MODE CHOICE, LOGSUMS, AND AUTO OWNERSHIP MODEL ESTIMATION

SOUNDCAST ACTIVITY-BASED TRAVEL MODEL FOR PSRC

PUGET SOUND REGIONAL COUNCIL
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This document presents auto ownership, accessibility logsums, and mode choice model estimation results.

AUTO OWNERSHIP MODEL

Model Structure

This is a multinomial logit model which predicts the number of automobiles owned by household. The choices range from no cars to 4+ cars.

The most predictive variables in this model are the number of drivers and workers in the household. Household income is also highly predictive. The model also includes variables related to household and work transportation accessibility, and land use around the home parcel.

MODE CHOICE MODELS

Model Structure

As auto ownership also has a strong impact on mode choice, this document reports the results of estimation of three sets of mode choice models:

(1) Detailed models at the tour level

(2) Simplified models at the tour level, for use in calculating aggregate accessibility logsums

(3) Detailed models at the trip level, constrained by the tour level modes

All the mode choice models are either nested logit or multinomial logit.

There are seven home-based tour purposes (work, school, escort, personal business, shopping, meal, and social/recreation) plus one work-based purpose. There are also eight modes, although some of them are only available for specific purposes. They are listed below along with the availability rules, the same priority order as used to determine the main mode of a multi-mode tour:

(1) DT- Drive to Transit: Available only in the Home-based Work model, for tours with a valid drive to transit path in both the outbound and return observed tour

(2) WT- Walk to Transit: Available in all models except for Home-based Escort, for tours with a valid walk to transit path in both the outbound and return observed tour periods.

(3) SB: School Bus: Available only in the Home-based School model, for all tours.

(4) S3- Shared Ride 3+: Available in all models, for all tours.

(5) S2- Shared Ride 2: Available in all models, for all tours.

(6) DA- Drive Alone: Available in all models except for Home-based Escort, for tours made by persons age 16+ in car-owning households.

(7) BI- Bike: Available in all models except for Home-based Escort, for all tours with round trip road distance of 30 miles or less.

(8) WK- Walk: Available in all models, for all tours with round trip road distance of 10 miles or less.

ACCESSIBILITY LOGSUMS

UPWARD INTEGRATION OF HIERARCHICAL ACTIVITY-BASED MODELS OR SENSITIVITY TO IMPEDANCE AND SPATIAL ATTRIBUTES IN ACTIVITY-BASED MODELS

A frequent critique of some trip-based models is that, for some aspects of travel choice that are sensitive to travel level of service (LOS), the travel demand models are NOT sensitive to travel level of service. This often includes trip generation and time-of-day aspects, and if the model is not properly equilibrated with the traffic assignment model, then it also includes trip distribution and mode choice. A second criticism, heard less often but still important, is that sometimes the techniques used to make the models sensitive to LOS are flawed, yielding inaccurate sensitivity to LOS. For example, if a destination choice or trip distribution model uses auto travel time and ignores transit time, then it is sensitive to auto LOS, but completely insensitive to transit LOS. It is even possible to construct composite accessibility measures that are sensitive in the wrong direction: improve transit service and transit mode share predictions fall. One argument in favor of properly constructed nested logit models has been that their logsum variable captures LOS effects at the upper level of a nested model in a way that takes into consideration all lower level alternatives and avoids counter-intuitive effects (Ben-Akiva and Lerman, 1985).

A similar critique can be made for models' sensitivity to spatial attributes, such as the distribution of employment, housing and other activity opportunities. Although proper sensitivity to these does not necessarily require equilibration with a traffic assignment model, since these attributes depend on land development processes, it still requires integration of the model components. For example, although a person or household's trip generation rates may depend significantly on the distribution of activity opportunities, model sensitivity to activity opportunities may be limited to the trip distribution or destination choice model. It is possible to use ad hoc measures, such as the density of activity opportunities of certain types within certain distances, to capture sensitivity of trip generation to activity opportunities. Here again, however, it is easy to make the models inappropriately sensitive in ways that bias predictions, and the use of logsum measures have been highly regarded as perhaps the best available means of capturing composite effects that cannot be measured directly in a model.

In recent years, activity-based models have been widely praised as being behaviorally more realistic than traditional trip-based models. They are supposed to achieve this by modeling aspects of choice that trip-based models ignore, by integrating the choices made by an individual over the course of a day, and in some cases, by integrating choices made by members of the same household. To the authors' knowledge, all current practical activity-based models with a behavioral foundation, including those under development, model the many aspects of choice by breaking the outcome into a conditional model hierarchy or a chain of models. Models lower in the hierarchy (or later in the chain) take as given the outcomes higher in the hierarchy. This achieves what has been referred to by Vovsha, Bradley and Bowman (2004) as downward vertical integrity. Done properly, it assures that lower level models adhere to constraints imposed at higher levels, and makes the lower level models indirectly sensitive to all variables that directly affect the upper level outcomes.

Just as important as downward vertical integrity is upward vertical integrity (In this paper we ignore the likely problems caused by choosing an inferior hierarchy or forcing a network of interrelated choice aspects into a hierarchy or chain). Upward vertical integrity comes from making the upper level models appropriately sensitive to variables that affect the upper level outcome, but can't be measured directly because they differ among the undetermined lower level model outcomes. In formal nested logit hierarchies the upward integrity comes from the logsum, the composite measure of expected utility across the lower level alternatives.

One of the key contributions made by Bowman (1995) when he first developed a hierarchical model system representing a person's entire day, was his demonstration that the model of a person's choice of overarching day activity pattern can be made sensitive to transportation level of service, via logsum variables based on nested logit concepts. By doing that he also gave evidence that the choice of day activity pattern is indeed sensitive to transportation level of service. In other words, he demonstrated the need for upward vertical integrity and a way to achieve it.

Unfortunately, the strength of the logsum variable as a composite measure rests in a feature that makes it computationally expensive, and essentially infeasible with very large and detailed hierarchical model systems: it requires the calculation of utility for every single alternative in the hierarchy below the level being modeled. In order to model the highest level outcome, utilities of all alternatives in the entire hierarchy must be computed.

Therefore, none of the practical activity-based models implemented since Bowman's prototype (with the exception of the first models implemented at Portland METRO) have used logsums at the highest levels of the model system. Instead, they have resorted to the kinds of ad hoc measures that have been criticized in trip-based models, measures that tend to ignore or distort important indirect effects on upper level outcomes, most notably the effect of transportation level of service and land development attributes on the whole day activity pattern. For example, it is common to use a measure such as the number of jobs accessible within a certain amount of time by a certain mode, with separate variables calculated for auto and transit. However, the variables are correlated in the data, preventing the accurate identification of separate parameters; one of the parameters tends to dominate, and as a result the model gives too much weight to that mode, and ignores the effect of other modes.

