Puget Sound Regional Council
PSRC

DEVELOPMENT AND IMPLEMENTATION OF AN

ACTIVITY-BASED TRANSPORT MODEL SYSTEM

Report 1

Design Issues and Their Resolution

WORKING DRAFT—May 29, 2009

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INTRODUCTION

This report is the first deliverable of the project to develop and implement an activity-based transport model at PSRC. The Work Plan Report, RFP and Proposal left a few specific issues unanswered, which were to be addressed during Task 1 of the project. This report documents each issue and its resolution.

ISSUE 1: SPATIAL DETAIL

Background

Issue Statement from Proposal. Because UrbanSim uses buildings instead of parcels to represent future year development, PSRC has asked to use buildings instead of parcels to represent spatial choice alternatives and their attributes. An important implication of the switch to buildings for the demand models is that the spatial data prepared in Task 1 for model estimation must be building data, rather than parcel data. The ability to generate data that accurately represents base year reality at the building level needs to be verified at the beginning of the project.

Additional aspects of the issue. At the kickoff meeting, PSRC and Urban Analytics explained that the building data lacks xy coordinates from which buffer variables can be calculated, and there might be additional complications of trying to define building attributes. They suggested the possibility of defining attributes and buffers at the parcel level. The problem with this relates to the original reason for shifting toward the use of buildings instead of parcels: UrbanSim does not subdivide parcels to represent future year development. As a result, for large undeveloped parcels where development is forecast, the large parcels would provide poor attribute measures. This re-opens the issue of whether and how to use buildings and/or parcels as location choice alternatives and their attributes.

Options

The three basic options, described below, are (1) buildings, (2) parcels, and (3) hybrid.

1. **Buildings**. Use buildings as location choice alternatives and use building attributes (including buffers) for most location attributes. This would require a means of locating buildings and measuring proximity to them, probably by assigning an XY centroid to each building (This was the intended approach at the end of the prior planning and design project. John Bowman has handwritten notes from prior discussions indicating that UrbanSim would use grid cells to generate buffer attributes, although it would presumably be possible, but slower, to generate them around each building centroid instead.)

2. **Parcels**. Revert to the use of parcels as location choice alternatives and use parcel attributes (including buffers) for all location attributes. Some of the parcel attributes would be generated by aggregating values from the parcel's buildings. Option 2 has two sub-options:

   2.1 For future year development, enhance UrbanSim or use ad hoc procedures to subdivide parcels.

   2.2 For future years, do not subdivide parcels. (However, the values of parcel attributes would change to reflect development).

3. **Hybrid**. Use buildings as location choice alternatives. Use building attributes for some location attributes and attributes of the building's parcel for other attributes. The type of value for each attribute under each of the three options is summarized in Table 1.1. This shows that under the hybrid option, which assumes that XY coordinates are not available for buildings, it is generally the buffer density variables that are used at the parcel level. For forecasting, however, it is questionable whether there is any advantage in predicting location choices at the building level instead of the parcel level if the building cannot be located in space.

To help guide this discussion it would be useful to have some data on how many parcels have multiple buildings, perhaps in the form of a frequency distribution of buildings per parcel, along with some information (place name, square feet, number of buildings) about a few of the parcels with the most buildings. This would be useful both for 2006 and for a forecast year.

