Puget Sound Regional Council
PSRC

ACTIVITY MODEL WORK PLAN & ACTIVITY GENERATION MODEL

Work Plan Report

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Prepared by:

BRADLEY, BOWMAN & CASTIGLIONE

Mark A. Bradley
524 Arroyo Ave.
Santa Barbara, CA 93109
805-564-3908
Mark_Bradley@cox.net

John L Bowman, PhD
28 Beals Street
Brookline, MA 02446
617-232-8189
John_L_Bowman@alum.mit.edu
www.JBowman.net

Joe Castiglione
29 Belmont Street
Somerville, MA 02143
617-666-8278
joe@joecastiglione.com

TABLE OF CONTENTS

INITIAL REQUIREMENTS

Prior to digging into the details of the recommended model design we asked PSRC to identify requirements that they would like us to incorporate into the design. This resulted in the following list of requirements. Unless the design document explicitly identifies otherwise, these requirements remain and can be considered part of the design.

1. **Spatial detail for demand models**. We will assume that the demand models should use parcel data. Our design work related to parcel geography will focus on how to do it.

   September 2008 adjustment: There are some measurements that may use grid cells to improve processing times.

2. **Spatial detail for traffic assignment**. PSRC intends to increase the number of zones, probably into the range from 2000-4000. The change will probably be implemented late in 2008.

3. **Temporal detail for demand models**. We will assume the use of a quasi-continuous approach in the time-of-day models, implemented via discrete choice models, with time periods of 30 minutes.

4. **Equilibrium assignment**. For the AB model implementation, we will assume traditional traffic and transit assignment models, at least for the initial application.

5. **Assignment model software**. PSRC is considering a change from Emme3, partly because of license cost increases associated with the number of zones, and partly because of functionality issues. If a change is made, it will probably occur in late 2008.

6. **Highway assignment time periods**. Highway assignment is carried out using five time periods with iterative demand feedback. After convergence, the two 3-hour peak period assignments are split into twelve 30-minute periods for final assignment. The design needs to take advantage of the availability of distinct LOS skims for 15 different time periods.

7. **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			

8. **Interface with UrbanSim.** PSRC desires to have model outcomes that are longer term than one day to come from UrbanSim rather than the AB model, so that they can interact more flexibly with the other long term model outcomes. These include, at least, residential location of households and non-institutional group quarters residents, usual work location of workers, usual school location of students and household auto ownership.

9. **OPUS framework.** The travel forecasting model system needs to operate within the Opus software framework used by UrbanSim.

   September 2008 addition: The implementation should include the capability to re-estimate and apply models within the OPUS framework.