Scant attention has been given to this problem since Bowman's prototype, and good solutions are still needed. Solutions far superior to the best current approaches should be possible. In private correspondence, Vovsha has suggested that in the context of a microsimulation that is iterated to achieve equilibration between demand and traffic assignment, it may be feasible to use actual utilities of the simulated chosen alternative from prior iterations instead of calculating the logsum every iteration, since the logsum represents the expected maximum utility, and the utility of the simulated outcome represents the simulated maximum utility. It may be appropriate to retain simulated outcome utlilities from all prior iterations and use a moving average to reduce random fluctuations and improve convergence. Another possibility that might work, again in the context of iterative microsimulation, is to use logsums but only re-simulate a fraction of the activity schedules, or only recalculate a fraction of the logsums, during each iteration.

In DaySim, two other techniques are used in an effort to achieve better upward vertical integrity. The basic idea of the first technique is to avoid the use of a logsum when applying an upper level model by treating as given a conditional outcome that is not known, and would otherwise require the calculation of a logsum from all possible conditional outcomes. The assumed conditional outcome is selected by a Monte Carlo draw using approximate probabilities for the conditional outcome. Rather than making every simulated outcome sensitive to variability in the conditional outcome, sensitivity is achieved across the population through the variability of outcome in the Monte Carlo draws. This technique is used to include time-of-day sensitivity in the tour destination choice models, along with tour mode choice logsums. In this way, the destination choice models are sensitive to variations in transport level of service and spatial attributes across all possible combinations of time-of-day and mode, with the affects approximately weighted by the joint time-of-day and mode choice probabilities.

The basic idea of the second technique is to calculate an approximate, or aggregate, logsum. It is calculated in the same basic way as a true logsum, by calculating the utility of multiple alternatives, and then taking expectation across the alternatives by calculating the log of the sum of the exponentiated utilities. However, the amount of computation is reduced, either by ignoring some differences among decisionmakers, or by calculating utility for a carefully chosen subset or aggregation of the available alternatives. The approximate logsum is pre-calculated and used by several of the model components, and can be re-used for many persons. The categories of decisionmakers and the aggregation of alternatives are chosen so that in all choice cases an approximate logsum is available that closely approximates the true logsum. In essence, this is a sophisticated ad hoc measure that is intended to achieve most of the realism of the true logsum at a small fraction of the cost. Two kinds of approximate logsums are used, an approximate tour mode-destination choice logsum and an approximate intermediate stop location choice logsum.

The approximate tour mode-destination choice logsum is used in situations where information is needed about accessibility to activity opportunities in all surrounding locations by all available transport modes at all times of day. Because of the large amount of computation required for calculating a true logsum for all feasible combinations in these three dimensions, an approximate logsum is used with several simplifications. First, it ignores socio-demographic characteristics, except for car availability. Second, it uses aggregate distance bands for transit walk access. Third, sometimes it uses a logsum for a composite or most likely purpose instead of calculating it across a full set of specific purposes. Finally, instead of basing the logsum on the exact available time window of the choice situation, and calculating it across all of the available time period combinations within the window, it uses a particular available time window size and time period combination. With these simplifications, it is possible to pre-calculate a relatively small number of logsums for each TAZ, and use them when needed at any point in the simulation of any person's day activity schedule.

The approximate intermediate stop location choice logsum is used in the activity pattern models, where accessibility for making intermediate stops affects whether the pattern will include intermediate stops on tours, and how many. Four logsums are calculated for each OD zone pair, distinguished by tour mode (transit or auto) and time of day (peak or offpeak). Each logsum is calculated across all possible intermediate stop zones, each stop's utility is a function of travel time and zonal attractiveness, and zonal attractiveness is a function of employment and school enrollment, taken from an estimated purpose-non-specific location choice model.

Auto Ownership Model variables

Variables

Traveler/household characteristics

A driver was defined as person ages 16 or older. In this structure, it is assumed that the household's auto availability decision is made with full knowledge of all household members' usual work and school locations.

1 driver in HH – 1 if there is only one driver in the household, zero otherwise

2 drivers in HH – 1 if there are only two drivers in the household, zero otherwise

3 drivers in HH – 1 if there are only three drivers in the household, zero otherwise

4+ drivers in HH – 1 if there are four or more drivers in the household, zero otherwise

At least as many cars as workers – 1 if there are at least as many cars as the sum of full time and part time workers, zero otherwise. Because the number of cars owned by the household is being estimated, this variable is calculated separately for each alternative based on the number of cars of the alternative. For the no car alternative, this variable will be 1 only if there are no workers in the household, which would be true in retired households.

Part-time workers per driver – the number of part-time workers in the household divided by the number of drivers in the household.

Elderly (75+) adults per driver – the number of elderly (age 75 and older) adults in the household divided by the number of drivers in the household

University students per driver – the number of university students in the household divided by the number of drivers in the household

Driving age children per driver – the number of driving age children in the household divided by the number of drivers in the household (Need to find out how Mark/John defined this category when they created it)

Children under 5 per driver – the number of children under age five in the household divided by the number of drivers in the household

HH Income under $15,000/year – 1 if the household's income is less than $15,000/year, zero otherwise

HH Income between $15,000/year and $30,000/year – 1 if the household's income is $15,000/year or greater but less than $30,000/year, zero otherwise

HH Income between $50,000/year and $75,000/year – 1 if the household's income is $50,000/year or greater but less than $75,000/year, zero otherwise

HH income above $75000/year – 1 if the household's income is $75,000 or greater, zero otherwise

HH income not reported – 1 if the household's income was not reported, zero otherwise (estimation only)

Transportation level of service

Log Distance to Transit Stop – This variable represents the natural log of the distance to the nearest transit stop from a home location.

Number of Transit Stops in the Household Buffer – This variable represents the number of transit stops in a weighted-by-distance buffer around a household's location.

(Acc. Var. Logsum FT worker) * (HH Inc Under $30k/yr) – Each worker in the household has a tour mode choice logsum between home and usual work location calculated in two ways. One, that each driver in the household has an auto available, and the other, that the household has no autos. For each person that is a full time worker and has a household income of under $30,000/yr, the difference between the logsums of full car ownership and no car ownership was calculated, and then this difference was summed for all people in the household. This is a measure of transit quality, because if transit is good in the vicinity of the household, then there will be a small difference between the two logsums and the effect of not having a car won't be as noticeable as if transit service is poor.

Acc. Var. Logsum Students – Full car and no car ownership tour mode choice logsums were also calculated for students between their home and usual school location. This variable was calculated similarly to the FT worker accessibility logsum.