Table 1.1: Building / Parcel attributes for the three options

Attribute	Work Plan Report Table No.	Mult-iple Cate-gories	Include buffers	Option 1—Building alts and attributes	Option 2—Parcel alts and attributes	Option 3—Building alts; some parcel attributes
Building ID	11			yes	no	yes
Parcel ID	11			yes	yes	yes
TAZ	11			yes	yes	yes
County	11			yes	yes	yes
X coordinate	11			building	parcel	parcel
Y coordinate	11			building	parcel	parcel
Area (sqft)	11 & 12			building & parcel	parcel	building & parcel
Housing units	11 & 12		yes	building	parcel	building (parcel for buffers)
Jobs	11	yes	yes	building	parcel	building (parcel for buffers)
Students	11	yes	yes	building	parcel	building (parcel for buffers)
nodes (street network)	11	yes	only	building	parcel	parcel (for buffers)
Distance to transit stop	11	yes		building	parcel	parcel
parking spaces	11	yes	yes	building	parcel	building (parcel for buffers)
Parking price	11	yes	yes	building	parcel	building (parcel for buffers)
city_id	12			parcel	parcel	parcel
is_inside_urban_growth_boundary	12			parcel	parcel	parcel
land_us_type_id	12			parcel	parcel	parcel
unit_price (per sq ft)	12			parcel	parcel	parcel
num_building_records	12		yes	parcel (building for buffers)	parcel	parcel
plan_type_id	12			parcel	parcel	parcel
tax_exempt_flag	12			parcel	parcel	parcel
building type				building		
predominant Building_type_id	12			parcel	parcel	parcel
non-residential (building) sqft	12		yes	building	parcel	building (parcel for buffers)
sqft_per_unit	12			building & parcel	parcel	building & parcel
first year_built	12		yes	building	parcel	building (parcel for buffers)
last year built	12		yes	building	parcel	building (parcel for buffers)

Table 1.2 compares the options using several criteria.

Table 1.2: Comparison of options

	Importance	1--Building	2.1—Parcel (fixed)	2.2—Parcel (subdivided)	2.3 (Hybrid)
Task 1 data prep delays	High	?	?	?	?
Person-time required to implement automated data generation procedures	?	More?—for building-level buffer generation?	Less	More—for parcel subdivision (may also require extra time for manual data generation with each forecast scenario)	Less
Computer run time for data generation	?	probably more			
DaySim run time		slightly more for data input			slightly more for data input
attribute measurement in most cases	High	Best	Good	Good	Slightly better
attribute measurement for new developments	?	Best	Worst	Good (depends on subdivision method)	Good for basic size variables; bad for buffers
measurement errors caused by bad data	?	Worst	Best	Best	Worst
overall quality for demand forecasting	High	Best, if buildings are effectively located	Worst, because of poor measures for newly developed large parcels	Nearly best, if parcels are effectively subdivided	Nearly worst, because building detail is of little value if buildings aren't located

Resolution

Discussion at a project management meeting on May 11, 2009, resulted in the **selection of Option 2.2 for this project (Parcels, without subdividing for future years)**. A future objective would be to shift to Option 2.1. The following notes provide some discussion and clarification.

1. For purposes of the activity models, the value of building attributes, without locating the buildings in space, is quite limited, so the hybrid option 3 is not a good one.

2. Using parcels as destination alternatives and implementing the capability of subdividing parcels according to forecast developments, would provide the important spatial information needed for the activity models. Although the subdivision capability is not practical for this project, implementing parcels as destinations now would allow a natural transition when that capability is implemented.

3. For this project, and moving forward into the future until the forecast-based parcel subdivision capability is implemented, it will be helpful to carry out an ongoing program of evaluating the largest parcels and subdividing those for which available facts on the ground enable parcel subdivision that would improve the quality of the models. The parcels can be sorted into a priority sequence for examination. The priorities, which can be further discussed as PSRC begins this program, can include acreage (e.g., over 10 acres), inside/outside UGB, jobs in parcel, housing units in parcel, and heterogeneity of parcel attributes used in the AB model (e.g., transit accessibility via all-streets network). For this project, two time points of value for implementing subdivision of large parcels are immediately before the first round of model estimation (i.e., by end of June 2009), and immediately before the second round of model estimation with new zone structure (circa October 2009.)

4. In contrast to the activity models, for the long-term employment and residential location choice there is more benefit of using building attributes (job type and housing type) in modeling and constraining choices. These models are already implemented and will continue to operate at the building level. Also, jobs by type at the building level can be used to adjust (or can be aggregated and used instead of?) parcel-level employment by industry category to improve the parcel-level employment variables used in the AB models. For example, Amazon and Starbucks (retail) and Boeing (industrial) have large concentration of office employment in some parcels, that attract non-work travel quite differently than their industry classification would suggest.

