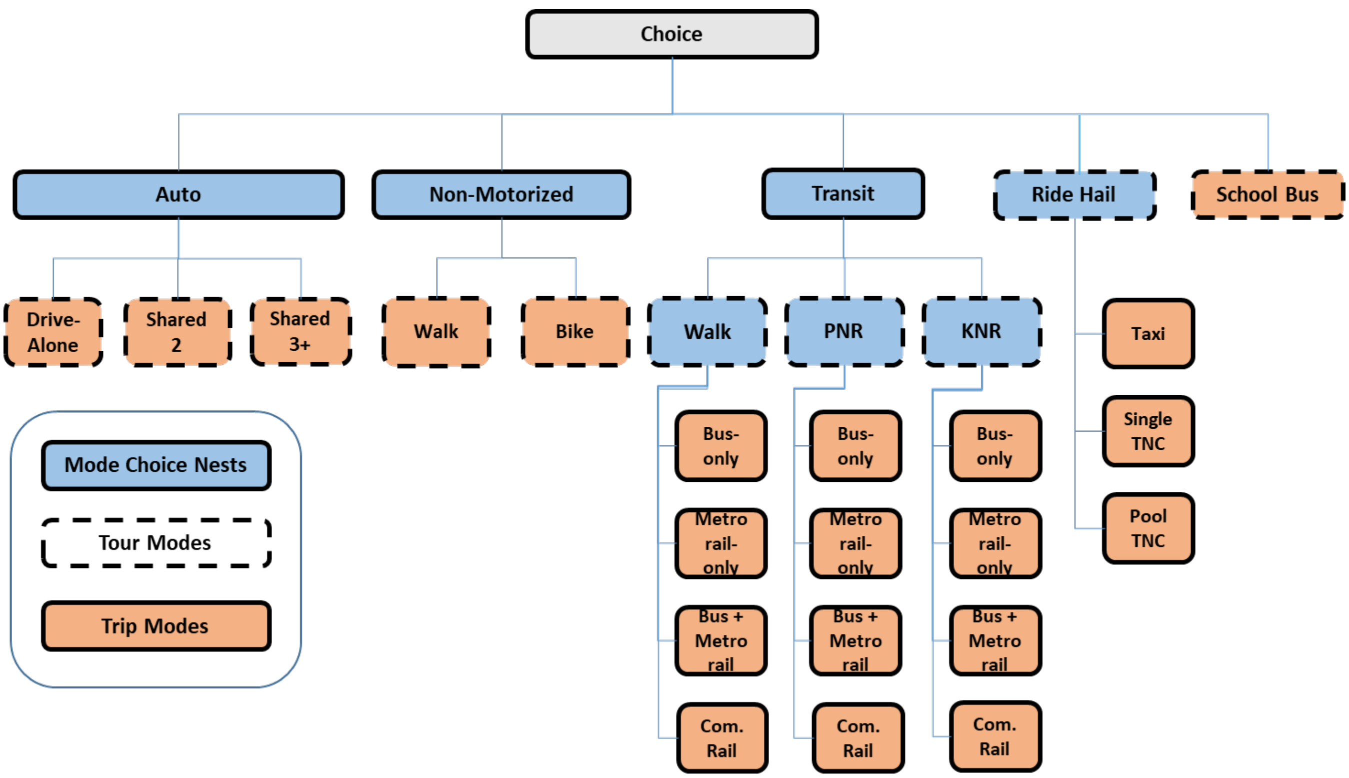


FIGURE 3: MODE CHOICE STRUCTURE FOR GEN3 MODEL, PHASE I

The tour mode level can be thought of as a mode preference model, while the trip mode choice model can be thought of as a mode switching model. Tour mode choice is used to constrain stop location choice as well as trip mode choice. The modes, or elemental alternatives, for both models are the same, but the higher level of the nesting structure constrains lower-level decisions. This can be visualized in Figure 3, which shows the entire nesting structure for both tour and trip mode choice. However, for the purposes of downstream models, only tour modes (indicated by the 10 alternatives with dashed lines in the figure) are retained from the tour mode choice model. Lower-level choices, such as transit path type (bus only, Metrorail only, bus plus Metrorail, and commuter rail) are used to calculate the upper-level nest logsums, but are not used to constrain trip mode choice.

The tour mode choice is not reported in the household travel survey and is coded based on the mode used for the trips on the tour. The coding of tour mode involves applying the hierarchical set of rules – summarized in Table – that determines the tour's primary mode.

TABLE 1: RULES APPLIED BY SPA TO CODE TOUR MODE

TOUR MODE CODING
If any trip on tour is School Bus, tour mode is School Bus
else if trip on tour is PNR Commuter Rail, tour mode is PNR Commuter Rail
else if trip on tour is PNR Bus-Metrorail, tour mode is PNR Bus-Metrorail
else if trip on tour is PNR Metrorail, tour mode is PNR Metrorail
else if trip on tour is PNR Bus, tour mode is PNR Bus
else if trip on tour is KNR Commuter Rail, tour mode is KNR Commuter Rail
else if trip on tour is KNR Bus-Metrorail, tour mode is KNR Bus-Metrorail
else if trip on tour is KNR Metrorail, tour mode is KNR Metrorail
else if trip on tour is KNR Bus, tour mode is KNR Bus
else if trip on tour is Walk Commuter Rail, tour mode is Walk Commuter Rail
else if trip on tour is Walk Bus-Metrorail, tour mode is Walk Bus-Metrorail
else if trip on tour is Walk Metrorail, tour mode is Walk Metrorail
else if trip on tour is Walk Bus, tour mode is Walk Bus
else if any trip on tour is TNC-Pool, tour mode is TNC-Pool
else if any trip on tour is TNC-Single, tour mode is TNC-Single
else if any trip on tour is Taxi, tour mode is Taxi
else if any trip on tour is Bike, tour mode is Bike
else if any trip on tour is Walk, tour mode is Walk
else if any trip on tour is HOV3, tour mode is HOV3
else if any trip on tour is HOV2, tour mode is HOV2
else if any trip on tour is SOV, tour mode is SOV
else tour mode is other

The tour mode choice is estimated based on the round-trip level-of-service (LOS) between the tour anchor location (home for home-based tours and work for at-work sub-tours) and the tour primary destination. The tour mode is chosen based on LOS variables for both directions according to the time periods for the tour departure from the anchor and the arrival back at the anchor. This is one of the fundamental advantages of the tour-based approach. For example, a commuter can have very attractive transit service in the a.m. peak period in the outbound direction, but if the return home time is in the midday or later at night, the commuter may prefer private auto due to lower off-peak transit service.

The appropriate skim values for the tour mode choice are a function of the TAZ of the tour origin and TAZ of the tour primary destination. The tour mode choice model contains many household and person attributes, including income, auto sufficiency (typically defined as a comparison of the number of autos to the number of drivers in the household), age, etc. Urban form variables are also important, particularly related to the choice of non-motorized modes.

4.0 DATA USED FOR MODEL ESTIMATION

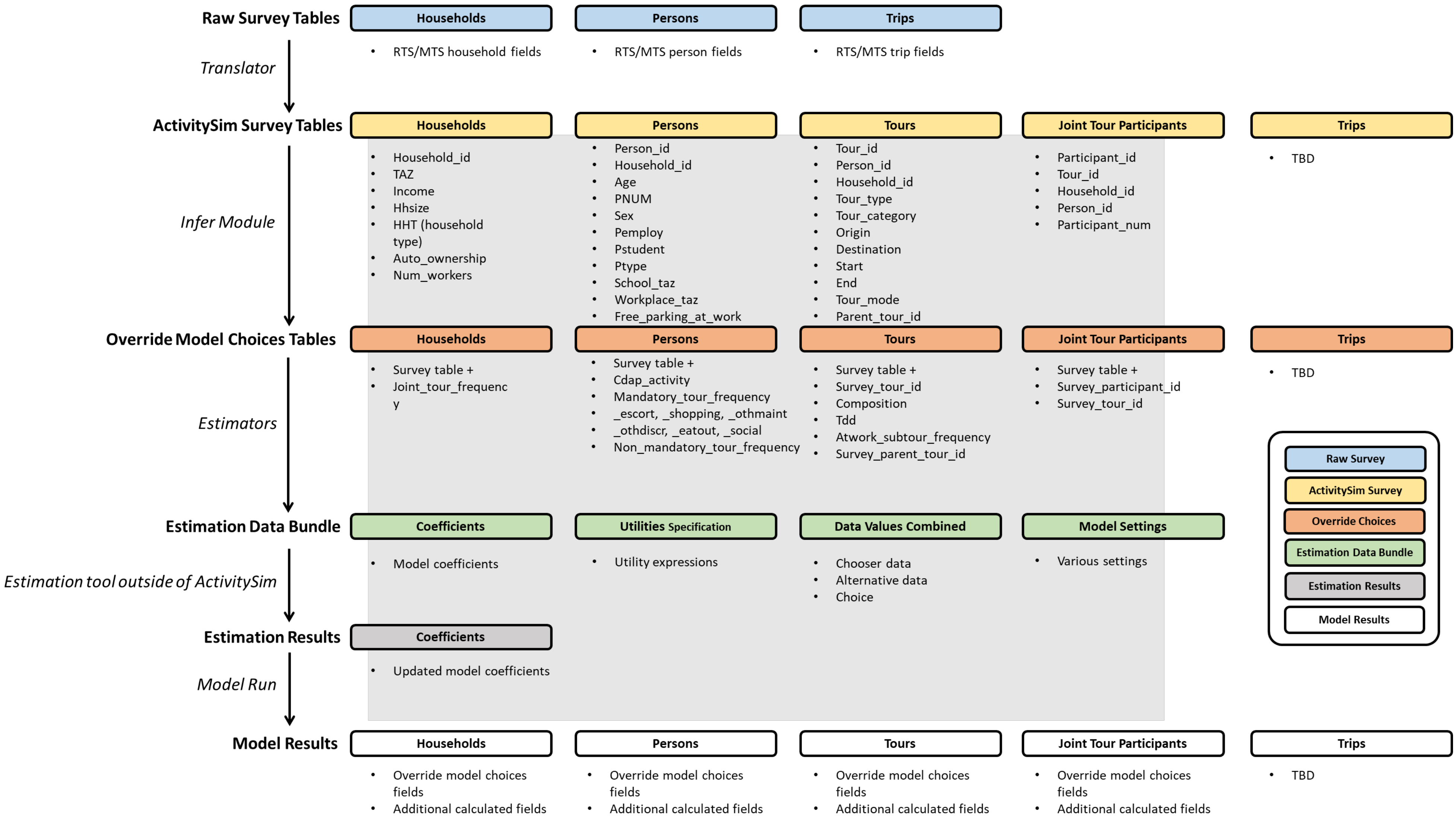
Model estimation is the process by which a statistical process implemented in software is used to fit model parameters to match observed data. Transforming the observed data into a readable format for the estimation software with all the necessary information included is essential to this process. This chapter describes how raw survey data was processed to be compatible with ActivitySim's estimation mode and presents key summaries from the estimation data set.