Amount by which distance to nearest transit stop is less than 0.5 miles (capped at .25) – The closer a local, premium, or rail stop is to the home, the bigger this variable will be (in the range of .25 to 0). If the distance is greater than 0.5 miles, then this variable will be equal to zero.

Land Use variables

Natural log of food, service, retail and medical employment density – The log of 1 plus the residence zone parcel employment in the buffer

Estimation Statistics
Analysis is based on 4741 observations
Likelihood with Zero Coefficients = -7630.3451
Final value of Likelihood = -4568.1948
"Rho-Squared" w.r.t. Zero = .4013

Table 1 shows the results of model estimation and calibration, and a description of the model variables follows with a summary of the estimation results.

Alternative	Variable Definition	Coefficient	t- stat
0 cars	household has 1 driver	-5.92	-12.36
0 cars	household has 2 drivers	-6.40	-12.91
0 cars	household has 3 drivers	-5.77	-6.74
0 cars	household has 4 or more drivers	-4.82	-4.91
0 cars	household has no full or part time worker	0.42	3.86
0 cars	household Part time Workers Per Driving Age Members	0.20	0.60
0 cars	household has 0 to 15K Income	2.01	4.86
0 cars	household has 50 to 75K Income	-1.67	-5.63
0 cars	household has 75K Income	-3.36	-7.04
0 cars	household has missing income	-1.62	-4.77
0 cars	work tour logsum difference	-0.21	-3.22
0 cars	school tour logsum difference	-1.39	-0.63
0 cars	Log(distance to Stop)	-0.57	-5.21
0 cars	Log of food, retail, service, and medical jobs in buffer 1	0.54	7.90
0 cars	ruralFlag	1.06	1.98
1 car	household has 2 drivers	-1.74	-9.63
1 car	household has 3 drivers	-2.36	-6.89
1 car	household has 4 or more drivers	-2.48	-4.39
1 car	household Has1or less full or part time workers	0.42	3.86
1 car	household Part time Workers Per Driving Age Members	0.02	0.13
1 car	household Retired Adults Per Driving Age Members	0.23	2.04
1 car	household university students per driving age members	1.44	3.69
1 car	household Driving Age Students Per Driving Age Members	2.25	3.32
1 car	household has 0 to 15K Income	0.48	1.26
1 car	household has 50 to 75K Income	-0.59	-4.66

1 car	household has 75K Income	-1.04	-8.87
1 car	household has missing income	-0.64	-4.33
1 car	work tour logsum difference * household has more drivers than 1	-0.09	-4.70
1 car	Math.Log(1 + household residence parcels stops in transit buffer 1) * household has more drivers than 1	0.22	3.08
1 car	Log of food, retail, service, and medical jobs in buffer 1 * household has more drivers than 1	0.16	3.46
2 cars	household has 1 driver	-2.04	-19.59
2 cars	household has 3 drivers	-0.72	-3.17
2 cars	household has 4 or more drivers	-1.19	-3.24
2 cars	household Has2or less full or part time workers	0.42	3.86
2 cars	work tour logsum difference * household has more drivers than 2	-0.09	-4.70
2 cars	Math.Log(1 + household residence parcels stops in transit buffer 1) * household has more drivers than 2	0.22	3.08
2 cars	Log of food, retail, service, and medical jobs in buffer 1 * household has more drivers than 2	0.16	3.46
3 cars	household has 1 driver	-3.73	-19.55
3 cars	household has 2 drivers	-1.25	-9.90
3 cars	household has 4 or more drivers	-0.67	-1.93
3 cars	household Has3or less full or part time workers	0.42	3.86
3 cars	household Retired Adults Per Driving Age Members	-0.33	-1.99
3 cars	household university students per driving age members	0.59	1.28
3 cars	household home based persons per driving age members	-2.13	-1.27
3 cars	household Children Under 5 Per Driving Age Members	-0.23	-1.13
3 cars	household has 50 to 75K Income	0.16	1.07
3 cars	household has 75K Income	0.11	0.87
3 cars	household has missing income	-0.06	-0.32
3 cars	work tour logsum difference * household has more drivers than 3	-0.09	-4.70
3 cars	Math.Log(1 + household residence parcels stops in transit buffer 1) * household has more drivers than 3	0.22	3.08
3 cars	Log of food, retail, service, and medical jobs in buffer 1 * household	0.16	3.46

	has more drivers than 3		
4 cars	household has 1 driver	-4.28	-16.89
4 cars	household has 2 drivers	-2.47	-11.76
4 cars	household has 3 drivers	-1.11	-4.10
4 cars	household Has 4 or less full or part time workers	0.42	3.86
4 cars	household Part time Workers Per Driving Age Members	-0.23	-0.75
4 cars	household Retired Adults Per Driving Age Members	-0.80	-2.95
4 cars	household Driving Age Students Per Driving Age Members	-0.33	-0.53
4 cars	household Children Under 5 Per Driving Age Members	-1.58	-3.38
4 cars	household has 50 to 75K Income	0.40	1.66
4 cars	household has 75K Income	0.43	2.02
4 cars	household has missing income	0.78	3.16
4 cars	work tour logsum difference * household has more drivers than 4	-0.09	-4.70
4 cars	Math.Log(1 + household residence parcels stops in transit buffer 1) * household has more drivers than 4	0.22	3.08
4 cars	Log of food, retail, service, and medical jobs in buffer 1 * household has more drivers than 4	0.16	3.46

MODE CHOICE MODEL VARIABLES

In order to get enough transit and bicycle tours to provide reasonable estimates, the home-based non-mandatory purposes of shopping, personal business, meal and social/recreation were grouped in a single model, but using purpose-specific dummy variables to allow for different mode shares for different purposes. So, there are five different tour mode choice models, with results shown in Tables 3 to 7 below.

Land use variables: Two land use variables came out as significant in many of the models, increasing the probability of walk, bike and transit.

Mixed use density: This is defined as the geometric average of retail and service employment (RS) and households (HH) within a half mile of the origin or destination parcel, in units of thousands of persons (= 0.001 * RS * HH / (RS + HH)). This value is highest when jobs and households are both high and balanced. High values near the tour origin tend to encourage walking and biking, while high values near the tour destination more often encourage transit use.

Intersection density: This is defined as the number of 4-way intersections plus one half the number of 3-way intersections within a half mile of the origin or destination parcel. Higher values tend to encourage walking for School and Escort tours, where safety for children is an issue, and also to encourage walking, biking and transit for Home-Based Other tours.