ISSUE 2—MODES AND TOLLS

Background

Issue Statement from Proposal. We anticipate modeling the 18 transport modes as desired by PSRC. Although using the mode choice models to determine tolled vs. non-tolled route selection, and to determine transit submode, has advantages, it is not by itself adequate to fully deal with these choices. The reason for this is that the choice is more complex than can be depicted in the choice model. For example, on a long trip, there may be several different tolled path choices, with differing costs and benefits. To deal with this, it may be desirable to skim two or more paths for each tolled mode and each transit submode, with a different assumed value-of-time category for each one. This would be combined with the simulation of random values of time for all tours, and with multi-class assignment that uses value of time to distinguish classes. A final decision about mode choice modeling, assignment and skimming for tolled vs. non-tolled traveler choices will need to be made at the beginning of the project so that PSRC can generate correct skim data for model estimation.

Relevant design excerpt from the Work Plan Report. The following paragraph and table identify the needed PSRC modes, as documented in the Work Plan Report.

> **Modes for demand models**. PSRC desires to have the following 18 transport modes considered explicitly in the mode choice models of the AB model system.

Highway modes are distinguished by occupancy and toll vs non-toll paths, and transit modes are distinguished by five submodes and walk vs drive access.

SOV No-Toll	Walk	Walk Access Ferry	Drive Access Ferry
SOV Toll	Bicycle	Walk Access Commuter Rail	Drive Access Commuter Rail
HOV2 No-Toll		Walk Access Light Rail	Drive Access Light Rail
HOV2 Toll		Walk Access Express Bus	Drive Access Express Bus
HOV3+ No-Toll		Walk Access Local Bus	Drive Access Local Bus
HOV3+ Toll			

Relevant design excerpt from the proposal. The following two paragraphs describe the design as it was documented in the original proposal, and they still hold.

Modeling toll/non-toll choice at the mode choice level: This feature involves bringing in separate highway cost and time skims for the best tolled and non-tolled paths, and including a sub-model in mode choice to predict diversion to facilities such as HOT lanes.

Drawing value of time from a distribution: The PSRC analysis of the Traffic Choices experiment data was able to produce value of time (VOT) distributions across the population. While VOT is related to income, it is also related to many unobservable factors that can be trip-specific. We plan to use empirical VOT distributions to stochastically draw a separate value of time for each simulated tour, which will influence the destination choice, mode choice (including toll/non-toll), and time of day choices for that tour.

Recent guidance from PSRC (Maren Outwater, May 8, 2009). I do want to modify the statement that PSRC has determined that we should have toll nests in mode choice. I think this is something we want to consider and get your input on, rather than starting with this as a done deal.

Options

The above May 8 request from PSRC to include an option that excludes toll nests in the mode choice model, broadens the consideration options into two major categories: (1) options with toll/non-toll nests in mode choice, and (2) options without toll/non-toll pathtype choice.

Options with toll/non-toll nests in mode choice

Although the above background section identifies the mode/toll issue as unresolved, the Work Plan Report and Proposal nevertheless are oriented toward a solution with toll/non-toll nests in mode choice. In addition, the design also calls for using distributed value of time in the demand models. In this case, the demand models would provide two extra pieces of information for each auto trip:

--The Value of Time used for the tour

--The predicted binary choice – toll path or non-toll path

The question then is whether and how to use this information in traffic assignment and skimming. The five basic options, described below, are (1) don't use VOT or toll classes, (2) use VOT classes, (3) use Toll classes, (4) use Toll classes with VOT subclasses, and (5) use Toll classes with variable VOT. **Within this group of options, our**

recommendation would be to use toll classes with VOT subclasses (option 4), and revert to option 3 during development if it becomes clear that option 4 will be unwieldy.

1. **don't use VOT or toll classes**. This option would ignore the information completely in assignment. It would still be necessary to generate skims for toll and non-toll paths for all OD pairs, and the quality of the skims would be suspect. **Option 1 is not recommended** because it would not provide adequate assignment results, nor would it provide good skim values to the DaySim demand models.