Data Formatting and Workflow

The 2017-18 MWCOG Regional Travel Survey (RTS) and the 2018-19 Maryland Travel Survey (MTS) are the primary data source used to estimate the tour mode choice and destination choice models for the MWCOG ActivitySim model. The overview of the data processing workflow from the household travel survey to ActivitySim estimation mode output is shown in

Figure 4. Note that we have not yet modified our survey processing procedures to generate trip level model estimation mode inputs; thus TBD is shown under "Trips".

FIGURE 4: ESTIMATION MODE FLOW CHART



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 the required information is met, the survey data is run through the *infer* module (a python script named *infer.py*[10]) 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*[11] configuration file are created and ready for use in model estimation.

Household Travel Survey Processing

The RTS/MTS data contains roughly 35,000 individuals across 16,000 households. Coding of the RTS/MTS data into linked trips and tours was performed using the MWCOG Survey Processing Application (SPA) as described in the *Gen3 Phase 1 Data Development Report.*[12] Following SPA processing, further formatting of the data was required before passing the tables to the Infer module. There are specific tour patterns that ActivitySim expects, and the survey data can be incomplete or inconsistent leading to ActivitySim crashes. The following list enumerates the processing steps that were required to turn the SPA output into ActivitySim-compliant survey data. Table 2 provides a summary of these steps and the result of each step.

- **Unique IDs:** ActivitySim requires unique IDs for households, persons, tours, and trips. Only household IDs are unique in the SPA output, while person, tour, and trip IDs restart from one 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 participant 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. The SPA tours file contains a duplicate of the joint tour for each tour participant, but for ActivitySim estimation mode, it should contain only a single instance of that tour. Only the first instance of the joint tour from the SPA output is kept in the ActivitySim table.

[10] ActivitySim Infer module: https://github.com/ActivitySim/activitysim/blob/master/activitysim/examples/example_estimation/scripts/infer.py
[11] ActivitySim Estimation Mode settings file: https://github.com/ActivitySim/activitysim/blob/master/activitysim/examples/example_estimation/configs/estimation.yaml
[12] Gen3 Phase 1 Data Development Report: https://app.box.com/s/xe5vb28daox1aqtw895iy2r5ocy584w8

- **Household income:** Household income is kept in a categorical variable in the RTS/MTS data and through the MWCOG 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 are missing income values are assigned a randomly selected income drawn from the distribution of income values in the survey. None of the households in the RTS/MTS data had missing income.
- **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.
- **Employment status:** The synthetic population generally includes variables for the number of hours worked and the number of weeks worked per year (WKHP and WKW variables in the PUMS data dictionary[13]). These variables are required in ActivitySim to distinguish between part-time and full-time workers. The WKHP and WKW variables were not available in the RTS/MTS data and the part-time status was imputed using a model developed for the SEMCOG HTS.[14] The Part-time status imputation model only generates a dummy variable indicating Part-time status.. However, ActivitySim's person coding logic requires the WKHP and WKW variables. Therefore, appropriate assumptions were made for the value of these variables for Full-time and Part-time workers; in the case that a worker is imputed as part-time, they are coded with WKHP value equal to 25; otherwise they will have a WKHP value of 40. Full-time workers were assumed to work between 50 and 52 weeks per year (WKW = 1) and 40 hours per week (WKHP = 40), and part-time workers were assigned 14-26 weeks per year (WKW = 5) at 25 hours per week (WKHP = 25).
- **Student status:** ActivitySim determines student status based on the SCHG variable ("Grade level attending") in the PUMS data which has separate categories for each grade, but the SPA tool just distinguishes by university and school. University was coded to mean undergraduate (SCHG = 15) and school was arbitrarily coded to be grade 6 (SCHG = 6), which falls in the middle of the range from Kindergarten to 12th grade. Like WKW and WKHP, SCHG is just used to determine person type.
- **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

[13] "2014-2018 ACS PUMS Data Dictionary." U.S. Census Bureau, January 30, 2020. https://www2.census.gov/programs-surveys/acs/tech_docs/pums/data_dict/PUMS_Data_Dictionary_2014-2018.pdf
[14] More details on part-time status imputation can be found in the Gen3 Phase 1 Data Development Report (https://app.box.com/s/xe5vb28daox1aqtw895iy2r5ocy584w8)

set. Everyone who makes a work or school tour needs to be labeled as a worker or student.

Employment Status Recode (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 or university. 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.

Persons who are coded as non-student workers but perform a school tour and not a work tour 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.

- **Workplace TAZ:** For workers with missing workplace TAZ, the first work tour destination was selected as their workplace TAZ, if available.
- **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 destination was assumed to be their school TAZ in a survey pre-processing step. 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.
- **Tour purpose:** SPA tour purposes such as "loop" tours were changed to other maintenance or other discretionary purposes. ActivitySim does not have a university tour type, so university tour types were changed to school.
- **Tour type:** In ActivitySim, at-work subtours are coded as *business, eat (eating out), and maint (maintenance)*. Work subtours are mapped to *business*, eat out subtours are mapped to *eat*, and all other at-work subtour purposes are mapped to *maint*.
- **Tour Locations:** If tour destinations are not within the MWCOG modeled region or are not reported, those tours do not have a valid start or end TAZ. These tours were removed. A total of 1,974 out of 45,938 (~4%) total tours were tagged due to invalid start or end locations.
- **Tour Times:** Tour start times must be before tour end times, neither can be missing, and they must occur during a 24-hour period. Tours were removed if they did not fit this specification. A total of 2,010 tours (~4%) were tagged due to bad start/end times.
- **Tour Frequencies:** There are configuration files for each tour category that specify the allowed sets of tour frequencies. A person can make only 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 non-mandatory purposes.

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 3,442 tours (~7%) that did not have an allowed tour frequency were tagged in the data.

- **Joint Tour Type**: Joint escorting tours are not allowed in ActivitySim. These tours were re-categorized to non-mandatory escorting tours.
- **Joint Tour Frequency:** Joint tours have restrictions on frequencies just like individual tours. The procedure for removing joint tours that did not fall in the frequency alternatives is the same as for non-joint tours.
- If a parent tour was removed for any of the above reasons, all subtours of the parent were also removed.
- Finally, all tours tagged for removal were dropped. A total of 5,554 (~12%) of the tours were dropped.

TABLE 2: HTS PROCESSING SUMMARY

No	Data processing step	Description	Associated table	Result
1	Unique IDs	ActivitySim requires unique IDs for households, persons, tours, and trips	household, person, tours, trips	unique IDs in all tables
2	Household income	Categorical to numerical income. Impute missing income	household	No missing income
3	Household size	Reported household size should match number of persons	household, persons	All consistent
4	Employment Status	Assume appropriate values for WKW and WKHP for full and part-time workers	persons	Representative values based on part-time status
5	Student Status	Assume appropriate values of SCHG based on student status	persons	SCHG coded with representative values

No	Data processing step	Description	Associated table	Result
				based on reported student status
6	Person Type	Set ESR=1 for workers. Update person type for non-workers or non-students with work or school tours	persons	91 workers coded as students. 124 students coded as fulltime workers. 63 fulltime workers coded as part-time workers
7	Workplace TAZ	Impute workplace TAZ for workers with missing workplace TAZ. Workplace TAZ need to be consistent with employment data	persons	Number of invalid workplace TAZs reassigned: 27
8	School TAZ	Impute school TAZ for students with missing school TAZ. School TAZ need to be consistent with enrollment data	persons	Number of invalid school TAZs reassigned: 1228
9	Tour purpose	Recode tour purpose unavailable in ActivitySim (e.g., loop tour, university, etc.)	tours	Number of university tours changed to school: 737
10	Tour type	Recode at-work subtour purpose	tours	All at-work subtours tour type coded as business, eating out, and maintenance
11	Tour locations	Check for valid start and end TAZ	tours	Tagged 1,974 out of 45,938 (~4%)
12	Tour times	Start must be before end. Can't be missing	tours	Tagged 2,010 tours (~4%)
13	Tour frequencies	Tour frequencies need to be consistent with ActivitySim alternatives. Remove extra tours	tours	Tagged 3,442 tours (~7%)
14	Joint tour type	Recode join tour purposes that are unavailable in ActivitySim (e.g., escorting)	tours	Recoded invalid purposes to shopping, maintenance, eating out, visiting, or discretionary
16	External TAZs	Filter out records with home TAZs outside the modeled region	hh, persons, tours	filtered out 37 households

No	Data processing step	Description	Associated table	Result
17	Disconnected TAZs	Filter out records with home in disconnected TAZs	hh, persons, tours	Filtered out 2 households in TAZ 382
18	All tour checks	all tour checks combined	tours	Removed 5,554 tours (~12%)

After all bad tours are removed and the household and person-level data are 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.

Creating 'Estimation Data Bundles'

Running ActivitySim in estimation mode resembles a base run of ActivitySim except for an added set of configuration files containing the estimation mode settings – which identifies models to estimate, how to estimate them, and the new set of input override tables.[15] Run time for the entire survey is about seven hours[16] with significant RAM requirements (80+ GB). Multiprocessing in estimation mode has not yet been developed, so run time cannot yet be improved by adding additional computational resources.

The ActivitySim estimation mode produces an estimation data bundle for each specified model. The estimation data bundle for tour destination choice includes two primary tables: choosers and alternatives. The chooser table contains the chosen destination for each tour, and the alternatives table contains the values for each term in the model specification for each destination alternative. The estimation data bundle for tour mode choice includes a model specification file and a combined data file that contains household, person, zonal, and network-level variables for each tour. Also, output from the ActivitySim estimation mode are the final person, household, and tour files just like in a base ActivitySim run.

The alternatives file for tour destination choice is usually very big (8 GB+ for ~40K tours with 3,675 zone alternatives). These large files take a long time to load into the Larch environment leading to longer runtimes for estimations. Therefore, all destination choice models were instead estimated using ALOGIT. This required post-processing of alternatives file into ALOGIT format and removing all the redundant fields to reduce the file size for faster loading in ALOGIT. We developed a Jupyter notebook[17] () to generate an ALOGIT input table from the choosers and

[15] Example configuration files: https://github.com/ActivitySim/activitysim/tree/master/activitysim/examples/example_estimation/configs
[16] Server specifications: Intel(R) Xeon(R) Gold 6126 CPU @ 2.6GHz, 240 GB RAM, 24 virtual cores
[17] Jupyter Notebook: create_alogit_input.ipynb, file location: https://app.box.com/s/71f8lrdzcanf8k61e1wgrzkrmdr57iht

alternatives tables for destination choice estimation. The ALOGIT input table has rows for each tour, and columns for the chosen destination from the choosers table, the distance and logsum values to all other alternatives, and household and person-level information.