Pattern-specific variables: In terms of the activity pattern, the variable that influences mode choice the most is whether or not there are intermediate stops along the tour. With our model design, we do not predict the exact number and purpose of stops on a tour until AFTER tour mode choice is predicted, so we do not know the exact stops on the tour. From the pattern model, however, we do know how many tours are made during the day, as well as for which purposes stops and tours are made. So, if the tour is the only one made during the person-day (which is true in the majority of cases), then we do know when we apply the mode choice models whether or not there are stops on the tour for each purpose. Two variables are used in the models to reflect this type of knowledge:

Escort stop dummy divided by the number of tours in the day: The higher this variable, the higher the chance that there is an escort stop on the tour (the maximum value is 1.0). This variable significantly increases the chance of choosing Shared Ride and decreases the chance of choosing Drive Alone, as one would expect. The effect is strongest for Work tours, but also found for School and HBOther tours.

Number of other stop purposes divided by the number of tours in the day: This variable is analogous to the one for escort stops, but adds together all other stop purposes. The higher this variables, the higher the chance of choosing both Shared Ride and Drive Alone, as the automobile is more conducive to making multi-stop tours. The effects are not as strong as those found for escort stops, however.

Other variables: The other variables in the model are those that are related to the household and the person, and many are those typically found in mode choice models.

Car availability: There are three separate variables:

- HH has no cars
- HH has cars but fewer cars than drivers,

- HH has cars but fewer cars than workers

All of these variables have significant effects in most of the models.

Income: The income effects are not very strong, but there are a few effects discouraging car use for lower income households.

Gender: The only gender effect is one that is often found – that males are more likely to go by bicycle than females.

Age: As one would expect, the strongest age effects are in the School model, with students of various age groups preferring different modes. For the other purposes, there is less chance of choosing Bike (and sometimes Walk) for those over age 50,

Household size: There are strong effects that reduce the chance of Shared Ride 3+ in 1-person or 2-person households and reduce the chance of Shared Ride 2 in 1-person households, reflecting the fact that most "carpools" are intra-household, even for Work tours. There are also effects by age group, with the number of children under 5 and age 5-15 increasing the probability of Shared Ride for Work and Other tours, and the number of children age 16-17 and non-working adults decreasing the probability of Shared Ride. Household size is the strongest variable in the Escort tour model, with both Shared Ride 3+ and Walk becoming more likely relative to Shared Ride 2+ as the number of young children increases.

Mode to work: It is a typical finding that the most important single variable determining mode choice for work-based tours is the mode used to get to work, with people tending to use that same mode for their work-based tours.

Sub-purposes: In the HBOther model, the results show that, relative to Personal Business tours…

- Shopping tours are more likely to go by Shared Ride and less likely to go by Transit.
- Meal tours are more likely to go by Shared Ride, Transit and Walk.
- Social/recreation tours are more likely to go by Shared Ride, Bike and Walk.

Level of service variables with Skims and Path Type models

The mode choice models use the typical impedance skims for each o-d pair, time of day, and mode combination like in-vehicle time and out-vehicle time. These impedance skims are used to calculate path type logsums used to calculate generalized time values. In general, the Path Type model compares the travel impedance across different types of travelpaths for a given mode, and returns

(a) a utility logsum across all available path types, and

(b) a single chosen path type and the travel time, cost and distance via that mode

In most cases, the chosen path type is simply the one with the best utility.

The utility functions used in the path type model depend on the mode, as follows.

WALK MODE:

Currently, there is only one path type used for Walk (full network), and the utility is simply a function of time:

Path Utility = Time Coefficient

** Walk Time*

** Path Impedance Walk Time Weight*

BIKE MODE:

Currently, there is only one path type used for Bike (full network), and, by default, the utility is simply a function of tir

Path Utility = Time Coefficient

** Bike Time*

** Path Impedance Bike Time Weight*

AUTO MODES (SOV, HOV2, HOV3):

For the auto modes, the main idea behind the path type model is to allow for separate skims for the full network, including tolled links, versus a restricted network that does not include any tolled links.

*Path Utility = Time Coefficient * Auto Time*

*+ Cost Coefficient * (Auto Toll Cost + Auto Distance * Path Impedance AutoOperating Cost Per Mile)*

*+ Toll Dummy * Path Impedance Auto Tolled Path Constant*

TRANSIT MODE (walk access and egress):

As can be seen below, the transit utility depends on a variety of different user configuration inputs, several of which are path type-specific

Path Utility =

*Cost Coefficient * fare +*

*Time Coefficient **

*(Path Impedance Transit In-Vehicle Time Weight * total In Vehicle Time +*

*Path Impedance Transit First Wait Time Weight * initial Wait Time +*

*Path Impedance Transit Transfer Wait Time Weight * transfer Wait Time +*

*Path Impedance Transit Number Boardings Weight * number Of Boardings +*

*Path Impedance Transit Walk Access Time Weight * (AccessWalkTime + EgressWalkTime) +*

*Light Rail Path Dummy * Path Impedance Transit Light Rail Time Additive Weight * lightRailInVehicleTime +*

*Commuter Rail Path Dummy * Path Impedance Commuter Rail Time Additive Weight * commuter Rail In-VehicleTime +*

*Ferry Path Dummy * Path Impedance Ferry Time Additive Weight * ferry In Vehicle Time)*

PARK AND RIDE (drive access to transit)

For the transit leg of the drive-transit paths, the path type model uses essentially the same logic as listed above for TRANSIT. The differences for the park and ride model are as follows:

(a) The park and ride model is always applied round-trip, since it is only used as a tour-level mode alternative.

(b) Drive access time is substituted for walk access time at the home end for both half tours (SOV is assumed)

(c) PathImpedance_TransitDriveAccessTimeWeight is used as the utility weight on the drive access time

(d) The park and ride lot parking cost (given in the park and ride node file) is added to the transit fare for the total path cost

(e) Parcel-to-parcel drive access time is approximated by using the parcel that is nearest to the park and ride node

(f) If ShouldReadParkAndRideNodeSkim=TRUE and the user provides a skim matrix of the best park and ride node for each

O-D/path type/time of day in the roster file, then that node is used as the best park and ride path.

OTHERWISE, this model does a search across all possible park and ride nodes to choose the one that provides the

Combined auto+transit path with the best utility for the given O-D pair/path type/times of day.

The last feature - the ability to do "on the fly" search for the best p&r path - is a new feature of Daysim that allows a more detailed treatment than doing it in the network software, with tour-specific VOT, parcel-based drive access time, etc.

Note that if the user does not provide a park and ride node file, then it is assumed that park and ride is not relevant for the region, and the park and ride mode alternative is never available.