2. **VOT classes**. In this option, there would be a number of different user classes that are made up of different VOT classes (at least 5 VOT classes should be used, and probably more). The binary toll/non-toll mode choice would be ignored during assignment. Instead, the toll/non-toll path choice would be determined in path building during assignment, so it would not necessarily be the same as that predicted by the upper level models. The skims would be VOT-class-specific, so that the LOS faced in the demand model choices would correspond to the best path LOS for trips of the same VOT category. **Option 2 is not recommended** because of the inconsistency between the DaySim demand model toll choices and the assigned paths.

3. **Toll classes**. In this option, there would be two user classes, one which is forced to use the best toll-path, and one which is forced to use the best non-toll path during each iteration. In both cases, assignment would be made without regard to differences in VOT among the trips being assigned. The skims would be toll-class-specific, providing different LOS values for the toll and non-toll mode alternatives. During the assignment iterations, the best tolled path might shift away from the one that was used in the previous skims. Travel times for both types of paths might also change. So, the assignment would need to be iterated with the demand model in the usual way. It is not clear if adding the toll/non-toll path choice in the upper level models would increase the required number of full iteration loops. **Option 3 is recommended as a fallback during development if it becomes clear that Option 4 will be unwieldy**.

4. **Toll classes with VOT subclasses**. This option would use two toll classes (toll and non-toll), and would also subdivide the toll class into two to four VOT classes. The non-toll class would not benefit from VOT subclassification, because only non-tolled paths would be available anyway. However, for the tolled class, the selected path might depend on the VOT class of the traveler. Separate skims would be generated for the non-toll class and for each VOT subclass of the tolled class. This VOT subclassification would become more valuable as the toll scenarios in the region became complex, offering travelers multiple toll paths with different trade-offs between travel time and cost for the same OD pair. **Option 4 is the recommended option**.

5. **Toll classes with variable VOT.** This option is like option 4, but instead of using VOT subclasses, it would employ an assignment procedure that accommodates variable VOT according to a parametrized distribution, or via disaggregate

assignment with a distinct VOT associated with each assigned trip. For purposes of providing LOS information to DaySim, a discrete set of skims with VOT classes would be generated, as in option 4, or, if a disaggregate assigner were used, the LOS might be generated "on the fly" as needed for a particular VOT. **Option 5 is not recommended** because we anticipate that the assignment software PSRC intends to use would not support this approach.

Options without toll/non-toll nests in mode choice

In a discussion section to follow we present reasons that it may be better to model the toll/non-toll choice as part of the larger route choice problem within traffic assignment, rather than putting it with mode choice. In such a case, the demand models could supply information about Value of Time for each trip. The question then is how to incorporate the toll/non-toll choices realistically in assignment, taking into consideration the traveler's value of time for each modeled trip. The two additional options, described below, are (6) use VOT classes, (7) use Toll classes with variable VOT. **Within this group of options, our understanding is that only option 6 is feasible, because the EMME assignment software cannot handle option 7.**

6. **VOT classes**. In this option, there would be a number of different user classes that are made up of different VOT classes (at least 5 VOT classes should be used, and probably more). The toll/non-toll path choice would be determined in path building during assignment. The skims would be VOT-class-specific, so that the LOS faced in the demand model choices would correspond to the best path LOS for trips of the same VOT category.

7. **Variable VOT.** This option is like option 6, but instead of using VOT subclasses, it would employ an assignment procedure that accommodates variable VOT according to a parametrized distribution, or via disaggregate assignment with a distinct VOT associated with each assigned trip. For purposes of providing LOS information to DaySim, a discrete set of skims with VOT classes would be generated, as in option 6, or, if a disaggregate assigner were used, the LOS might be generated "on the fly" as needed for a particular VOT.

Discussion: Model Toll/non-Toll in Mode Choice?