Separate ALOGIT input tables were created for school, work, and non-mandatory purposes, and at-work subtours. The non-mandatory location choice tables include both joint and non-joint tours. ALOGIT does not allow for categorical variables in the input table, so all categorical variables had to be mapped to integers. Headers are also not allowed in ALOGIT input tables, so column names were removed, and a list of column names was then added to the ALOGIT configuration file.

The Gen3 Model land-use data is also used as input to the tour destination choice model estimation. The land-use data was created in a format required for ALOGIT including the number of households, school and university enrollment, and the number of jobs by employment category. In addition, TAZ-level data on open park space and golf course acres was joined to this table to be used as attraction variables for discretionary destination choice models.

Estimation Data Summaries

Table 3 summarizes tours in the estimation dataset by tour mode and tour purpose. The school purpose includes both university and grade school tours. The maintenance purpose includes shopping and other maintenance tours, while the discretionary purpose includes eating out, social, and other discretionary tours. The estimation data set for the tour mode choice estimation included a total of 37,734 tours. More than 70% of the total tours are auto tours, ~10% transit, and the modes for the rest are non-motorized, school buses, ride-hail services, and taxis. Most of the transit tours are for work purpose. The non-work purposes have very few transit tours and among them the majority are walk-access. A low sample size for drive-transit tours for non-work purposes makes it very hard to estimate coefficients for these modes. In some cases, these modes need to be turned off in the estimation or the coefficients are constrained to a more reasonable value.

TABLE 3: TOURS BY TOUR MODE AND TOUR PURPOSE

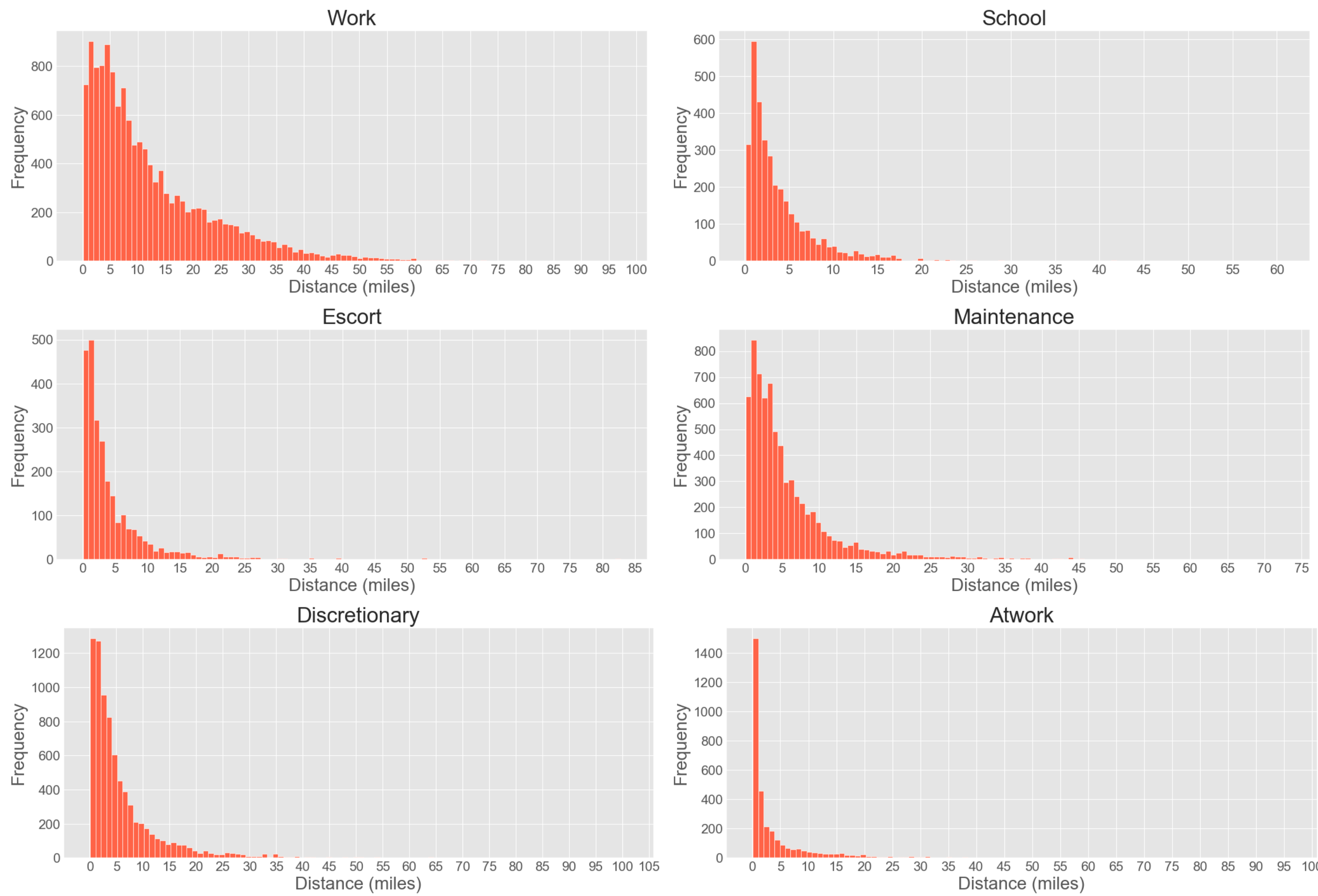
	TOUR PURPOSE													
TOUR MODE	WORK		SCHOOL		ESCORT		MAINTENANCE		DISCRETIONARY		AT WORK		TOTAL	
DRIVEALONE	7,517	55.4%	100	2.9%	2	0.1%	3,524	50.3%	3,270	41.4%	1,450	44.2%	15,863	42.0%
HOV2	1,410	10.4%	489	14.3%	1,245	48.1%	1,751	25.0%	2,034	25.8%	243	7.4%	7,172	19.0%
HOV3+	608	4.5%	803	23.5%	936	36.2%	766	10.9%	1,121	14.2%	134	4.1%	4,368	11.6%
WALK	596	4.4%	355	10.4%	371	14.3%	629	9.0%	978	12.4%	1,173	35.8%	4,102	10.9%
BIKE	287	2.1%	40	1.2%	12	0.5%	35	0.5%	97	1.2%	23	0.7%	494	1.3%
WALK_AB	401	3.0%	40	1.2%	7	0.3%	138	2.0%	94	1.2%	14	0.4%	694	1.8%
WALK_BM	377	2.8%	13	0.4%	2	0.1%	22	0.3%	25	0.3%	-	0.0%	439	1.2%
WALK_CR	22	0.2%	-	0.0%	-	0.0%	-	0.0%	2	0.0%	-	0.0%	24	0.1%
WALK_MR	1,136	8.4%	13	0.4%	3	0.1%	69	1.0%	112	1.4%	98	3.0%	1,431	3.8%
PNR_AB	107	0.8%	-	0.0%	-	0.0%	1	0.0%	1	0.0%	1	0.0%	110	0.3%
PNR_BM	54	0.4%	-	0.0%	-	0.0%	1	0.0%	5	0.1%	-	0.0%	60	0.2%
PNR_CR	120	0.9%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	120	0.3%
PNR_MR	544	4.0%	1	0.0%	3	0.1%	10	0.1%	43	0.5%	4	0.1%	605	1.6%
KNR_AB	14	0.1%	4	0.1%	-	0.0%	3	0.0%	2	0.0%	1	0.0%	24	0.1%
KNR_BM	39	0.3%	3	0.1%	-	0.0%	1	0.0%	1	0.0%	-	0.0%	44	0.1%
KNR_CR	11	0.1%	-	0.0%	-	0.0%	1	0.0%	-	0.0%	-	0.0%	12	0.0%
KNR_MR	125	0.9%	2	0.1%	2	0.1%	6	0.1%	17	0.2%	4	0.1%	156	0.4%
SCHOOLBUS	5	0.0%	1,538	45.1%	2	0.1%	2	0.0%	4	0.1%	4	0.1%	1,555	4.1%
TAXI	41	0.3%	6	0.2%	1	0.0%	23	0.3%	13	0.2%	71	2.2%	155	0.4%
TNC_SHARED	22	0.2%	-	0.0%	-	0.0%	3	0.0%	14	0.2%	18	0.5%	57	0.2%
TNC_SINGLE	122	0.9%	4	0.1%	1	0.0%	24	0.3%	59	0.7%	39	1.2%	249	0.7%
TOTAL	13,558	100.0%	3,411	100.0%	2,587	100.0%	7,009	100.0%	7,892	100.0%	3,277	100.0%	37,734	100.0%

Table 4 presents the unweighted tour length statistics by tour purpose from the RTS/MTS data. Figure 5 shows the tour-length-frequency distributions (TLFD) by tour purpose. The school tours have the shortest average tour length of ~4 miles. The average tour lengths of escort tours and at-work subtours are under 5 miles. The at-work TLFD is highly skewed towards the left with only 25% of the subtours above 4.6 miles. There are a few subtours with longer tour lengths that push the average subtour tour length towards right. The maintenance and discretionary tours have an average tour length of ~6 miles with a TLFD that tapers after 15 miles. The average work tour length is ~12.5 miles with ~25% of the tours above 18 miles.

TABLE 4: TOUR LENGTH (MILES) STATISTICS – UNWEIGHTED

Tour Purpose	Count	Mean	Min	25%	50%	75%	Max
Work	13,558	12.52	0.1	4.1	8.8	17.8	97.1
School	3,411	4.03	0.1	1.3	2.6	5.1	60.7
Escort	2,587	4.67	0.1	1.1	2.6	5.6	82.8
Maintenance	7,009	5.90	0.1	1.8	3.8	7.4	72.5
Discretionary	7,892	6.29	0.1	1.6	3.6	7.5	100.8
At Work	3,277	4.73	0.1	0.4	1.3	4.6	96.1

FIGURE 5: TOUR LENGTH FREQUENCY DISTRIBUTION BY PURPOSE - RTS/MTS



5.0 ESTIMATION RESULTS

This section describes tour and mode choice estimation results.