PSRC CONFIGURED PARAMETERS FOR MODE CHOICE

PathImpedance_PathChoiceScaleFactor = 1.5
PathImpedance_AutoOperatingCostPerMile = 0.10
PathImpedance_TransitInVehicleTimeWeight = 1.0
PathImpedance_TransitFirstWaitTimeWeight = 2.0
PathImpedance_TransitTransferWaitTimeWeight = 2.0

PathImpedance_TransitNumberBoardingsWeight = 8.0
PathImpedance_TransitDriveAccessTimeWeight = 2.0
PathImpedance_TransitWalkAccessTimeWeight = 2.0
PathImpedance_WalkTimeWeight = 2.5
PathImpedance_BikeTimeWeight = 2.5
PathImpedance_WalkMinutesPerMile = 20.0
PathImpedance_TransitWalkAccessDistanceLimit = 1.0
PathImpedance_TransitWalkAccessDirectLimit = 1.0
PathImpedance_TransitSingleBoardingLimit = 1.1
PathImpedance_AutoTolledPathConstant = 0.0
PathImpedance_AvailablePathUpperTimeLimit = 200.0
PathImpedance_TransitLightRailPathConstant = 0.0
PathImpedance_TransitCommuterRailPathConstant = 0.0
PathImpedance_TransitFerryPathConstant = 0.0
PathImpedance_TransitUsePathTypeSpecificTime = true
PathImpedance_TransitLightRailTimeAdditiveWeight = -0.10
PathImpedance_TransitCommuterRailTimeAdditiveWeight = -0.30
PathImpedance_TransitFerryTimeAdditiveWeight = -0.40
PathImpedance_BikeUseTypeSpecificDistanceFractions = false
PathImpedance_TransitUseFareDiscountFractions = true
PathImpedance_TransitFareDiscountFractionChildUnder5 = 0.8
PathImpedance_TransitFareDiscountFractionChild5To15 = 0.5
PathImpedance_TransitFareDiscountFractionHighSchoolStudent = 0.5
PathImpedance_TransitFareDiscountFractionUniverityStudent = 0.5
PathImpedance_TransitFareDiscountFractionAge65Up = 0.5
Coefficients_BaseCostCoefficientPerDollar = -0.15
Coefficients_BaseCostCoefficientIncomeLevel = 30000
Coefficients_CostCoefficientIncomePower_Work = 0.6
Coefficients_CostCoefficientIncomePower_Other = 0.3
Coefficients_MeanTimeCoefficient_Work = -0.03
Coefficients_MeanTimeCoefficient_Other = -0.015
Coefficients_StdDeviationTimeCoefficient_Work = 0.8
Coefficients_StdDeviationTimeCoefficient_Other = 1.0
Coefficients_HOV2CostDivisor_Work = 1.741
Coefficients_HOV2CostDivisor_Other = 1.741
Coefficients_HOV3CostDivisor_Work = 2.408
Coefficients_HOV3CostDivisor_Other = 2.158

USE OF DISTRIBUTED VALUE OF TIME

Each tour simulated in DaySIM can have its own time/cost tradeoff, with the functions used to set the cost coefficient (c[i]) and time coefficient (t[i]) shown in Figure 5 below. The cost coefficient is based on an inverse power function of income and car occupancy, with the power exponents differing for work and non-work tours. The time coefficient also has different functions for work and non-work tours, and uses a log-normal distribution (see Figure 6) to simulate random variation around the mean.

Note that this random variation in VOT is not used in model estimation, and can also be switched off by the user for model application, in which case the mean value is assumed. Also note that this value is for auto in-vehicle time. Relative values for other types of travel time can be specified by the user as part of the DaySIM configuration.

Table 2. Functions from SHRP 2 C04 for Tour-Specific Value of Time

Work tours

c(i) = -0.15/$ / [((income(i) / 30,000) ^ 0.6) * (occupancy(i) ^ 0.8)]

t(i) = -0.030/min * draw from a log-normal distribution, with mean 1.0 and std. deviation 0.8

Non-work tours

c(i) = -0.15/$ / [((income(i) / 30,000) ^ 0.5) * (occupancy(i) ^ 0.7)]

t(i) = -0.015/min * draw from a log-normal distribution, with mean 1.0 and std. deviation 1.0

Nesting: A number of different nesting structures were tested. In particular, three nests that combined:

(1) Drive to Transit with Walk to Transit

(2) Shared Ride 2 with Shared Ride 3+

(3) Bike with Walk

were tested with separate coefficients, and all coefficients were less than 1.0 but not significantly different from each other. Because ALOGIT gives more stable results with fewer different nesting parameters (due to the need to define dummy nests for each parameter), it was decided to estimate a single nesting parameter that would apply to all 3 nests (as well as to the 2 additional "nests" that only have one alternative each: Drive Alone, and School Bus). Note that the Transit nest only has a single alternative – Walk to Transit - in all models except for Work.

The estimated logsum parameters are 0.91 for Work, 0.70 for School, 0.72 for Work-Based and 0.80 for Other.

No nesting was used for the Escort model, as it contains only 3 alternatives and is a very simple model.

Table 3: Home-Based Work Tour Mode Choice Model

Modes	Variable	Coefficient	T-Stat
	Level of Service		
DA,S2,S3,DT,WT	Generalized Cost * Cost Coefficient	0.507	6.48
DA,S2,S3,DT,WT	Generalized Time from Path Type Utility * Time Coefficient	0.458	15.8
	Mode-specific		
DT	Constant	0.446	1.1
DT	No cars in HH	-2	Const
DT	HH fewer cars than workers	-0.684	-2.4
WT	Constant	-0.145	-0.3
WT, DT	Origin Mixed Used Density	0.572	1.79
WT, DT	Destination Employment Density	0.000035	8.81
S3	Constant	-0.315	-0.77
S3	One person HH	-1.04	-5.92
S3	Two person HH	-1.06	-8.95
S2	Constant	0.0078	-2
S2	One person HH	-0.96	-6.3
S2,S3	HH # children under age 5	0.409	5.5
S2,S3	HH # children age 5-15	0.343	6.6
S2,S3	Log of auto distance (miles)	-1.34	-4.1
S2,S3	No cars in HH	-3.54	-6.3
S2,S3	HH fewer cars than drivers	-0.153	-1.6
S2,S3	Escort stop purpose / # tours in day	2.23	8.3
S2,S3	Other stop purposes / # tours in day	0.13	2.4
DA	Constant	2.047	4.7
DA	HH fewer cars than workers	-1.721	-9.35
DA	HH income under $25K	-0.262	-3
DA	Escort stop purpose / # tours in day	-3.441	-8.35
DA	Other stop purposes / # tours in day	0.117	2.38
BI	Constant	-2.392	-6.2
BI	Male	1.044	5.17
BI	Age over 50	-1.045	-4.8
BI	Mixed use density at origin	0.224	0.52
BI	Mixed use density at destination	1.09	2.19
WK	Male	0.712	3.47
	Mixed use density at destination	0.343	1.27
All	Mode nesting parameter	0.914	13.5