OVERVIEW OF DESIGN

Model System Description

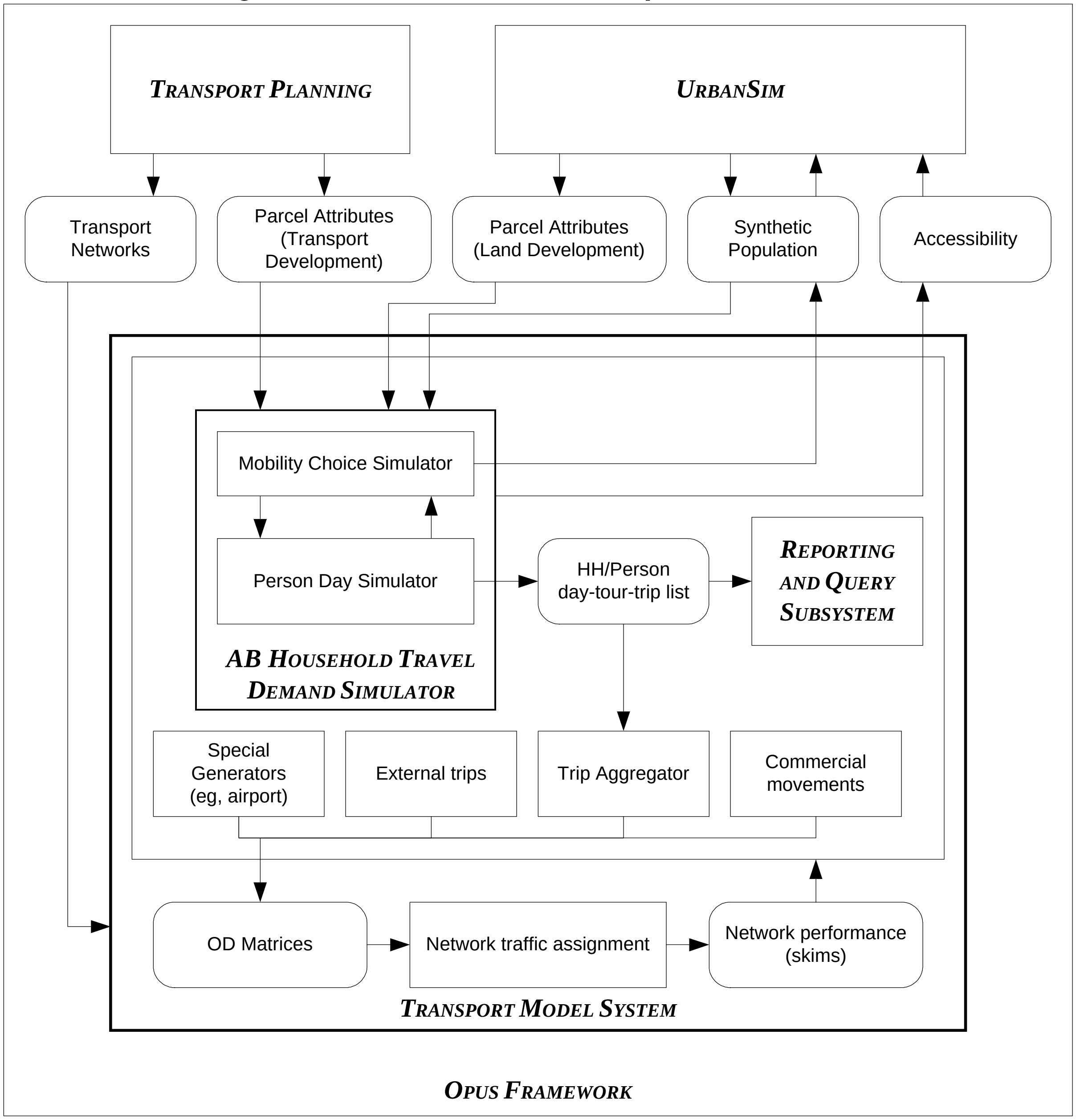
Figure 1 shows the proposed new transport forecasting model system integrated with UrbanSim within an Opus framework, where they iterate over time. The figure emphasizes the principal components of the transport model and their interaction, the inputs and outputs of that model system, and the needed interfaces with UrbanSim and the PSRC geodatabase.

As proposed, UrbanSim updates a census-based synthetic population to include residential, work and school locations of all household members for each forecast year, and also supplies parcel level forecast information about employment, population and the built environment. PSRC generates transport scenarios and associated network-based parcel attributes using its geodatabase tools.

The Activity-Based Household Travel Demand Simulator (AB Simulator) simulates mobility choices that are not included in UrbanSim (usual mode to work, etc) for all members of the population. It then creates a one-day activity and travel schedule for each person in the population, including a list of their tours and the trips on each tour. The trips predicted by the AB simulator are aggregated into trip matrices and combined with predicted trips for special generators, external trips and commercial traffic into time- and mode-specific trip matrices. The highway and transit assignment models load the trips onto the network. Assignment is iteratively equilibrated with the AB simulator and the other demand models.

The equilibrated transport model adds mobility information to the synthetic population and provides UrbanSim with accessibility information; creates day, tour and trip lists representing regional transport demand; and generates loaded network and skim matrices representing regional travel conditions.