5.1 TOUR DESTINATION CHOICE

This section describes the estimation results for tour destination choice models including both mandatory location choice and non-mandatory destination choice. As described in Section 3.1, we include both mode choice logsum and distance terms in the model specification, in order to provide sensitivities to all modes of transportation, as well as terms that better reflect the trip length frequency distributions shown in Section 4.0. Due to the correlation between mode choice logsum and distance, it is often not possible to estimate a model with all terms simultaneously. Therefore, we employ a method whereby we first attempt to estimate a simple model with only mode choice logsum and distance; we then constrain the mode choice logsum term to the previously-estimated value and add distance terms to control the distribution. Only final model estimation results are shown below, in which case the t-statistic of the estimated logsum term is not provided as the coefficient for this term is asserted.

Table 5 shows the estimated coefficients and t-statistics for the “quality” variables (variables reflecting accessibility or interaction of demographics and distance) for mandatory location choice models.

Table 6 shows estimated size term parameters. Size term variables include the following:

- Office employment: All general office, administrative, and service functions which do not require production or distribution activity.
- Industrial employment: Production, distribution (non-retail), and manufacturing activities including warehousing and storage.
- Retail employment: All business and personal services sales and related activities that are not wholesale in nature.
- Other employment: Facilities such as military bases, universities, schools, hospitals, and special health facilities, including nursing home, churches, museums, and sporting, recreation, and entertainment venues.
- Total households: Total households in the zone.
- K-8 enrollment: Enrollment for kindergarten through 8th grade.
- 9-12 enrollment: Enrollment for grades 9 through 12 (high school).
- Golf course acres: Acres of land for golf courses.

- Park acres: Acres of land for parks.

Note that the mandatory location choice for college/university students was not estimated as part of Phase I since the household travel survey excludes students living in group quarters and may under-estimate students living in non-family households. Instead, the Gen3 Phase I model will continue to rely upon the college/university location choice model parameters from the donor (Metropolitan Transportation Commission (MTC)) model.

Work Location Choice

The work purpose model includes a mode choice logsum parameter of 0.25 and distance parameters on linear distance, distance squared, distance cubed, and the natural log of distance. The work purpose model has the lowest logsum coefficient among all tour purposes as work tours have the least flexibility in terms of destination choice and the least influence from modal accessibility and congestion effects on the choice of work locations. The model also includes distance interaction parameters on household and person variables as follows:

- Younger (age less than or equal to 25) and older (greater than or equal to 65) workers are more likely to travel a shorter distance to work than other age groups. That may reflect more limited accessibilities for these workers or more spatially distributed job opportunities.
- Female workers are more likely to travel a shorter distance to work than male or gender not identified workers. That may be due to female workers household roles as caregivers for dependents.
- Part-time workers are more likely to travel a shorter distance to work than full-time workers. That may reflect more spatially distributed job opportunities for part-time workers.
- Workers in zero-auto households are more likely to travel a shorter distance to work than workers in households with at least one auto. This likely reflects more limited accessibilities for workers without access to a household vehicle.
- Distance to work is positively correlated with household income; that is commute distance tends to increase with household income, all else being equal.

For work location choice, size terms are segmented by the household income and employment type of the worker. In all worker income categories, office employment is used as the base employment type category (size term parameter of 1.0). All other size term parameters can be compared to this base category. The following observations can be made about work location choice size terms:

- Industrial employment is equally likely to attract low-income workers as Office employment. Retail and Other employment are over twice as likely to attract low-income workers as Office employment.
- Industrial employment is much less likely to attract medium-income workers than Office employment. Retail employment is a bit more than one-half as likely to attract medium-income workers as Office employment. Other employment is 1.3 times as likely to attract medium-income workers as Office employment.
- Industrial employment is approximately one-third as likely to attract high-income workers as Office employment. Retail employment is approximately one-quarter as likely to attract high-income workers as Office employment. Other employment is 0.8 times as likely to attract high-income workers as Office employment.
- Industrial and Retail employment are much less likely to attract very high-income workers than Office employment. Other employment is 0.8 times as likely to attract very high-income workers as Office employment.

School Location Choice

School location choice models were estimated with one set of accessibility and distance interaction parameters for all students, and separate size terms by grade (K-8 versus 9-12). The school purpose model includes a mode choice logsum parameter of 0.30 and distance parameters on linear distance and the natural log of distance. The model also includes distance interaction parameters on household and person variables as follows:

- Students who are also part-time workers are more likely to travel a shorter distance to school than non-workers.
- Students who are from low-income households and very high-income households are more likely to travel a shorter distance to school than students from medium or high-income households.

The size term for each student depends on the grade of the student, where students in grades K-8 are attracted to zones with K-8 enrollment, and students in grades 9-12 are attracted to zones with 9-12 enrollment.

TABLE 5: MANDATORY LOCATION CHOICE MODEL ESTIMATION RESULTS (QUALITY VARIABLES)[18]

Variable	Work		K-12	
	Coefficient	T-Stat	Coefficient	T-Stat
Accessibility Variables				

[18] A T-stat of +/-1.64 corresponds to 90% confidence level. Any estimated coefficient with an absolute T-stat of 1.5 or lower were dropped.

Variable	Work		K-12	
	Coefficient	T-Stat	Coefficient	T-Stat
Mode Choice logsum	0.2500[19]		0.3000[20]	
Distance	-0.0430	-14.80	-0.0760	-9.99
Distance^2 (capped at 30 mi.)	0.0027	8.79		
Distance^3 (capped at 30 mi.)	-0.0001	-8.24		
Log(Dist + 1)	-0.8552	-25.78	-2.0735	-37.70
Distance X Demographics				
Young (age<=25)	-0.0367	-9.27		
Old (age>=65)	-0.0137	-4.35		
Female	-0.0107	-5.40		
Part-time worker	-0.0162	-7.23	-0.0491	-2.02
Student	-0.0260	-4.63		
Zero Auto HH	-0.0337	-4.85		
Low Income (< $50K)	-0.0188	-5.67	-0.0285	-2.08
Medium Income ($50K-$100K)	-0.0048	-2.29		
Very High Income (>= $150K)	0.0057	3.04	-0.0187	-2.55
Child aged 6 to 12			-0.0516	-6.57
Joint tour				
Model Statistics	Value		Value	
Number of workers/students	17,526		4,864	
Log-Likelihood w 0 coeffs	-143491		-33480	
Final Log-Likelihood	-104206		-15222	
Rho-squared w.r.t zero	0.2738		0.5453	

TABLE 6: MANDATORY LOCATION CHOICE MODEL ESTIMATION RESULTS (SIZE TERM VARIABLES)

Size Variables	Work	Non-Univ School
	Coefficient	Coefficient
K_8		1.000
G9_12		1.000
Office Employment x Low Income	1.000	
Office Employment x Med Income	1.000	

[19] The logsum parameter was very significant (T-stat of 177) when estimated using a simple specification.
[20] The logsum parameter was very significant (T-stat of 85) when estimated using a simple specification.

Size Variables	Work	Non-Univ School
	Coefficient	Coefficient
Office Employment x High Income	1.000	
Office Employment x Very High Income	1.000	
Industry Employment x Low Income	1.000	
Industry Employment x Med Income	0.283	
Industry Employment x High Income	0.353	
Industry Employment x Very High Income	0.152	
Retail Employment x Low Income	2.313	
Retail Employment x Med Income	0.575	
Retail Employment x High Income	0.259	
Retail Employment x Very High Income	0.135	
Other Employment x Low Income	2.257	
Other Employment x Med Income	1.307	
Other Employment x High Income	0.810	
Other Employment x Very High Income	0.810	

Escorting Tour Destination Choice

Table 7 shows the estimated coefficients and t-statistics for the "quality" variables (variables reflecting accessibility or interaction of demographics and distance) for non-mandatory tour destination choice models. Table 8 shows estimated size term parameters. The escorting tour purpose covers tours whose main purpose is the pick-up or drop-off of other household members (and non-members, though this includes a very small percentage of all pick-up/drop-off activities). The escorting purpose includes a mode choice logsum parameter of 0.676 and distance parameters on linear distance and the natural log of distance. The model also includes a distance interaction parameter for households with children (age <18) which indicates that escort tours made by members of households with children are more likely to travel shorter distances to the primary pick-up/drop-off location than members of households without children. This is likely because most pick-up/drop-off tours for children are at school locations which tend to be relatively close to the household location.

The base size term for escorting tours is on K-8 enrollment, and size terms for all other employment types, households, and grades 9-12 enrollment are smaller than the base category, indicating the strong attraction of grade school enrollment on escorting tours.

Shopping Tour Destination Choice

The shopping purpose includes a mode choice logsum parameter of 0.676 and distance parameters on linear distance, distance squared, and the natural log of distance. The model also includes distance interaction parameters on household and person variables as follows:

- Younger (age<=25) shoppers are more likely to travel further for shopping than older shoppers. This may be due to less travel time sensitivity or more specialized shopping needs for younger shoppers.
- Female shoppers are more likely to travel further for shopping than male shoppers. This may be due to greater responsibilities for household shopping needs among female shoppers.

The base size term variable for shopping tours is Retail employment. The office employment has a coefficient smaller than retail.

Maintenance Tour Destination Choice

Maintenance tours include medical appointments, banking, and other personal services not otherwise classified. The maintenance purpose includes a mode choice logsum parameter of 0.676 and distance parameters on linear distance, distance squared, and the natural log of distance. The model also includes distance interaction parameters on household and person variables as follows:

- Younger (age<=25) travelers are more likely to travel shorter for maintenance tours than other travelers. This may indicate that younger travelers have a lower priority for maintenance activities and are less likely to spend a lot of time traveling for maintenance activities.
- Part-time workers are more likely to travel shorter for maintenance tours than other travelers. This may be because part-time workers generally undertake more non-mandatory activities compared to full-time workers and as a result may have higher time-pressure for traveling farther.
- Joint tours (where two or more household members travel together on the tour) are more likely to travel longer for maintenance tours than individual tour. This may indicate something about the special nature of fully joint travel for maintenance purposes compared to individual travel.

Retail employment is the base size term category for maintenance tours. All other size term coefficients are smaller than retail; Other employment is roughly one-half the size of Retail employment. There are small size term parameters estimated for Office employment and households and a very small parameter on Industrial employment.