Analysis is based on 8234 observations
Likelihood with Zero Coefficients = -14926.1370
Final value of Likelihood = -7712.7960
"Rho-Squared" w.r.t. Zero = 0.4833

Table 4: Home-Based School Tour Mode Choice Model

Modes	Variable	Coefficient	T-Stat
	Level of Service		
DA,S2,S3,WT	Generalized Cost* Cost coefficient	0.08	Const
DA,S2,S3,WT	Generalized Time from Path Type Utility * Time Coefficient	1.79	9.79
	Mode-specific		
SB	Constant	-0.33	-2.03
SB	Child under age 5	-5.75	-4.83
SB	Adult age 18+	-5	Const
WT	Constant	-0.77	-1.31
WT	No cars in HH	3.42	3.69
WT	HH fewer cars than drivers	2.02	5.12
WT	Child under age 5	-5	Const
WT	Adult age 18+	3.43	6.49
WT	Child age 16-17	-0.37	-0.81
S3	Constant	-0.44	-2.63
S3	One or two person HH	-1.44	-4.7
S2	Constant	-0.26	-0.21
S2	One person HH	-1.31	-7.6
S2,S3	No cars in HH	-5	constr
S2,S3	HH income under $25K	-1.94	-4.21
S2,S3	HH income $25-50K	-1.03	-5.19
S2,S3	Child under age 5	1.82	2.6
S2,S3	Escort stop purpose / # tours in day	1.16	3.93

S2,S3	Other stop purposes / # tours in day	-0.13	-0.18
DA	Constant	2.28	5.38
DA	HH fewer cars than drivers	-2.35	-6.7
DA	HH income under $25K	-0.3	-0.45
DA	HH income over $75K	0.56	2.02
DA	Child age 16-17	-2.06	-5.44
DA	Escort stop purpose / # tours in day	-6.85	-3.7
DA	Other stop purposes / # tours in day	0.2	1.34
BI	Constant	-3.99	-7.87
BI	Male	0.69	1.88
BI	Adult age 18+	1.34	1.67
WK	Adult age 18+	0.48	0.64
All	Mode nesting parameter	0.7	1

Analysis is based on 3248 observations
Likelihood with Zero Coefficients = -5583.6485
Final value of Likelihood = -3830.6969
"Rho-Squared" w.r.t. Zero = 0 .3139

Table 5: Home-Based Escort Tour Mode Choice Mode

Modes	Variable	Coefficient
	Level of Service	
S2,S3,WK	Generalized Time from Path Type Utility * Time Coefficient	2.29
	Mode-specific	
S2	Constant	-0.13
S3	Constant	-0.93
S3	HH # children under age 5	1.34
S3	HH # children age 5-15	0.53
S3	HH # children age 16-17	0.28
S2,S3	No cars in HH	-5.91
S2, S3	Cars less than drivers	0.02

WK WK WK WK	Age over 50 HH # children under age 5 HH # children age 5-15 HH # children age 16-17	-2.3 0.55 0.22 -3.8
All	Mode nesting parameter	0.54

Table 6: Work-Based Tour Mode Choice Model

Modes	Variable	Coefficient	T-Stat
	Level of Service		
DA,S2,S3,WT, WK, BI	Generalized Cost * Cost Coefficient	1.47	2.36
DA,S2,S3,WT, WK, BI	Generalized Time from Path Type Utility * Time Coefficient	4.58	2.45
	Mode-specific		
WT	Constant	-3.63	-2.38
S3	Constant	-5.59	-2.78
S2	Constant	-5.17	-2.67
S2,S3	Drive alone to work	0.79	1.26
S2,S3	Shared ride to work	1.62	1.71
DA	Constant	-3.94	-2.32
DA	HH income under $25K	0.33	0.31
DA	Drive alone to work	2.83	2.24
DA	Shared ride to work	1.91	1.84
BI	Constant	-22.66	-0.02
BI	Male	14.43	0.01
BI	Bike to work	4.25	Const
WK	Walk to work	5.00	Const
All	Mode nesting parameter	0.72	2.48

Analysis is based on 641 observations

Likelihood with Zero Coefficients = -1075.3415
Final value of Likelihood = -489.4023
"Rho-Squared" w.r.t. Zero = .5449

Table 7: Home-Based Other Tour Mode Choice Model

Modes	Variable	Coefficient	T-Stat
	Level of Service		
DA,S2,S3,WT	Generalized Cost * Cost Coeffienct	0.17	2.21
DA,S2,S3,WT, WK, BI	Generalized Time * Time Coefficient	1.95	16.26
	Mode-specific		
WT	Constant	-1.89	-7.32
WT	No cars in HH	3.68	7.99
WT	Employment density at destination	0.00004	6.07
WT	Shopping tour	-0.61	-1.71
S3	Constant	-1.07	-6.03
S3	One person HH	-2.87	-16.1
S3	Two person HH	-2.09	-25.18
S2	Constant	-1.46	-8.26
S2	One person HH	-1.52	-10.59
S2,S3	HH # children under age 5	0.59	6.87
S2,S3	HH # children age 5-15	0.35	6.73
S2,S3	HH # non-working adults 18+	0.18	4.63
S2,S3	Log of auto distance (miles)	0.18	5.33
S2,S3	No cars in HH	-0.73	-2.06
S2,S3	HH fewer cars than workers	-0.73	-3.57
S2,S3	Escort stop purpose / # tours in day	0.55	2.75
S2,S3	Other stop purposes / # tours in day	-0.05	-1.42
S2,S3	Shopping tour	0.2	2.15
S2,S3	Meal tour	1.89	11.97
S2,S3	Social/recreation tour	0.6	6.84
DA	Constant	0.71	4.33
DA	HH fewer cars than drivers	-0.75	-7.72
DA	Other stop purposes / # tours in day	-0.06	-1.84
BI	Constant	-4.08	-12.26
BI	Male	1.28	5.08
BI	Age over 50	-1.34	-4.81
BI	Origin Household Density	0.000145	1.4
BI	Destination Employment Density	0.000002	0.11
BI	Social/recreation tour	1.26	5.1
WK	Employment density at destination	0.0001	2.34
WK	Household density at origin	0.00023	3.67
WK	Meal tour	1.05	5.25
WK	Social/recreation tour	1.7	11.19
All	Mode nesting parameter	0.8	17.26

Analysis is based on 10119 observations
Likelihood with Zero Coefficients = -16661.7454
Final value of Likelihood = -9723.3970
"Rho-Squared" w.r.t. Zero = .4164

TRIP LEVEL MODE CHOICE MODEL

For model estimation, trips were excluded for the same for a number of reasons:

- Walk trips on walk tours were excluded because only one alternative is available
- Trips were excluded when they were the last chronological trip in the tour, and no previous trip in the tour had used the main tour mode. In those cases, by definition, the last trip must be the main tour mode.
- Various other trips were dropped when the chosen mode was not available in the networks.