Figure 1: New PSRC Regional Transport Forecasting Model System Integrated with UrbanSim within Opus Framework



A major design issue involves where to put models of outcomes that are determined on a longer time horizon than within-day. In past implementations of AB models, usual work location, usual school location and auto ownership have been incorporated into the transport model. PSRC has expressed a desire to instead put many of these within UrbanSim, because they interact with other outcomes modeled by UrbanSim. In this design document we categorize these longer term outcomes as either spatial and economic outcomes, on the one hand, or mobility outcomes, on the other. Spatial and economic outcomes include residential location, employment status, usual work location, student status, usual school location and household income. Mobility outcomes include auto ownership, vehicle type, usual mode to work, auto and transit pass holdings and parking subsidies. We recommend incorporating the spatial and economic outcomes into UrbanSim, for the reasons cited above. We recommend incorporating the mobility outcomes into the transport model because of the great degree of interaction that these outcomes have with daily transport decisions. However, the transport model can treat mobility outcomes as inputs instead of modeling them.

Comparison to PSRC Model System with Activity Generator

The PSRC Activity Generator now being implemented was designed to enable a smooth transition to the more complete AB model system, and the recommended design for the AB Model System carries through with that objective. As a result there are significant similarities between them.

1. The above AB Household Travel Demand Simulator (AB Simulator) is an enhanced version of the Activity Generator. It uses the same synthetic population input, has a similar activity pattern model and generates trips for all persons in the synthetic population.

2. One big difference is that the AB Simulator simulates the locations (at parcel level), modes and times of day for all activities and travel, rather than relying on the current zone-based model system.

3. In order to do the additional travel simulation, the AB Simulator requires a substantial amount of parcel-level information that the current model system doesn't use. This includes information primarily about land development that comes from UrbanSim, and information primarily about the transport system that comes from the PSRC planning process via the geo-database.

4. The new Transport Model System relies on existing procedures for predicting special generators, external trips and commercial movements, with the predicted trip matrices derived from the AB Simulator being merged with these other trips.

5. The basic interaction of the demand models with the network traffic (and transit) assignment is basically the same, although the network models might be enhanced to adjust the modes and time periods somewhat.

6. The accessibility information returned from the Transport Model System to UrbanSim is similar to that which is returned now, but the AB Simulator can produce logsum accessibility measures that we hope will provide superior information to UrbanSim.

Similarities to the SACOG Model System

The recommended PSRC model design represents an enhancement of the SACOG model system design. As such it retains key structural advantages of the SACOG model:

1. The model uses a microsimulation structure, predicting outcomes for each household and person in order to produce activity/trip records comparable to those from a household survey.

2. The AB model works at 4 integrated levels—longer term person and household choices, single day-long activity pattern choices, tour-level choices, and trip-level choices.

3. The upper level models of longer terms decisions and activity/tour generation are sensitive to network accessibility and a variety of land use variables.

4. The model uses 7 purposes for both tours and intermediate stops (work, school, escort, shop, personal business, meal, social/recreation).

5. The model allows the specific work and/or school tour destination for the day to differ from the person's usual work and school location.

6. The model predicts locations down to the single parcel level.

7. The model predicts the time that each trip and activity starts and ends to the nearest 30 minutes, using an internally consistent scheduling structure that is also sensitive to differences in travel times across the day.

8. The accessibility variables used in the upper level models are approximations to a true expected utility structure, with single variables ("logsums") encapsulating differences across different modes, destinations and times of day. Some of these are person-specific, and some of them are "aggregate" (representing important categories of person and household types.

9. The model accounts explicitly for time-space constraints in destination, mode and time-of-day choice to prevent the prediction of impossible combinations of choices.

10. The software implementation of the AB models allows the transport model to be used in several distinct ways, including (a) long-term, where all the mobility and within-day models are run, (b) short-term, where the mobility model outcomes are held fixed, and (c) FHWA New Starts mode, where the models down through tour destination choice are held fixed.

Differences from the SACOG Model System

The PSRC design includes a number of differences, enhancements and optional enhancements relative to the SACOG model, because of specific requirements of PSRC, and also because of lessons learned and advances that have occurred since the SACOG model was designed:

1. The AB Simulator and Transport Model System will be integrated with the UrbanSim models within the PSRC OPUS framework.

2. The design of the activity pattern model has been enhanced to better model work-at-home choices.

3. Several additional models might be included in the AB Simulator, including regular mode to work, type of vehicle, transit pass holding, household day pattern, household joint tour generation and participation, vehicle used for tour, and parking location choices. These are all described in the following section.