Eating Out Tour Destination Choice

The eating out purpose includes a mode choice logsum parameter of 0.79 and a distance parameter on the natural log of distance. The higher logsum coefficient than other tour purposes indicates more flexibility with respect to destination choice and a greater influence of modal accessibility and congestion effects on the destination of eating out (and other discretionary) tours. The model also includes distance interaction parameters on household and person variables as follows:

- Younger (age<=25) travelers are more likely to travel further for eating out tours than other travelers. This may reflect more selectivity on the part of younger travelers, or more free time available for eating out.
- Part-time workers are more likely to travel further for eating out tours than other travelers. Again this may reflect more free time available for eating out for part-time workers.
- Persons in households with children are more likely to travel shorter for eating out tours than other travelers. This may reflect the need to stay closer to home when eating out with children, or when leaving children with babysitters.
- Persons from very high-income households are more likely to travel shorter distances for eating out tours than other travelers. This may be due to the home location of the very

high-income households. The very high-income neighborhoods are generally closer to good restaurants.

Retail employment is the base size term category for eating out tours. There are also very small coefficients on Other employment and households.

Visiting Tour Destination Choice

The visiting purpose includes a mode choice logsum parameter of 0.79 and a distance parameter on the natural log of distance. The model also includes distance interaction parameters on household and person variables as follows:

- Female travelers are more likely to travel shorter distances for visiting tours than other travelers. This may indicate that female travelers generally have a closer social network compared to male travelers.
- Persons from very high-income households are more likely to travel shorter distances for visiting tours than other travelers. Again, this may reflect that very high-income households typically reside in the same neighborhoods and have smaller social networks.

Total households is the base size term category for eating out tours. There is also a size term coefficient on Retail employment.

Discretionary Tour Destination Choice

The discretionary tour purpose includes discretionary tours other than eating out and visiting, such as recreational tours, attending religious services, sporting events, and other discretionary activities. The Model includes a mode choice logsum parameter of 0.79 and parameters on linear distance, distance squared, and the natural log of distance. The model also includes distance interaction parameters on household and person variables as follows:

- Younger (age<=25) travelers are more likely to travel further for discretionary tours than other travelers
- Female travelers are more likely to travel shorter distances for discretionary tours than other travelers
- Travelers from zero auto households are more likely to travel further distances for discretionary tours than other travelers; this may be compensating for the smaller mode choice logsum for zero auto households.
- Persons from very high-income households are more likely to travel shorter distances for discretionary tours than other travelers.
- Joint tours are more likely to travel further for discretionary tours than individual tours.

The base size term category for discretionary tours is Other employment. There are coefficients on other employment categories as well as a coefficient on households. This purpose also has coefficients on total park acres and golf course acres.

At-Work Subtour Destination Choice

The at-work subtours include all workplace-based tours. The mode choice logsum for this model was estimated at 0.42. Other accessibility terms include linear, squared, cubed, and the natural log of distance. This model also includes distance interaction terms on household and person variables as follows:

- Female workers are more likely to travel shorter distances for at work subtours compared to other travelers
- Workers from zero-auto households are less likely to travel farther for at-work subtours compared to other workers.

The base size term category for at-work subtours is Retail employment. There is also a coefficient on Office employment.

TABLE 7: NON-MANDATORY LOCATION CHOICE MODEL ESTIMATION RESULTS (QUALITY VARIABLES)

	Escorting		Shopping		Maintenance		Eating Out		Visiting		Discretionary		At-work Subtour	
Variable	**Coeff.**	**T-Stat**	**Coeff.**	**T-Stat**	**Coeff.**	**T-Stat**	**Coeff.**	**T-Stat**	**Coeff.**	**T-Stat**	**Coeff.**	**T-Stat**	**Coeff.**	**T-Stat**
Accessibility Variables														
Mode Choice logsum	0.6760[21]		0.6760		0.6760		0.7900[22]		0.7900		0.7900		0.42	4.90
Distance	0.0467	7.83	-0.0466	-3.67	-0.0406	-5.83					0.0158	2.66	0.4873	21.07
Distance^2			-0.0010	-1.56	-0.0014	-2.07					-0.0018	-5.12	-0.0075	-14.54
Distance^3													2.58E-5	9.91
Log(Dist + 1)	-2.4038	-41.08	-2.2976	-43.40	-1.2703	-20.04	-1.9046	-45.98	-1.4089	-24.44	-1.6884	-44.15	-5.3228	-54.92
Distance X Demographics														
Young (age<=25)			0.0320	2.60	-0.0491	-4.84	0.0237	1.62			0.0237	3.66		
Female[23]			0.0213	3.26					-0.0083	-1.06	-0.0088	-2.02	-0.0332	-6.12
Part-time worker[24]					-0.0194	-1.97	0.0244	2.27						
Children in Household	-0.0784	-10.54					-0.0341	-3.15			-0.0168	-3.46		
Zero Auto Household[25]											0.0652	5.32	-0.1352	-3.18
Very High Income >= 150K[26]							-0.0308	-3.28	-0.0189	-1.88	-0.0082	-1.94		

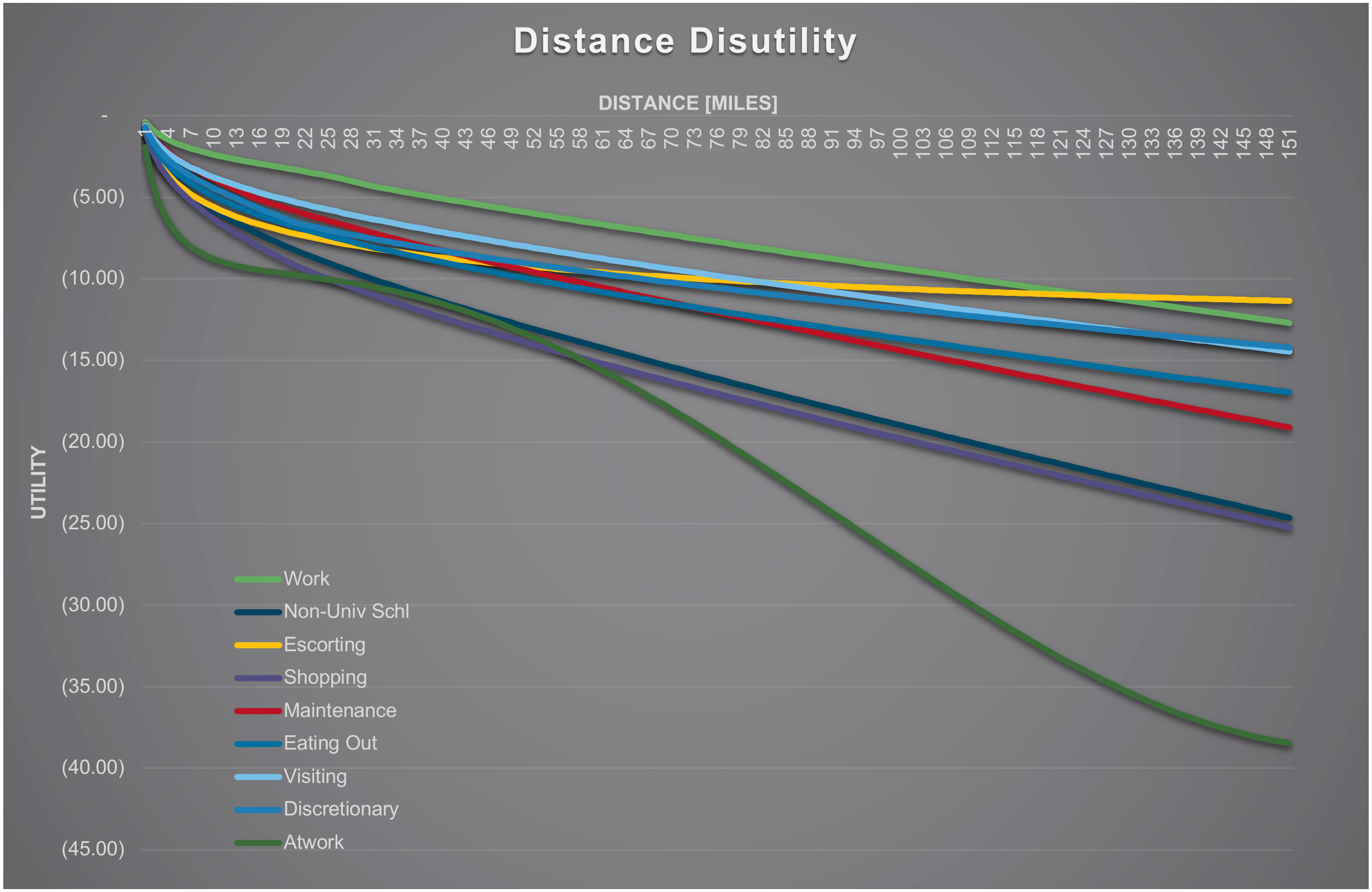
[21] The mode choice logsum coefficients for escorting and shopping purposes were constrained to be the same as maintenance purpose.
[22] The mode choice logsum coefficients for the eating out and visiting purposes were constrained to be the same as discretionary purpose.
[23] Base category is Male or missing gender
[24] Base category is all other person types
[25] Base category is households with at least one car
[26] Base category is households with income < $150K

Joint tour					0.0202	3.10					0.0140	2.55		
Model Statistics														
Number of Tours	2,585		3,984		2,922		1,938		865		5,080		3,232	
Log-Likelihood w 0 coeffs	-21145		-32454		-23922		-15851		-7032		-41579		-26460	
Final Log-Likelihood	-11158		-21194		-14982		-8782		-4563		-25392		-19116	

TABLE 8: NON-MANDATORY LOCATION CHOICE MODEL ESTIMATION RESULTS (SIZE TERM VARIABLES)

Size Variable	**Escorting Coefficient**	**Shopping Coefficient**	**Maintenance Coefficient**	**Eating Out Coefficient**	**Visiting Coefficient**	**Discretionary Coefficient**	**At-work Coefficient**
Office Employment	0.088	0.642	0.216			0.268	0.544
Industry Employment	0.456		0.018				
Retail Employment	0.267	1.000	1.000	1.000	0.377	0.268	1.000
Other Employment	0.739		0.502	0.088		1.000	
Total HH	0.356		0.112	0.029	1.000	0.343	
K_8	1.000						
G9_12	0.552						
Golf Course Acres						1.619	
Park Acres						0.343	

FIGURE 6: DISTANCE DISUTILITY PLOT FOR TOUR DESTINATION CHOICE MODELS



Distance Disutility

Figure 6 shows a distance disutility plot for each tour purpose. This is useful to ensure that the destination choice utility with respect to distance is monotonically decreasing across the range of distance. Otherwise, an inflection point would cause trip lengths to increase for a given range of the distribution which runs counter to the expectation that more accessible destinations should be more attractive, all else being equal. We cap the distance for squared and cubed terms after inspection of the distance disutility plot, by setting the cap just before the inflection point in the curve. The distance caps are shown in Table 9. Distance and natural log of distance terms (which are negative for each purpose) and the mode choice logsum term (positive for each purpose) controls the quality utility of each alternative beyond the cap.