The table below shows the estimated coefficients for the model. A key variable was the generalized cost of the trip. To calculate the generalized cost, all time and cost variables were multiplied by the estimated coefficients for the appropriate tour level mode choice model. assuming that the value of time is the same for all trips along the same tour. The model also includes three new types of variables that are specific to the trip-level data. A large proportion of the mixed drive alone (DA)/shared ride (SR) tours are tours that contain at least one escort (pick up/drop off) stop. The first set of variables attempt to explain which trips are shared ride by looking at both the origin purpose and destination purpose, as well as the time of day. Not surprisingly, trips to work in the morning after dropping someone off and from work in the afternoon before picking someone up are rarely shared ride trips. The opposite side of these are the positive SR coefficients for trips from home to drop off in the AM and trips from pick up to home in the PM. Trips from an escort stop back home in the AM, and to an escort stop in the midday tend not to be shared ride.

Table 8: Trip mode choice model coefficients

Variable	Coefficient	T-statistic
Generalized Cost * Cost Coefficient	0.21	2.94
Generalized Time * Time Coefficient	1.86	19.89
WT – constant	-0.63	-3.15
WT- cars < household drivers	-0.05	-0.33
S3- constant	2.35	10.5
S3- One person household	-0.95	-8.1
S3- Two person household	-0.47	-7.76
S2- Constant	1.62	7.65
S2- One person household	-0.73	-7.7
SR- Household members age 5-15	-0.25	-11.92
SR- Household non-working adults	0.14	4.68
SR- No cars in household	-1.82	-6.88
SR- work tour	-2.33	-15.84
SR – school tour	-1.54	-8.93
SR – escort tour	-1.53	-12.19
SR – shopping tour	1.49	8.75
SR – meal tour	1.1	6.35

SR – social/rec tour	0.17	1.49
DA- constant	1.35	7.35
DA- cars < household drivers	-0.27	-4.4
DA- household income <$25000	-0.19	-1.38
DA- household income $25-45000	-0.39	-4.75
DA – age 16-17	-0.66	-4.34
BI- constant	-2.11	-7.41
BI- male	0.51	2.78
BI – age under 35	0.17	0.78
BI – origin intersection density	0.01	3.24
BI - work-based tour	-0.85	-0.71
WK – age under 35	0.39	3.36
WK – origin intersection density	0.02	12.17
WK – destination mixed use density	0.71	3.48
WK – work tour	1.39	12.04
WK – school tour	0.92	6.03
SR - escort to work trip / am peak period	-2.48	-11.21
SR – work to escort trip / pm peak period	-1.21	-6.56
SR – home to escort trip / am peak period	3.03	14.94
SR – home to escort trip / midday period	-1.24	-9.25
SR – home to escort trip / pm peak period	-1.06	-8.22
SR – home to escort trip / evening period	-1.39	-6.06
SR – escort to home trip / am peak period	-3.53	-16.36
SR – escort to home trip / midday period	-0.51	-3.21
SR – escort to home trip / pm peak period	0.68	4.95
SR – escort to home trip / evening period	-0.71	-3.77

Table 9: Trip mode choice model coefficients (continued)

Variable	**Coefficient**	**T-statistic**
All – Same as tour mode	4.05	19.28
All- same as tour mode – only outbound trip	1.02	17.22
All- same as tour mode – only return trip	0.94	15.05
All- same as tour mode – first of 2+ outbound trips	0.03	0.39
All- same as tour mode – first of 2+ return trips	0.11	1.83
All- same as tour mode – last of 2+ outbound trips	0.10	1.50
All- same as tour mode – last of 2+ return trips	0.03	0.51
S3 – WT tour	-2.06	-7.52
S3 – SB tour	2.38	9.09

S2 – WT tour	-0.77	-3.05
S2 – SB tour	2.79	10.21
S2 – S3 tour	3.45	13.69
DA – DT tour	-1.67	constr
DA – WT tour	-3.27	-9.84
DA – S3 tour	2.35	12.27
DA – S2 tour	2.42	12.31
BI – WT tour	-0.74	-2.63
BI - S2 tour	-0.72	-2.48
BI – DA tour	-1.23	-3.67

There are mainly positive coefficients for the likelihood that the trip mode is the same as the tour mode, regardless of mode. This is particularly true when the half tour only has one trip (no intermediate stops). In cases where the half tour has 2+ trips, the mode for the first outbound trip and last return trip are the least likely to be the same as the tour mode, although these effects are not strong.

Finally, there are variables for specific trip mode/tour mode combinations, all relative to the "base" trip mode of walk. The general pattern in these coefficients is:

- Relative to the walk mode, school bus (SB), shared ride (S3,S2) and drive alone (DA) are not likely as part of transit tours (DT,WT)
- Relative to the walk mode, shared ride (S2,S3) are more likely as part of school bus (SB) tours.
- The strongest positive switching is for S2 on S3 tours.
- Relative to the walk mode, drive alone (DA) is more likely on shared ride (S2, S3) tours.
- Relative to the walk mode, bike (BI) is not likely to be a part of any tours that are not bike-only tours.

Details of Accessibility Logsum Implementation

Aggregate accessibility logsums are used for several upper level models in the system, as shown in the next to last column in Table 1. The form is that of mode-destination choice logsums to indicate the accessibility of various zones for non-mandatory activity purposes. To make it feasible to use such measures, they are pre-calculated for a limited number of segments. Those segments are each combination of:

Non-mandatory tour purpose:

(1) Home-based personal business

(2) Home-based shopping

(3) Home-based meal

(4) Home-based social/recreation

(5) Home-based escort

(6) All home-based purposes combined

(7) Work-based

Car availability segment:

(1) Child age under 16

(2) Adult in HH with no cars

(3) Adult in HH with cars, but fewer cars than drivers

(4) Adult in HH with 1+ cars per driver

Transit accessibility:

(1) Origin is within ¼ mile of transit stop

(2) Origin is more than ¼ mile from transit stop, but walk to transit is available

(3) Walk to transit not available

In total, this makes 7 * 4 * 3 = 84 combinations for each origin zone.