4. The long-term models have been divided into two classes: (1) household spatial and economic outcomes, and (2) mobility choices. The spatial and economic outcomes, including usual work and school location, will be excluded from the AB Simulator because they are being incorporated directly into UrbanSim where they will interact more directly with other models of economic and land development.

5. The definition of parcel attributes has been improved, additional parcel attributes made available by UrbanSim will be tested for their impact on activity and travel choices, and the interface that supplies parcel level data is expected to be more seamless, primarily because we expect much of the data to be produced automatically by UrbanSim.

6. The network models are expected to provide more detailed mode and time-of-day information to the AB Simulator, and the AB Simulator will likewise model a more specific mode choice outcome.

7. We are recommending that the AB Simulator include a Reporting and Query subsystem that enables users to easily generate pre-defined useful reports and custom queries, to take advantage of the information contained in the day, tour and trip lists produced by the AB Simulator.

AB MODELS

Model Structure

Table 1 lists all the proposed core and optional components of the AB model system, in order corresponding to a conditional hierarchy. Models lower in the hierarchy are conditioned by the outcomes of models higher in the hierarchy. Most of the models simulate multiple outcomes for a given household, and the simulation sequence proceeds as follows:

- All person-level outcomes are modeled one person at a time, in a fixed priority sequence
- Person-day outcomes are modeled one person at a time, in a fixed priority sequence
- All model outcomes above the tour level are simulated before any tour-level models are run.
- All tour-level and trip level outcomes are modeled one tour at a time, in a fixed priority sequence.
- Time window availability is restricted as tours and trips are simulated.

Within the above framework, the models simulate outcomes higher in the hierarchy first, so that their outcomes can be used to condition the models lower in the hierarchy.

Table 1: Model Conditional Hierarchy

	Model Name	**Level**	**What is predicted**
	Mobility models		
1.1	Regular mode to work (optional)	Worker	Mode used to work at least 80% (other %?) of time
1.2	Transit pass (optional)	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)	Vehicle	Type of vehicle
	Day-level models		
2.1	Household day pattern (optional)	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
2.2	Household joint tour generation (optional)	HH-day	Number and purpose of joint tours in the household
2.3	Joint tour participation (optional)	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)	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
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	Trip	Park-and-ride lot for transit-auto-access trip

	Model Name	Level	What is predicted
	(optional)		
4.7	Park-and-Walk lot choice (optional)	Trip	Parking lot choice for auto trips that require parking

The core models, unshaded in the table below, are included in the model system currently being used by SACOG. The optional models are not included in the existing SACOG model system, but the household-day models have been, or are currently being, implemented in other AB model systems, and most of the others have been implemented in other model systems in the US or Europe.

Mobility models

Regular mode to work (1.1)—Optional

Many workers regularly commute using the same travel mode, making it appropriate to model regular mode to work as a mobility choice. To our knowledge, no regional travel demand model has ever included this choice. However, the PSRC household survey asked workers to identify their travel mode to work in each of the previous ten days, providing good information with which to infer whether a worker has a regular mode to work, and what that mode is. Adding this model would realistically provide better information to the auto availability model and transit pass model, and increase the precision of the accessibility information used in the day activity pattern model.

The household survey variables are W1MODE1-W1MODE8 (number of times out of 10 for each of 8 modes. We examined these data items in the survey data to determine their completeness, and to identify for each respondent the number of times out of ten that they used the same mode to travel to work. **Table 2** shows that, among those who provided data, nearly 83% used the same mode on all ten days, and only 5% used their most frequent mode on less than 7 out of 10 days. This clearly indicates the behavioral realism of modeling regular work mode as a choice that conditions the day activity pattern, with a conditional within-day mode-to-work choice that uses the worker's regular mode as an explanatory variable. "Regular work mode" would be defined as the mode that is used for at least X% of work commutes (probably 70%, 80% or 90%). One of the choice alternatives would be "no regular work mode", which would be assigned in the survey sample to those who reported less than X% of their commutes by the same mode.