Based on the above analysis, the design decision boils down to the two following options:

4. Mode choice: Model toll/non-toll
   Assignment: Use toll classes with 2-4 VOT subclasses.

6. Mode choice: Don't model toll/non-toll
   Assignment: Use at least 5 VOT classes.

Arguments for including toll/non-toll in mode choice

A discrete choice model can typically be specified more completely than a generalized cost minimization function used in highway path choice software. This can include additional variables, more complete market / VOT segmentation, and more complex, probabilistic choice functions which take into account the fact that not everyone chooses the "best" option. It is doubtful whether the network software can accommodate many of these aspects.

A discrete choice model produces a logsum measure across route types that can be used at higher levels of the model system. For example, having BOTH a good tolled path and a good alternative non-tolled path will increase the overall chance of using the auto mode. Network software typically only produces the best path, with no indication of how good the alternative paths are.

The weaknesses of binary toll/non-toll choice (see below) can be partially overcome by using VOT classes in assignment, so that the skim information used in the binary choice is VOT-class-specific.

This option retains the use of VOT-specific multi-class path assignment to realistically model the choice among a multitude of tolled path options faced by the traveler willing to pay tolls.

The result of the toll/non-toll choice can be retained in the disaggregate trip output of the AB microsimulator, enabling the impacts of toll policies (ie, usage/non-usage of tolls) to be studied for any desired subset of the population.

Mike Florian of INRO strongly recommends including toll/non-toll in mode choice. In his experience, this approach has worked better. He cites examples where models that rely on assignment to distinguish toll from non-toll demand tend toward "all-or-nothing" assignment on toll facilities.

Arguments for excluding toll/non-toll from mode choice

Network-based path selection algorithms can realistically account for the multitude of path options and trade-offs faced by a traveler on the network. In contrast, the skim information made available to a binary toll/non-toll choice is overly simplistic. For example, long trips may encounter multiple toll vs. no-toll choices in parallel, some with different prices. Using VOT classes can help resolve this problem. However, some trips may encounter such choices in series. That is, they have a choice to pay all of the tolls on the quickest path, or pay one but avoid the other, etc. Toll vs. Non-Toll is too simple a description of their choice set. Skims accumulate the total price of all tolls accepted at the assumed VOT. Situations like these will likely lead to poorly modeled binary outcomes that subsequently incorrectly constrain the assignment to choose an inferior solution (tolled when it should be un-tolled, or vice-versa).

Although both options involve multi-class assignment, this option would exclude the distinction between toll and non-toll classes, allowing more VOT classes to be used for the same amount of runtime, thereby improving the quality of the link flow predictions on tolled links.

This option avoids the awkward and questionable task of trying to force the network software to find the best tolled path and the best un-tolled path.

This option is simpler.

Additional issue related to transit with drive access

Five of the 18 modes represent transit with drive access or egress. These five modes don't explicitly identify the drive portion as being toll or free, nor do they identify occupancy. In order to combine the drive portion of those trips with other trips for assignment, it will be necessary to assign them to a class of occupancy (SOV, HOV2, HOV3+). If it is decided to use multi-class assignment for toll and non-toll classes, then it will also be necessary to assign them to a toll class (toll or non-toll).

Options for assigning auto portion of transit-drive trips to either toll or non-toll class (only needed if toll classes are used in assignment).

1. **Use toll/non-toll submodel** as is planned for the auto toll/non-toll modes. This would effectively increase the number of modes from 18 to 23.

2. **Assume non-toll.**

Option 1 is the recommended option, with option 2 to serve as a fallback during development if it becomes clear that option 1 is more complicated than it is worth.

Options for assigning occupancy class of transit-drive trips.

3. **Assume SOV**. This would be consistent with current assumptions in the park and ride model that all auto-transit trips are park and ride.

4. **Use a Monte Carlo draw** to determine whether the trip is park and ride (SOV) or kiss and ride (HOV2). The MC probabilities could be provided by a user-supplied assumption. Only the SOV transit-drive trips would need to be parked in the park and ride model. Eventually, a model could be used to distinguish park and ride from kiss and ride.

5. **Include a kiss-and-ride mode choice alternative.** For joint half-tours to work we would include kiss-and-ride as a mode choice alternative, and assume that kiss-and-ride trips use HOV2 for access and egress. Otherwise, SOV would be the assumed access and egress mode.