So, the simplified mode and destination choice models include only those variables that are defined by those segments. Other simplifications include:

- Only TAZ-based information is used, and no parcel-based land use information.
- Drive to transit, school bus and bike are all omitted, and shared ride is a single mode. This leaves 4 modes: WT – Walk to Transit, SR – Shared Ride 2+, DA – Drive Alone, and WK – Walk.

The resulting estimates for mode choice are shown in Table 8 of Tech Memo 4.

The application of these models has been programmed, and incorporated into a routine that calculates mode/destination choice logsums from every possible origin zone for each of the 84 segment combinations. This application code for precalculating the accessibility logsums essentially applies two steps of a 4-step zonal aggregate travel demand model system:

- Loop on origin zones

    - Loop on 84 tour purpose/car availability/transit accessibility segments
        - Loop on destinations zones and calculate mode choice utilities, mode choice logsums, destination choice utilities and accessibility logsum

A second routine also calculates intermediate stop logsums for car tours. As shown in the last column in Table 2.1, these measures are used in the pattern models (2.1 and 4.1) to make intermediate stops more likely between zone pairs where useful stop locations can be conveniently reached. This routine takes longer to run than the first one described above, because it uses 3 nested zone loops:

- Loop on time periods (peak, off-peak)
    - Loop on origin zones
        - Loop on destination zones
            - Loop on all intermediate stop zones and calculate intermediate stop location choice logsum using the formula below

Logsum is the log of the sum over all zones of : Size * exp (- 2 * extra time / 6.0 minutes)

Where Size is a weighted function of various attraction variables (the size variable function estimated for the composite non-mandatory tour purpose in the aggregate destination choice model), and Extra time is the auto travel time from the origin zone to the stop zone plus the auto travel time from the stop zone to the destination zone, minus the direct auto travel time from the origin zone to the destination zone (i.e. the detour time required to make the stop on the way from the origin to the destination).

Table 10. Simplified Mode Choice Models for Calculating Aggregate Logsums

		All Home-Based		Work-Based		HB Escort		HB Pers.Bus		HB Shop		HB Meal		HB SocRec	
Mode	Variable	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
DA, SR, WT	Cost ($)	-0.1826	-7.2	-0.2008	-4.6	-0.12	*	-0.2361	-5.2	-0.4386	-6.8	-0.1215	-1.1	-0.3194	-5.4
DA, SR, WT	In-vehicle time (min)	-0.025	*	-0.025	*	-0.04	*	-0.02	*	-0.025	*	-0.03	*	-0.025	*
WT, WK	Out-of-vehicle time (min)	-0.07227	-17.5	-0.08339	-9.4	-0.1296	-7.2	-0.05341	-8.4	-0.0757	-9.1	-0.09441	-4.8	-0.06894	-9.6
DA	Constant	-0.5821	-4.5	-1.358	-5.9	-5.619	-10.5	0.4807	1.8	0.03664	0.1	-1.793	-3.2	-0.7357	-3.1
DA	HH fewer cars than drivers	-0.3404	-3.2	-0.5896	-3.3	0.3267	1.1	-0.3777	-1.7	-0.3622	-1.7	-0.4127	-1.0	-0.9187	-3.7
SR	Constant	-0.4841	-3.6	-2.396	-9.6	-1.073	-2.8	-0.03517	-0.1	-0.4242	-1.5	-0.685	-1.2	-1.047	-4.2
SR	Child under age 16	0.2458	1.9	1.033	3.7	1.822	4.0	1.194	2.7	0.3822	1.3	-1.72	-2.8	0.2101	1.0
SR	No cars in HH	-2.518	-9.4	-1.782	-3.5	-5.265	-4.9	-1.73	-3.9	-2.187	-5.0	-2.472	-2.2	-1.933	-2.8
SR	HH fewer cars than drivers	-0.1648	-1.5	-0.1185	-0.7	0.4327	1.6	-0.1929	-0.9	-0.3522	-1.7	-0.4882	-1.2	-0.4833	-2.0

WT	Constant	-3.911	-9.7	-4.792	-5.6	-3.447	-2.7	-2.712	-4.6	-3.0	*	-4.013	-2.9	-3.589	-4.2
WT	Child under age 16	-1.0	*	0.0	*	-1.0	*	-1.0	*	-1	*	-1	*	-1.0	*
WT	No cars in HH	2.722	7.3	2.048	2.9	1.0	*	3.117	5.1	1.91	3.1	2.663	2.4	2.485	2.5
WT	HH fewer cars than drivers	0.7025	2.0	1.226	2.4	0.004716	0.0	-0.1959	-0.4	1.049	2.0	1.798	1.4	-0.2369	-0.3
WT	Walk at origin>0.25 miles	-1.958	-1.6	-1.268	-0.8	-2.0	*	-2.0	*	-2	*	-2.0	*	-2.0	*
	*=constrained														

TABLE 11. IMPEDANCE MEASURES AND LOGSUMS USE IN MODEL COMPONENTS

	Model	Direct measures of travel impedance	Direct measures of spatial attributes	Tour mode choice logsum	Simulated conditional outcomes	Aggregate tour mode-destination choice logsum	Aggregate intermediate stop location choice logsum
1.2	Usual Work Location	Distance. Distance from school.	Employment, enrollment, households. Parking & employment mix. Grid connectivity.	Yes.		At destination.	
1.3	School Location	Distance.	Employment, enrollment, households.	Yes.		At destination.	
1.4	HH Auto Availability	Distance to transit stop.	Parking price near home. Commercial employment near home.	To work. To school.		At home.	
2.1	Day Activity Pattern		Mixed use density near home. Intersection density near home.	For work & school.		At home.	Yes.
2.2	Number of Tours (by purpose)			For work and school tours.		At home.	
3.1	Tour Destination	Distance. Distance from work. Distance from school.	Employment, enrollment, households. Parking & employment mix Grid connectivity.	Yes.	Primary activity periods	At destination.	
3.2	Number & purpose of work-based tours		Commercial employment near work. School enrollment near work.				
3.3	Tour Primary Activity Timing (begin and end		Mixed use density	Yes.			

	time periods)						
3.4	Tour Mode	All LOS variables	Parking costs. Transit accessibility. Mixed use density.				
4.1	Number & Purpose of Intermediate Stops		Grid connectivity X commercial employment at tour dest.				For auto-based tour modes.
4.2	Stop Location	Generalized time. Distance. Distance from tour origin. Distance from tour destin.	Employment, enrollment, households. Parking & employment mix.				
4.3	Trip Mode	All LOS variables	Parking costs. Transit accessibility.				
4.4	Trip Departure Time	Travel times					