Unfortunately, the regular mode information is not available for workers whose survey was completed by a proxy, so only 2556 of 5350 workers (47.8%) have it. In order to include this model it would be necessary to estimate the regular mode to work with this limited subset of records. For the within-day work mode choice it would be necessary to identify an additional regular work mode of "unknown" and use this as an explanatory variable during model estimation. Since there are only 40 university or school students with the information, the model would need to be limited to full-time and part-time workers. **Table 3** shows the regular mode to work of full-time and part-time workers, where mode is defined as regular if it was used at least 7 times out of 10 in the survey data. The infrequency with which non-auto modes are chosen might make it necessary to aggregate non-auto mode alternatives in the regular work mode model.

Table 2: Frequency of traveling to work by most frequently used mode as observed in the household survey data

Number days by most frequently used mode	FT Worker	PT Worker	Univ Student	School Student	Total
3	1				1
4	5	1			6
5	47	15	2		64
6	41	15			56
7	51	11	1		63
8	93	22			115
9	104	13	2	2	121
10	1664	420	26	7	2117
98	6	1			7
99	3	3			6
valid	2015	501	31	9	2556
missing	2269	408	59	58	2794
total	4284	909	90	67	5350

Table 3: Regular Mode to Work (used at least 7 out of 10 times) as observed in the household survey data

	Number of workers				**Percentage of workers**		
	FT Workers	**PT Workers**	**Total**		**FT Workers**	**PT Workers**	**Total**
None	95	31	126		4.7%	6.2%	5.0%
Car, driving alone	1332	340	1672		66.2%	67.9%	66.5%
Car, sharing a ride with others	147	23	170		7.3%	4.6%	6.8%
Bus or train using park and ride	130	11	141		6.5%	2.2%	5.6%
Other bus or train	121	18	139		6.0%	3.6%	5.5%
Bicycle	37	9	46		1.8%	1.8%	1.8%
Walking the entire way	139	64	203		6.9%	12.8%	8.1%
Ferry with car	3	3	6		0.1%	0.6%	0.2%
Other Ferry	8	2	10		0.4%	0.4%	0.4%
Total	2012	501	2513		100.0%	100.0%	100.0%

Transit pass (1.2)—Optional

Possession of a transit pass should have a direct and strong effect to increase the choice of transit for tours and trips, and might also significantly affect the person's day activity pattern. The survey variables that can be used to construct the dependent variable include the following:

person data TPASS (have pass)
person data PTYPE1-PTYPE3 (type of up to 3 passes)

Preliminary data analysis indicates that transit passholding data is present for all persons. **Table 4** shows that transit passholders conduct a much higher percentage of the transit tours than do non-passholders, suggesting that passholding would be a strong predictor of mode choice. **Table 5** shows that transit passholding is also strongly correlated with the household's auto ownership and number of workers. For workers it is probably desirable to model transit passholding jointly with usual mode to work, since these two outcomes are almost certainly highly correlated. An alternative hierarchy would condition both regular mode to work and transit passholding on household car ownership.

Table 4: Tours by Mode and Transit Pass-holding Status of Traveler

Tour Model	Total Number of Tours	By Passholders	By Non-passholders	% by Passholders
1 School bus	1163	17	1146	1.5%
2 Drive to ferry	243	108	135	44.4%
3 Drive to transit	391	326	65	83.4%
4 Walk on ferry	50	38	12	76.0%
5 Walk to transit	1014	733	281	72.3%
6 Shared ride 3+	5732	242	5490	4.2%
7 Shared ride 2	5559	535	5024	9.6%
8 Drive alone	10409	880	9529	8.5%
9 Bike	309	63	246	20.4%
10 Walk	1965	333	1632	16.9%
Total	26835	3275	23560	12.2%

Table 5: Transit Passholders by HH Vehicles per Worker Category

	0 veh 0 wkrs	0 veh 1+ wkrs	1+veh veh<wkrs	1+veh veh>=wkrs	Overall
Passholders	152	146	238	2102	2638
Non-passholders	134	122	734	17158	18148
Total	286	268	972	19260	20786
% passholders	53.1%	54.5%	24.5%	10.9%	12.7%

Table 6: Transit Passholding by Worker Status

	passholder	non-passholder	Total	% passholders
worker	879	4387	5266	16.7%
non-worker	341	2052	2393	14.2%
under 16	28	1912	1940	1.4%
Overall	1248	8351	9599	13.0%

Auto availability (1.3)

This model is applied at the household level, and determines the number of vehicles available to the household drivers. Key variables are the numbers of working adults, non-working adults, students of driving age, children below driving age, income, auto and non-auto accessibilities to work and school locations, and more general pedestrian, transit and auto accessibility to retail and service locations.