Option 3 is the recommended option, with option 2 to serve as a fallback option if it becomes clear that option 3 is more complicated than it is worth.

Project task and schedule implications.

If it is decided to use multi-class assignment with VOT and/or toll/non-toll classes, and to generate skims for those classes, then although the assignment and skimming don't need to be implemented in task 1 for purposes of model estimation, they need to be set up and tested for purposes of model application. This should still be done as part of task 1 so that it can be coordinated with the development of procedures for dealing with park and ride trips.

PSRC had no tolled facilities at the time of the household survey. Therefore, it will be impossible to estimate parameters for toll response, with or without distributed values of time, from the survey data. PSRC does have an SP survey that could provide some information in this regard. There are also other studies from which values of toll-related model coefficients can be inferred. The selection of detailed mode choice model specification and the source of parameters that can't be estimated from the HH survey will be made during the development of the mode choice models.

Resolution

A tentative decision has been reached to include toll/non-toll in mode choice. However, the exact method of handling assignment and skims needs to be worked out. If problems are encountered, we might revisit the decision about toll/non-toll mode choice. PSRC will lead the assignment design work as part of their task 1 responsibilities and coordinate it with John Gibb so he can develop consistent park-and-ride procedures.

Several aspects of the assignment design follow:

PSRC will ask INRO to provide an enhancement to EMME3 that generates skims for the best path that includes a toll.

The approach might allow for some discrepancies between the result of the toll/non-toll decision and the final assignment result. However, this should be reviewed to consider its conceptual soundness and the potential biases caused in the results. The skims produced need to be as consistent as possible with the behavioral basis and outcome of the mode choice toll/non-toll decision.

The assignment class definitions will change, probably along the following lines:

- SOV free
- SOV toll (2+ VOT classes)
- HOV2 free
- HOV2 toll
- HOV3 free
- HOV3 toll
- medium and heavy trucks (1+ classes by toll/free and/or VOT)

ISSUE 3—MODEL STRUCTURE

After the model structure was presented in the proposal, two model structure enhancements were identified: (1) improved structure for intra-household interactions, and (2) improved logsums via expanded and consistent use of time-dependent logsums.

Intra-household Interactions

First, for the new models that predict joint escort trips to work or school, which have never been implemented in any model system before, our thinking about the best way to incorporate the models has progressed. We now believe that the presence and participation in these joint travels should be modeled up at the household day level. This model will know which people in the household have mandatory patterns and are going to work or school, and will also know their usual work and school locations. Given that information, it will model the number, type, and participation in work/school/escort half tours at the HH level. The details of the trips will then be incorporated into the standard trip-level models. Table 3.1 presents the structure as presented in the proposal, with subsequent structural modifications shown in the darkly shaded rows. Details of the joint half-tour model will be worked out during the model development task of the project.

Table 3.1: Model Conditional Hierarchy

	Model Name	Level	What is predicted
	Mobility models		
1.1	Regular mode to work (optional)—INCLUDED	Worker	Mode used to work at least 80% (other %?) of time
1.2	Transit pass (optional)—INCLUDED	Person	Availability and type of transit pass
1.3	Auto Availability	Household	Number of autos available for use by members of the household
1.4	Auto type (optional)—EXCLUDED	Vehicle	Type of vehicle
	Day-level models		
2.1	Household day pattern (optional)—INCLUDED	HH-day	Whether pattern is (1) work or school on tour, (2) other on tour, or (3) at home all day for all persons in household
	Household joint half-tours to school or work Moved from model 4.2 below.	HH-day	Number and type of joint half-tours where one household member drops off or picks up another member at work or school
2.2	Household joint tour generation (optional)—INCLUDED	HH-day	Number and purpose of joint tours in the household
2.3	Joint tour participation (optional)—INCLUDED	HH-day	Persons on each joint tour
2.4	Person day pattern	Person-day	0 or 1+ tours for 7 activity purposes. 0 or 1+ stops for 7 activity purposes. 0 or 1 for work only at home (optional)
2.5	Exact Number of Tours	Person-day	For purposes with 1+ tours, 1, 2 or 3 tours.
	Tour-level models		
3.1	Tour Destination	Tour	Tour destination
3.2	Work-Based Subtour Generation	Work Tour	Number and purpose of any subtours made during a work tour
3.3	Tour Main Mode	(Sub)Tour	Main tour mode
3.4	Tour vehicle (optional)—EXCLUDED	Auto Tour	Vehicle used for tour
3.5	Tour Time of Day	(Sub)Tour	The 30-minute time period arriving and the 30-minute time period time period leaving primary destination
	Trip/stop-level models		
4.1	Intermediate Stop Generation	Half Tour	Number and activity purpose of any intermediate stops made on the half tour, conditional on day pattern
4.2	Linked Escort Trips (optional)—	Half-tour	Linkage of escort trips with trips of the escorted