TABLE 9: CAPS ON SQUARED AND CUBED DISTANCE TERMS IN DESTINATION CHOICE UTILITIES

Purpose	Distance cap
Work	30 miles
School	12 miles
Escort	15 miles
Shopping	20 miles
Maintenance	15 miles
Eating Out	15 miles
Visiting	15 miles
Discretionary	20 miles
At-work Subtour	No cap

5.2 TOUR MODE CHOICE

This section describes tour mode choice model estimation results. Tour mode choice models were estimated for the following purpose segments: Work, Non-Mandatory, and At-Work Subtours. Within the Non-Mandatory tour segment, alternative-specific constants were segmented for maintenance tours (including escort, shopping, other maintenance), discretionary tours (eating out, visiting, other discretionary), and joint tours. The estimated alternative-specific constants are shown in Section 7.0. Alternative-specific constants reflect non-included attributes of each alternative, as well as measurement error. Each constant must be interpreted relative to a base alternative, which is drive-alone. A negative constant reflects that the alternative has more disutility than the base alternative, all else being equal. A positive constant reflects that the alternative has more utility than the base alternative, all else being equal. All of the constants must be compared to the base alternative for the specific purpose and auto sufficiency segment (0 autos, autos less than workers, autos greater than/equal to workers).

Otherwise, coefficients were estimated simultaneously for models within each broader purpose category in order to maximize the data available for model estimation. Estimation statics (number of cases, initial and final log-likelihoods) are reported for the entire estimation across all tour purposes in Table 13. The results for the School and University tour purpose were illogical; the in-vehicle time coefficient was very small and many of the other parameters were insignificant. Therefore, we will continue to rely upon the tour mode choice model from the donor ActivitySim model (MTC) for School and University tours.

The estimation results are shown for multinomial logit models; an attempt was made to estimate nested logit models, but the results were not consistent with logit theory and the values of the estimated coefficients in some cases were illogical. Therefore, we plan to continue to use the nested structure from the donor ActivitySim model in the Gen3 Phase I model system but replace the coefficients with the ones described below. Alternative-specific constants and other parameters may be adjusted in calibration.

Work Tour Mode Choice

Table 10 shows tour mode choice estimation results for work tours, for all parameters with the exception of alternative-specific constants. The table shows the estimated value of the coefficient, the t-statistic, the ratio of the coefficient to the in-vehicle time coefficient (as a reasonableness check), and the final implemented value of the coefficient, which may be different than the estimated coefficient if the estimated coefficient was insignificant or otherwise unreasonable. In such cases, the final coefficient is highlighted in yellow.

The estimated in-vehicle time coefficient for work tours is -0.025. This is significantly higher than the coefficient from the donor MTC model (-0.0134). The estimated cost coefficient results in a value of time of $39.68/hour[27]. The average hourly wage rate for the MWCOG region was $34.12/hour in 2018.[28] Common modeling practice suggests that a reasonable value of time for work travel is in the range of 1/2 to 2/3 of the regional average hourly wage rate. Therefore, the final implemented cost coefficient was set to result in a value of time equal to 2/3 of the average hourly wage rate (at the higher end of the value of time range but closer to the estimated value).

The ratio of the walk and bike time, and other out-of-vehicle time coefficients (walk to/from transit, transit first wait, and transit transfer wait time) to in-vehicle time are reasonable, ranging between 1.4 and 1.8. The transfer wait time coefficient is a bit low compared to other models where walk and bike parameters can range between 2 and 5 times more onerous than in-vehicle time, but that may be reasonable given the relatively higher in-vehicle time coefficient. Insignificant coefficients and/or illogical coefficients include transfer walk time for transit (insignificant), drive access time for park-and-ride (positive, illogical) and kiss-and-ride modes (insignificant), and the coefficient on origin TAZ density[29] for walk-transit (negative, illogical). Insignificant and/or illogical out-of-vehicle coefficients were asserted to be twice as onerous as in-vehicle time, and the walk-transit coefficient on density was set to 0. Tours to the CBD are more likely to be made by walk-transit and drive-transit (by approximately 19 minutes and 47 minutes of in-vehicle time respectively). There are reasonable and significant coefficients on density for walk and bike modes. Age and household size affect auto mode utilities; workers aged 16-19 are less likely to drive alone, and workers aged 16+ are less likely to use shared-ride modes. Workers from household size 1 households are less likely to ride-share.

Alternative-specific constants, as shown in Section 7.0, were specified by transit technology and mode of access. The equivalent minutes of in-vehicle time suggest that workers prefer Metrorail and commuter rail to local bus. Not surprisingly, taking bus plus Metrorail (with a transfer required) is less preferable than taking just Metrorail. PNR to commuter rail is heavily preferred over other transit modes. Note that these coefficients will be adjusted in model calibration; therefore, even though some coefficients are insignificant or very large compared to the in-vehicle time coefficient, they will be implemented as-is, at least initially. Very few travelers choose KNR-commuter rail; thus, it has a very negative alternative-specific constant. This may

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[27] Value of time can be calculated by the following formula: ($\beta_{\text{in-vehicle time}}$ / β_{cost}) * 60 (min/hr)/ 100 (cents/dollar)

[28] See https://www.bls.gov/oes/2018/may/oes_47900.htm for the Bureau of Labor Services Washington-Arlington-Alexandria (DC-VA-MD-WV) MSA region mean average hourly wage rate for all occupations in 2018.

[29] TAZ density index is defined as: (TAZ household density * TAZ employment density)/(TAZ household density + TAZ employment density), where TAZ household density is defined as number of household per acre and TAZ employment density is defined as number of jobs per acre.

be revised in application depending upon analysis of Maryland Area Regional Commuter Train (MARC) and Virginia Railways Express (VRE) on-board survey data.

TABLE 10: WORK TOUR MODE CHOICE ESTIMATION RESULTS

Coefficient	Value	T-Stat	Ratio to IVT	Final
In-vehicle time	-0.0250	-17.16	1.00	-0.0250
Cost	-0.0004	-10.02	$ 39.68	-0.00066
Walk time	-0.0344	-16.45	1.38	-0.0344
Bike time	-0.0367	-10.58	1.47	-0.0367
Walk to/from transit time	-0.0457	-21.92	1.83	-0.0457
Transit transfer walk time	0.0062	0.25	-0.25	-0.0500
Drive-access time, PNR	0.0615	2.91	-2.46	-0.0500
Drive access time, KNR	-0.0454	-0.83	1.82	-0.0500
Transit first wait time	-0.0372	-5.47	1.49	-0.0372
Transfer wait time	-0.0382	-6.93	1.53	-0.0382
Walk-transit, CBD constant	0.4790	5.54	-19.16	0.4790
Drive-transit, CBD constant	1.1700	4.35	-46.80	1.1700
Density, walk mode	0.0580	8.95	-2.32	0.0580
Density, bike mode	0.0145	1.77	-0.58	0.0145
Density, walk-transit	-0.0107	-2.89	0.43	0
age 16-19, drive alone	-0.2050	-0.92	8.20	-0.2050
age 16+, shared ride	-0.4540	-3.24	18.16	-0.4540
household size 1, shared ride	-1.5000	-16.59	60.00	-1.5000
household size 2+, shared ride	-0.8950	-16.73	35.80	-0.8950
Walk transit, Metrorail only	1.0100	9.73	-40.40	1.0100
Walk transit, Bus + Metrorail	0.1490	1.23	-5.96	0.1490
Walk transit, Commuter rail	1.2000	2.62	-48.00	1.2000
PNR transit, Metrorail only	-0.8760	-2.66	35.04	-0.8760
PNR transit, Bus + Metrorail	-1.8900	-2.48	75.60	-1.8900
PNR transit, Commuter rail	2.0800	4.79	-83.20	2.0800
KNR transit, Metrorail only	0.4300	0.57	-17.20	0.4300
KNR transit, Bus + Metrorail	0.5580	0.61	-22.32	0.5580
KNR transit, Commuter rail	-8.8800	Not reported	355.20	-8.8800

Non-Mandatory Tour Mode Choice

Non-mandatory tour mode choice estimation results are shown in Table 11. The estimated in-vehicle time coefficient is -0.0213, not as onerous as work (-0.025) but 22% more onerous than the coefficient in the MTC model for non-mandatory tours (-0.0175). The cost coefficient results in a reasonable value of time for non-mandatory tours of $12.06/hour. Walk and bike mode time ratios to in-vehicle time are reasonable, at 2.3 and 2.5 times in-vehicle time respectively. The transit walk time parameter is reasonable at 1.7 times in-vehicle time. A number of other parameters, however, are insignificant or otherwise illogical. Transfer walk time and KNR drive-access time are insignificant and positive. PNR drive time is 16 times as onerous as in-vehicle time. Transit first wait time is 9x more onerous than in-vehicle time. Transfer wait time is insignificant. Illogical or insignificant coefficients were generally asserted to be twice as onerous as in-vehicle time, with the exception of transit first wait time which was asserted to be 1.5 times in-vehicle time, consistent with the work tour mode choice model.

Tours to the CBD are more likely to be made by walk-transit, by approximately 13 minutes of in-vehicle time. Density has positive effects on walking and biking. The density effect on walk-transit was insignificant and therefore will be set to zero. Younger travelers are less likely to walk-transit and drive-alone, and more likely to share a ride for non-mandatory travel. Transit technology constants are largely insignificant, except for the walk to bus and commuter rail, which is negative, likely due to the transfer required. There are few drive-transit tours in the observed data for non-mandatory purposes. In application, drive-transit may be made available based on analysis of observed on-board survey data; otherwise, it will be turned off.