Auto type (1.4)—Optional

This model assigns a vehicle type to each vehicle determined by the auto availability model. The definition of vehicle type can be devised so as to be useful for policy analysis, while at the same time distinguishing types that represent realistic differences that matter when households acquire vehicles. Possible determinants of the vehicle type definition include passenger capacity, cargo capacity, fuel efficiency, fuel technology and luxury classification. The data source for model estimation is the household survey, with the vehicle type variable derived from the vehicle make, model and year information collected for each household vehicle (HHVEHTY* and HHVEHYR*). Preliminary data analysis indicates that the presence of these data items is consistent with the number of vehicles ascribed to each household (HHNUMVEH).

Day-level models

Household day pattern (2.1)—Optional

This model determines the basic pattern type simultaneously for all members of the household. As implemented for ARC by Vovsha and Bradley, it defines three basic pattern type alternatives for each person: (1) work or school on tour, (2) other on tour, or (3) at home all day. An alternative definition would include work-at-home patterns in category (1). In the same way that the person day pattern model ties together the tours of one person within a day, this model ties together the day patterns of members of the household. It can thus naturally extend the day pattern approach to encompass the entire household. Starting at the top, the basic within-day hierarchy becomes household-day > person-day > tour > trip. The most tangible advantage of integrating the person-day models in this way is that it yields more realistic household day patterns, capturing tendencies for persons in a household to coordinate their schedules. For example, in two-worker households without children, workers might be inclined to work on the same days, whereas in two-worker households without children they might be inclined to not work on the same days, or to stay home when a child stays home. To our knowledge, there is no current evidence that modeling the household day pattern makes the model system more accurately sensitive to transport prices and policies, although it might.

Joint tour generation and participation (2.2-2.3)—Optional

The joint tour generation model identifies the number and purpose of tours that are conducted jointly by two or more members of the household, and the participation model identifies the household members who participate in each joint tour. A potential advantage of including this model is that the conditional models of destination, mode and timing might differ for joint tours than for individual tours. However, it is not clear that explicitly modeling joint tours actually improves the policy sensitivity of the model system.

Person-day activity pattern (2.4-2.5)

This model is a variation on the Bowman and Ben-Akiva approach, jointly predicting the number of home-based tours a person undertakes during a day for seven purposes, the occurrence of additional stops during the day for the same seven purposes, and the occurrence of at-home work. The seven purposes are work, school, escort, personal business, shopping, meal and social/recreational. The pattern choice is a function of many types of household and person characteristics, as well as land use and accessibility at the residence and, if relevant, the usual work location. The main pattern model (2.4) predicts the occurrence of tours (0 or 1+) and extra stops (0 or 1+) for each purpose, and for patterns with no work tours or stops, whether the person works at home. A simpler conditional model (2.5) predicts the exact number of tours for each purpose. This model, without the explicit at-home work component, is in use in the SACOG DaySim model, and being implemented in the PSRC Activity Generator model. The proposed enhancement enables the model to explicitly identify work at home, for those who usually work at home and for those with a non-home usual workplace. Accordingly it enables the model to include the explanatory factors that influence this decision, which may be different for these two situations.

Specifically, the pattern model would include a Boolean "Work only at home" attribute that could only be true in patterns with 0 work tours and 0 work stops:

> "work only at home" is true (1): means either that the person travels but not for work and has at-home work episode exceeding xx minutes, or that the person does not travel and declares work to be the major at-home activity
>
> "work only at home" is false (0): means either that the person travels for work, or that the person travels only for non-work and has no at-home work episode exceeding xx minutes, or that the person does not travel and does not declare work to be the major at-home activity.