	Model Name	Level	What is predicted
	INCLUDED Generation moved up to HH-day level; trip details modeled with other trip-level models		
4.3	Intermediate Stop Location	Trip	Location of each intermediate stop
4.4	Trip Mode Choice	Trip	Trip mode
4.5	Trip Departure Time	Trip	Departure time within 30 min. periods
4.6	Park-and-Ride lot choice (optional)—INCLUDED	Trip	Park-and-ride lot for transit-auto-access trip
4.7	Park-and-Walk lot choice (optional)—EXCLUDED	Trip	Parking lot choice for auto trips that require parking

Time-dependent logsums—overview

The enhanced design makes expanded and consistent use of time-dependent logsums. The benefit of this is that the models that that use logsums will be more realistically sensitive to time-of-day-specific changes of travel time and cost.

There are three basic types of logsums proposed for the PSRC model system (as used in the SACOG model): disaggregate tour mode choice, aggregate tour mode-dest choice, and aggregate intermediate stop location choice. Table 3.2 shows a list of the models in the model hierarchy, with use of logsums identified (trip/stop-level models are excluded because they don't use logsums; rather they use the destination, mode and time-of-day outcomes of the tour-level model). Since, in the model structure, the time-of-day models are conditioned by the destination and mode choice models, the logsum calculations use an assumed time of day. In the SACOG model, in a few cases the assumed time of day is drawn from a time-of-day distribution for tours of the type for which the logsum is needed. But in most cases, an arbitrary "most likely" time-of-day is assumed. The basic change is to draw time-of-day in all cases, from appropriate time-of-day distributions. This will make the logsums sensitive to time-of-day-specific changes in travel time and cost.

Table 3.2: Logsums in the model hierarchy

	Model	Disaggregate tour mode choice logsum	Aggregate tour mode-destination choice logsum	Aggregate intermediate stop location choice logsum
1.1	Regular mode to work		At usual workplace	Yes.
1.2	Transit pass	Tour destination		
1.3	Auto availability	Mode (to work, school)	At home.	
2.1	Household day pattern	Mode (to work, school)	At home	
	Household joint half-tours to school or work	to be determined	to be determined	to be determined
2.2	Household joint tour generation	to be determined	to be determined	to be determined
2.3	Joint tour participation	to be determined	to be determined	to be determined
2.4	Daily Activity Pattern	Mode (to work, school)	At home.	Yes.
2.5	Exact number of tours	Mode (to work, school)	At home.	
3.1	Tour destination	Mode	At destination.	Yes.
3.2	Work-based subtour generation (no. & purp, for tours to reg. workplace)		At regular workplace.	
3.3	Tour node		At destination.	Yes.
3.5	Tour time of day			
4.1	Intermediate stop generation (No. & purp)			For auto-based tour modes.

Time-dependent logsums—technical details

For **disaggregate tour mode logsums**, the logsum is calculated using the specific simulated arrival and departure times of the tour. For estimation of the mode choice model (used to calculate the logsums), the actual observed arrival and departure times are used.