TABLE 11: NON-MANDATORY TOUR MODE CHOICE ESTIMATION RESULTS

Coefficient	Value	T-Stat	Ratio to IVT	Final
In-vehicle time	-0.0213	-6.63	1.00	-0.0213
Cost	-0.0011	-12.11	$ 12.06	-0.0011
Walk time	-0.0488	-32.92	2.29	-0.0488
Bike time	-0.0522	-8.53	2.45	-0.0522
Walk to/from transit time	-0.0371	-9.81	1.74	-0.0371
Transit transfer walk time	0.0236	0.49	-1.11	-0.0426
Drive-access time, PNR	-0.3360	-2.62	15.77	-0.0426
Drive access time, KNR	0.0681	0.51	-3.20	-0.0426
Transit first wait time	-0.1930	-22.21	9.06	-0.0320
Transfer wait time	-0.0129	-1.08	0.61	-0.0426

Coefficient	Value	T-Stat	Ratio to IVT	Final
Walk-transit, CBD constant	0.2720	1.89	-12.77	0.2720
Drive-transit, CBD constant	0.0951	0.12	-4.46	0.0000
Density, walk mode	0.0579	10.42	-2.72	0.0579
Density, bike mode	0.0410	3.32	-1.92	0.0410
Density, walk-transit	-0.0157	-1.86	0.74	0
Age 0-10, walk-transit	-1.4900	-4.30	69.95	-1.4900
age 16-19, drive alone	-1.2300	-6.80	57.75	-1.2300
age 16+, shared ride	0.7900	8.61	-37.09	0.7900
household size 1, shared ride	-1.1300	-16.35	53.05	-1.1300
household size 2+, shared ride	-0.7570	-15.37	35.54	-0.7570
Walk transit, Metrorail only	-0.3020	-1.75	14.18	0.0000
Walk transit, Bus + Metrorail	-0.9790	-3.39	45.96	-0.9790
Walk transit, Commuter rail	2.0100	1.64	-94.37	2.0100

At-Work Subtour Mode Choice

At-work subtour mode choice is largely driven by mode to work and availability of modes at work. Mode use for at-work subtours is also heavily constrained by the amount of time available for the tour, where tours made for lunch or certain meetings have very strict schedules which create significant time pressure. This is in evidence in the at-work subtour mode choice estimation results, shown in Table 12. The in-vehicle time coefficient is quite high (-0.0361) compared to other estimated coefficients or the donor MTC model in-vehicle time coefficient (-0.0188). This also results in a very high value of time, at close to $50/hour for at-work subtours. This may reflect both the very high time pressure for completing these tours within the available time window and a lower cost sensitivity due to travel for business purposes such as work meetings.

While walk time and transit first wait time coefficients are significant and reasonable, other out-of-vehicle time parameters are either insignificant or unreasonable. These parameters were asserted to be twice as onerous as in-vehicle time, with the exception of transfer wait time which was asserted to be equal to the first wait time. Tours to the CBD are more likely to be made by walk-transit, all else being equal. Density has a positive effect on walk mode but is insignificant for bike and walk-transit on at-work subtours. Household and person attributes were not included in the at-work subtour model since the model already constrains the availability of driving alone based on the mode used to get to work (drive-alone is unavailable for at-work subtours unless auto was used as a mode to work). Metrorail is clearly preferred compared to local bus, all else being equal. Bus plus Metrorail and commuter rail have few observations for at-work subtours, as reflected in highly negative alternative-specific constants.

TABLE 12: AT-WORK SUBTOUR MODEL ESTIMATION RESULTS

Coefficient	Value	T-Stat	Ratio to IVT	Final
In-vehicle time	-0.0361	-2.62	1.00	-0.0361
Cost	-0.0004	-1.62	$ 49.91	-0.0004
Walk time	-0.0709	-15.86	1.96	-0.0709
Bike time	-0.0347	-1.21	0.96	-0.0722
Walk to/from transit time	-0.0414	-2.77	1.15	-0.0722
Transit transfer walk time	0.0835	0.36	-2.31	-0.0722
Transit first wait time	-0.1000	-2.03	2.77	-0.1000
Transfer wait time	0.0171	0.24	-0.47	-0.1000
Walk-transit, CBD constant	0.5800	1.03	-16.07	0.5800
Density, walk mode	0.0437	2.13	-1.21	0.0437
Density, bike mode	-0.0005	-0.01	0.01	0.0000
Density, walk-transit	-0.0116	-0.61	0.32	0
Walk transit, Metrorail only	1.9900	3.10	-55.12	1.9900
Walk transit, Bus + Metrorail	-14.3000	N.A.	396.12	-14.3000
Walk transit, Commuter rail	-2.6300	N.A.	72.85	-2.6300

TABLE 13: ESTIMATION STATISTICS FOR TOUR MODE CHOICE MODELS

Statistic	Aggregate	Per Case
Number of Cases	38,064	
Log Likelihood at Convergence	-33,025.33	-0.8676
Log Likelihood at Null Parameters	-75,265.14	-1.9773
Rho Squared w.r.t. Null Parameters	0.5612	

6.0 APPENDIX: IMPORTANCE SAMPLING CORRECTION FACTORS

This appendix describes the calculation of sampling factors used in destination choice. It relies on the following notation:

$i \in C$	=	unique alternatives from the full set
$i \in D \subset C$	=	unique alternatives from the sample
$q(i)$	=	selection probability (probability to be drawn)
n_i	=	selection frequency in the sample
N	=	sample size
V_i	=	utility of a choice alternative
$P(i)$	=	choice probability

Note that the selection frequencies in the sample over unique alternatives are totaled to the sample size:

$$\sum_{i \in D} n_i = N.$$

However, the number of unique alternatives in the sample D can be any number between 1 and N inclusive.

The choice probability with sampling correction factors can be calculated by the following formula:

$$P(i) = \frac{\exp\left[V_i + \ln\left(\frac{n_i}{N \times q(i)}\right)\right]}{\sum_{j \in D} \exp\left[V_j + \ln\left(\frac{n_j}{N \times q(j)}\right)\right]} = \frac{\left(\frac{n_i}{N \times q(i)}\right) \times \exp(V_i)}{\sum_{j \in D}\left(\frac{n_i}{N \times q(j)}\right) \times \exp(V_j)}. \quad \textbf{(1)}$$

Formula (1) assumes a utility correction factor of $\ln\left(\frac{n_i}{N \times q(i)}\right)$.

7.0 APPENDIX: ESTIMATED TOUR MODE CHOICE ALTERNATIVE-SPECIFIC CONSTANTS

TABLE 14: ALTERNATIVE -SPECIFIC CONSTANTS (ASCS) BY TOUR PURPOSE, TOUR MODE, AND AUTO SUFFICIENCY

Constant	Value	T-Statistic
sr2_ASC_no_auto_work	1.46	3.31
sr2_ASC_auto_deficient_work	-0.0356	-0.23
sr2_ASC_auto_sufficient_work	-0.856	-6.08
sr3p_ASC_no_auto_work	1.88	4.74
sr3p_ASC_auto_deficient_work	-1.18	-6.90
sr3p_ASC_auto_sufficient_work	-1.72	-11.99
walk_ASC_no_auto_work	5.00	10.97
walk_ASC_auto_deficient_work	1.25	7.65
walk_ASC_auto_sufficient_work	-0.488	-4.22
bike_ASC_no_auto_work	2.76	6.02
bike_ASC_auto_deficient_work	-0.696	-4.12
bike_ASC_auto_sufficient_work	-3.10	-19.81
walk_transit_ASC_no_auto_work	5.13	11.51
walk_transit_ASC_auto_deficient_work	0.967	5.91
walk_transit_ASC_auto_sufficient_work	-0.527	-3.32
pnr_transit_ASC_no_auto_work	0.00	0.00
pnr_transit_ASC_auto_deficient_work	-2.15	-4.55
pnr_transit_ASC_auto_sufficient_work	-2.80	-7.32
knr_transit_ASC_no_auto_work	0.576	0.57
knr_transit_ASC_auto_deficient_work	-3.68	-4.10
knr_transit_ASC_auto_sufficient_work	-4.34	-5.51
taxi_ASC_no_auto_work	2.38	4.77
taxi_ASC_auto_deficient_work	-1.62	-6.26
taxi_ASC_auto_sufficient_work	-3.15	-14.42
tnc_single_ASC_no_auto_work	3.08	6.88
tnc_single_ASC_auto_deficient_work	-1.26	-6.85
tnc_single_ASC_auto_sufficient_work	-3.73	-19.25

Constant	Value	T-Statistic
tnc_shared_ASC_no_auto_work	1.38	2.56
tnc_shared_ASC_auto_deficient_work	-2.84	-8.47
tnc_shared_ASC_auto_sufficient_work	-4.84	-16.98
sr2_ASC_no_auto_maintenance	1.28	2.90
sr2_ASC_auto_deficient_maintenance	-1.29	-7.55
sr2_ASC_auto_sufficient_maintenance	-2.14	-22.47
sr3p_ASC_no_auto_maintenance	1.36	3.13
sr3p_ASC_auto_deficient_maintenance	-1.65	-9.30
sr3p_ASC_auto_sufficient_maintenance	-2.48	-25.80
walk_ASC_no_auto_maintenance	6.14	13.99
walk_ASC_auto_deficient_maintenance	0.613	3.40
walk_ASC_auto_sufficient_maintenance	-0.360	-4.33
bike_ASC_no_auto_maintenance	0.232	0.32
bike_ASC_auto_deficient_maintenance	-3.31	-9.67
bike_ASC_auto_sufficient_maintenance	-5.18	-21.97
walk_transit_ASC_no_auto_maintenance	7.29	15.97
walk_transit_ASC_auto_deficient_maintenance	0.323	1.02
walk_transit_ASC_auto_sufficient_maintenance	-0.768	-3.42
pnr_transit_ASC_no_auto_maintenance	0.00	NA
pnr_transit_ASC_auto_deficient_maintenance	-31.6	-BIG
pnr_transit_ASC_auto_sufficient_maintenance	-33.3	-BIG
knr_transit_ASC_no_auto_maintenance	-31.7	-BIG
knr_transit_ASC_auto_deficient_maintenance	-34.6	-BIG
knr_transit_ASC_auto_sufficient_maintenance	-29.1	-BIG
taxi_ASC_no_auto_maintenance	5.20	9.35
taxi_ASC_auto_deficient_maintenance	-2.06	-2.02
taxi_ASC_auto_sufficient_maintenance	-1.73	-5.36
tnc_single_ASC_no_auto_maintenance	4.21	8.45
tnc_single_ASC_auto_deficient_maintenance	-2.61	-3.60
tnc_single_ASC_auto_sufficient_maintenance	-3.49	-9.87
tnc_shared_ASC_no_auto_maintenance	1.73	1.60
tnc_shared_ASC_auto_deficient_maintenance	-2.97	-2.93
tnc_shared_ASC_auto_sufficient_maintenance	-207.	-BIG
sr2_ASC_no_auto_discretionary	0.595	1.47
sr2_ASC_auto_deficient_discretionary	-1.38	-6.94
sr2_ASC_auto_sufficient_discretionary	-1.86	-19.43
sr3p_ASC_no_auto_discretionary	-0.299	-0.61

Constant	Value	T-Statistic
sr3p_ASC_auto_deficient_discretionary	-1.61	-7.68
sr3p_ASC_auto_sufficient_discretionary	-2.18	-22.33
walk_ASC_no_auto_discretionary	5.39	13.37
walk_ASC_auto_deficient_discretionary	2.10	10.95
walk_ASC_auto_sufficient_discretionary	0.505	5.94
walk_transit_ASC_no_auto_discretionary	5.98	14.27
walk_transit_ASC_auto_deficient_discretionary	2.04	7.08
walk_transit_ASC_auto_sufficient_discretionary	0.531	2.50
pnr_transit_ASC_no_auto_discretionary	0.00	0.00
pnr_transit_ASC_auto_deficient_discretionary	-34.3	-BIG
pnr_transit_ASC_auto_sufficient_discretionary	-14.5	-18.35
knr_transit_ASC_no_auto_discretionary	-10.8	-12.50
knr_transit_ASC_auto_deficient_discretionary	-35.0	-BIG
knr_transit_ASC_auto_sufficient_discretionary	-16.3	-21.05
taxi_ASC_no_auto_discretionary	3.53	5.07
taxi_ASC_auto_deficient_discretionary	-0.656	-0.65
taxi_ASC_auto_sufficient_discretionary	-1.46	-3.38
tnc_single_ASC_no_auto_discretionary	3.86	8.64
tnc_single_ASC_auto_deficient_discretionary	0.261	0.71
tnc_single_ASC_auto_sufficient_discretionary	-1.38	-6.26
tnc_shared_ASC_no_auto_discretionary	1.94	2.44
tnc_shared_ASC_auto_deficient_discretionary	-0.915	-1.26
tnc_shared_ASC_auto_sufficient_discretionary	-3.03	-5.88
joint_sr2_ASC_no_auto_all	0.00	NA
joint_sr2_ASC_auto_deficient_all	0.00	NA
joint_sr2_ASC_auto_sufficient_all	0.00	NA
joint_sr3p_ASC_no_auto_all	0.00	0.00
joint_sr3p_ASC_auto_deficient_all	0.00	0.00
joint_sr3p_ASC_auto_sufficient_all	0.00	0.00
joint_walk_ASC_no_auto_all	0.00	NA
joint_walk_ASC_auto_deficient_all	0.00	0.00
joint_walk_ASC_auto_sufficient_all	0.00	0.00
joint_bike_ASC_no_auto_all	0.00	0.00
joint_bike_ASC_auto_deficient_all	0.00	0.00
joint_bike_ASC_auto_sufficient_all	0.00	0.00
joint_walk_transit_ASC_no_auto_all	0.00	NA
joint_walk_transit_ASC_auto_deficient_all	0.00	NA

Constant	Value	T-Statistic
joint_walk_transit_ASC_auto_sufficient_all	0.00	NA
joint_pnr_transit_ASC_no_auto_all	0.00	NA
joint_pnr_transit_ASC_auto_deficient_all	0.00	0.00
joint_pnr_transit_ASC_auto_sufficient_all	0.00	0.00
joint_knr_transit_ASC_no_auto_all	0.00	0.00
joint_knr_transit_ASC_auto_deficient_all	0.00	0.00
joint_knr_transit_ASC_auto_sufficient_all	0.00	0.00
joint_taxi_ASC_no_auto_all	0.00	0.00
joint_taxi_ASC_auto_deficient_all	0.00	0.00
joint_taxi_ASC_auto_sufficient_all	0.00	NA
joint_tnc_single_ASC_no_auto_all	0.00	0.00
joint_tnc_single_ASC_auto_deficient_all	0.00	0.00
joint_tnc_single_ASC_auto_sufficient_all	0.00	NA
joint_tnc_shared_ASC_no_auto_all	0.00	0.00
joint_tnc_shared_ASC_auto_deficient_all	0.00	0.00
joint_tnc_shared_ASC_auto_sufficient_all	0.00	NA
joint_sr2_ASC_no_auto_maintenance	0.00	NA
sr2_ASC_no_auto_atwork	-13.2	-24.44
joint_sr2_ASC_auto_deficient_maintenance	0.00	NA
sr2_ASC_auto_deficient_atwork	4.63	11.62
joint_sr2_ASC_auto_sufficient_maintenance	0.00	NA
sr2_ASC_auto_sufficient_atwork	5.28	22.91
joint_sr3p_ASC_no_auto_maintenance	-0.678	-0.72
sr3p_ASC_no_auto_atwork	-13.0	-25.21
joint_sr3p_ASC_auto_deficient_maintenance	-4.55	-4.45
sr3p_ASC_auto_deficient_atwork	4.46	10.93
joint_sr3p_ASC_auto_sufficient_maintenance	-2.31	-22.06
sr3p_ASC_auto_sufficient_atwork	4.74	19.93
joint_walk_ASC_no_auto_maintenance	4.78	4.80
walk_ASC_no_auto_atwork	-14.7	-29.07
joint_walk_ASC_auto_deficient_maintenance	0.529	1.22
walk_ASC_auto_deficient_atwork	2.19	4.77
joint_walk_ASC_auto_sufficient_maintenance	0.401	1.98
walk_ASC_auto_sufficient_atwork	1.82	10.91
joint_bike_ASC_no_auto_maintenance	-10.6	-BIG
bike_ASC_no_auto_atwork	-19.1	-13.16
joint_bike_ASC_auto_deficient_maintenance	-45.2	-BIG

Constant	Value	T-Statistic
bike_ASC_auto_deficient_atwork	-0.937	-1.20
joint_bike_ASC_auto_sufficient_maintenance	-4.45	-8.32
bike_ASC_auto_sufficient_atwork	-1.34	-1.74
joint_walk_transit_ASC_no_auto_maintenance	4.23	4.68
walk_transit_ASC_no_auto_atwork	-20.8	-23.26
joint_walk_transit_ASC_auto_deficient_maintenance	-14.5	-BIG
walk_transit_ASC_auto_deficient_atwork	-3.65	-3.40
joint_walk_transit_ASC_auto_sufficient_maintenance	-0.0946	-0.21
walk_transit_ASC_auto_sufficient_atwork	-3.31	-3.47
joint_pnr_transit_ASC_no_auto_maintenance	0.00	NA
pnr_transit_ASC_no_auto_atwork	0.00	0.00
joint_pnr_transit_ASC_auto_deficient_maintenance	-29.8	-BIG
pnr_transit_ASC_auto_deficient_atwork	-0.688	-0.10
joint_pnr_transit_ASC_auto_sufficient_maintenance	-30.4	-BIG
pnr_transit_ASC_auto_sufficient_atwork	-4.27	-0.30
joint_knr_transit_ASC_no_auto_maintenance	-33.4	-BIG
knr_transit_ASC_no_auto_atwork	-76.7	-BIG
joint_knr_transit_ASC_auto_deficient_maintenance	-34.9	-BIG
knr_transit_ASC_auto_deficient_atwork	-52.5	-BIG
joint_knr_transit_ASC_auto_sufficient_maintenance	-27.7	-BIG
knr_transit_ASC_auto_sufficient_atwork	-30.8	-30.17
joint_taxi_ASC_no_auto_maintenance	4.40	4.32
taxi_ASC_no_auto_atwork	-20.2	-20.23
joint_taxi_ASC_auto_deficient_maintenance	-16.6	-BIG
taxi_ASC_auto_deficient_atwork	-2.96	-2.83
joint_taxi_ASC_auto_sufficient_maintenance	0.00	NA
taxi_ASC_auto_sufficient_atwork	-3.10	-3.74
joint_tnc_single_ASC_no_auto_maintenance	2.27	1.89
tnc_single_ASC_no_auto_atwork	-19.7	-30.05
joint_tnc_single_ASC_auto_deficient_maintenance	-14.0	-BIG
tnc_single_ASC_auto_deficient_atwork	-33.7	-BIG
joint_tnc_single_ASC_auto_sufficient_maintenance	0.00	NA
tnc_single_ASC_auto_sufficient_atwork	-4.21	-5.91
joint_tnc_shared_ASC_no_auto_maintenance	-19.1	-BIG
tnc_shared_ASC_no_auto_atwork	-50.7	-BIG
joint_tnc_shared_ASC_auto_deficient_maintenance	-14.1	-BIG
tnc_shared_ASC_auto_deficient_atwork	-21.8	-BIG

Constant	Value	T-Statistic
joint_tnc_shared_ASC_auto_sufficient_maintenance	0.00	NA
tnc_shared_ASC_auto_sufficient_atwork	-4.12	-4.75
joint_sr2_ASC_no_auto_discretionary	0.00	NA
joint_sr2_ASC_auto_deficient_discretionary	0.00	NA
joint_sr2_ASC_auto_sufficient_discretionary	0.00	NA
joint_sr3p_ASC_no_auto_discretionary	24.1	60.98
joint_sr3p_ASC_auto_deficient_discretionary	-1.41	-5.74
joint_sr3p_ASC_auto_sufficient_discretionary	-1.82	-22.76
joint_walk_ASC_no_auto_discretionary	28.6	69.32
joint_walk_ASC_auto_deficient_discretionary	2.06	7.51
joint_walk_ASC_auto_sufficient_discretionary	0.758	4.60
joint_bike_ASC_no_auto_discretionary	-8.32	-BIG
joint_bike_ASC_auto_deficient_discretionary	-2.47	-4.44
joint_bike_ASC_auto_sufficient_discretionary	-4.28	-9.58
joint_walk_transit_ASC_no_auto_discretionary	28.0	74.78
joint_walk_transit_ASC_auto_deficient_discretionary	0.818	1.66
joint_walk_transit_ASC_auto_sufficient_discretionary	-1.31	-1.78
joint_pnr_transit_ASC_no_auto_discretionary	0.00	NA
joint_pnr_transit_ASC_auto_deficient_discretionary	-10.7	-11.54
joint_pnr_transit_ASC_auto_sufficient_discretionary	-31.7	-BIG
joint_knr_transit_ASC_no_auto_discretionary	-5.28	-BIG
joint_knr_transit_ASC_auto_deficient_discretionary	-34.9	-BIG
joint_knr_transit_ASC_auto_sufficient_discretionary	-25.8	-BIG
joint_taxi_ASC_no_auto_discretionary	-1.26	-BIG
joint_taxi_ASC_auto_deficient_discretionary	0.413	0.56
joint_taxi_ASC_auto_sufficient_discretionary	0.00	NA
joint_tnc_single_ASC_no_auto_discretionary	-2.18	-BIG
joint_tnc_single_ASC_auto_deficient_discretionary	-1.57	-1.54
joint_tnc_single_ASC_auto_sufficient_discretionary	0.00	NA
joint_tnc_shared_ASC_no_auto_discretionary	-1.99	-BIG
joint_tnc_shared_ASC_auto_deficient_discretionary	-0.165	-0.27
joint_tnc_shared_ASC_auto_sufficient_discretionary	0.00	NA

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