For the **aggregate tour mode-dest logsums**, the number of pre-calculated logsums is increased by a factor of three, so that each logsum is TOD-specific, with three TOD categories (peak-peak, peak-offpeak and offpeak-offpeak). For model application, the simulated arrival and departure time are translated into one of these three categories. For estimation of the parameters of the model used to calculate the logsums, for each tour used in the estimation dataset, the mode and destination choice models use the LOS for the actual observed arrival and departure times (although the explanatory variables are limited to the three categories.)

For the **aggregate intermediate stop location logsums**, the two TOD categories used in the SACOG model are retained (peak and offpeak). For estimation of the logsum model parameters, for each intermediate stop used in the estimation dataset, the observed TOD of the arrival at or departure from the stop origin (whichever is applicable) is used

Times of day used in time-dependent logsums for model application

Times of day will be drawn stochastically at two main levels of the model system, to be used in model application when calculating or retrieving time-dependent logsums in models at that level (for which the soon-to-be simulated time-of-day outcomes are not yet known). The conditional distribution of times used in the draw will depend on outcomes known at that level.

For mobility and day-level models

For each employed person, simulate arrival and departure time pair for tours to an unknown usual workplace, and randomly select one of the times for intermediate stops, given person type and purpose (work). These are used for calculating disaggregate mode choice logsums for journeys to work.

For each student, simulate arrival and departure time pair for tours to an unknown usual school location, and randomly select one of the times for intermediate stops, given person type and school purpose. These are used for calculating disaggregate mode choice logsums for journeys to school.

For each employed person, simulate arrival and departure time for a work-based subtour, given person type. These are used for calculating aggregate mode-dest logsum at the usual work location.

For each household, simulate arrival and departure time pair for a tour, given that person is driver age and purpose is not work or school. These are used for calculating aggregate mode-dest logsums at the home location.

For tour-level models

For each tour, simulate tour arrival and departure time pair, and randomly select one of them for intermediate stops (for use when half-tour is not known), given whether tour is joint or individual, person type (for individual tours) and purpose (also use WB subtour, HB work tour to usual location, and HB work tour to non-usual location as 'purposes'). These are used for calculating disaggregate tour mode choice logsum, aggregate tour dest-mode choice logsum at tour destination, and aggregate intermediate stop logsum.

For each work tour, simulate WB sub-tour arrival and departure time pair, given person type and whether work tour is to usual or non-usual location. These are used for calculating aggregate tour dest-mode choice logsum at usual work location for WB subtour generation model.

Times of day used in time-dependent logsums for model estimation

To the extent possible, when estimating models that use logsums as explanatory variables, the times-of-day used to calculate the logsums should be actual times-of-day as observed in the data.

For mobility and day-level models

For each employed person, the usual arrival and departure time reported for journeys to work should be used if it is available. If it isn't available, then the actual arrival and departure time for a journey to the usual work location should be used. If it isn't available, then the actual arrival and departure time for the person's longest duration work tour should be used. If it isn't available, then the most frequently used time pair in the survey data for persons of the same person type should be used (consideration should be given to estimating a nuisance parameter for some of these fallback cases.)

For each student, similar logic should be used to define the 'actual' time period for journeys to the usual school location.

For calculation of aggregate mode-dest logsums, actual times of day for a given person and purpose will often be missing. Therefore, it will probably be best to assume the most likely time period pair, given person type and uncertain non-work/non-school purpose.

For tour-level models

For each tour, use the actual tour arrival and departure time pair. For intermediate stop logsums, if halftour is known (eg, intermediate stop generation model) then use actual tour dest arrival time for first halftour, and use actual tour dest departure time for second halftour; if halftour is not known (eg, in mode choice model), use most likely of actual arrival or departure time, given whether tour is joint or individual, person type (for individual tours) and purpose (also use WB subtour, HB work tour to usual location, and HB work tour to non-usual location as 'purposes'). (For work tours, the arrival and departure time pair should be for a work-based subtour, not for the home-based tour).

For each work tour, use most likely combination of arrival/departure time period for a WB subtour, given person type and whether work tour is to usual or non-usual location.

Resolution

We will proceed into model development with the above design for intra-household interactions and for time-dependent logsums, and allow for some adjustment as the details are implemented.