Since the day activity pattern model takes a long time to run, one simplifying option would be to aggregate some of the purposes in the main pattern model and use the conditional model to determine not only the exact number of tours but also the exact purpose of each tour.

Data analysis will need to be done to see how many people there would be fitting various definitions of the work only at home rules. Also, each at home stay has a single duration, but can have up to a few different activities listed for it (out-of-home activities can have that also, but people tend to list multiple activities more often for in-home). So a rule will be needed to define the duration when there are multiple purposes listed. The simplest rule would be to give it all to the first (main) activity mentioned.

Tour-level models

Within each tour, three main models are used, to first simulate the tour's destination, then the main mode used for the tour, and finally the beginning and ending period of the tour's primary activity. For work tours, the number of work-based subtours is also modeled, after destination choice, and before timing and travel mode.

Preliminary analysis of the data indicates that the basic information needed to model the tour and trip decisions of mode, destination and timing is present for the vast majority of tours and their component trips. However, 1470 of the 78,559 trips in the data set (1.9%) are missing xy coordinates for at least one of the trip ends. Some of the models for these trips, and perhaps the tours that include them, will need to be estimated without these records.

Option: consider using a different hierarchy for non-work and non-school tours.

Tour destination (3.1)

These models determine the primary destination parcel/building for home-based tours and work-based subtours. For the tour destination, the logsum from the mode choice model across all modes is used as the main level of service variable.

The universal choice set of destinations is very large, including all parcel/buildings within the metropolitan area. In any given situation, some of the parcel/buildings will be infeasible, either because the location cannot be reached in the available time, or because the desired activity cannot be accomplished there. Also, for the sake of computational feasibility, the huge size of the choice set makes it necessary to sample alternatives when applying the destination choice models. A sampling procedure deals with both of these issues. The available alternatives are sampled in a way that allows the probability of being drawn into the sample to be calculated for each drawn alternative. Statistical procedures are then used during model estimation and application to allow the sample to represent the entire set of available alternatives without biasing the results.

The recommended sampling procedure is called two-stage importance sampling with replacement. In the first stage, a TAZ is drawn with a known probability approximately equal to its chance of containing the chosen destination. Then, a parcel/building is drawn within that TAZ with a known probability approximately equal to its chance of being the chosen parcel/building within the TAZ. The two main criteria used in the design of the procedure are statistical soundness and computational efficiency.

The current implementation of Urbansim uses a fixed set of parcels and adds buildings where future development may occur rather than subdividing parcels before adding additional buildings. As a result, it may be better to use buildings as the choice set for destination choice rather than parcels to adequately address future development within the current Urbansim implementation.

Number and purpose of work-based tours (3.2)

For this model, the work tour destination is known, so variables measuring the number and accessibility of activity opportunities near the work site are expected to influence the number of work-based tours.

Tour main mode (3.3)

The tour mode choice model determines the main mode for each tour (a small percentage of tours are multi-modal), with the alternatives being defined as in Table 8.

Tour vehicle (3.4)—Optional

If the tour is by auto and the household has more than one vehicle, then the tour vehicle model determines which vehicle to use for the tour. Important variables explaining the vehicle selection include the vehicle type and allocation, the tour purpose, auto submode, and the time window availability of the household's autos. It would be possible to model tour vehicle choice without strictly accounting for the available time windows for each vehicle of the household's vehicles (in the same way that each person's available time windows are accounted for), in the same way that mode choice can (and usualy is) modeled without such strict accounting. However, including strict vehicle fleet accounting would enhance the quality of the vehicle type and mode choice predictions.

Tour time of day (3.5)

The dependent variables of this choice model are a pair of 30-minute time periods representing the times that the person arrives at and departs from the activity location. It therefore provides an approximation of both time-of-day and activity duration. Since entire tours, including stop outcomes are modeled one at a time, first for work and school tours and then for other tours, the hours away from home for each tour become unavailable for subsequently modeled tours. The time period of a work-based subtour is constrained to be within the time period of its parent tour. The logsum from the tour mode choice model may be used to capture any differences in travel time and accessibility between periods.

Trip/stop level models

Although the presence of extra (intermediate) stops in the day pattern is determined in the pattern model, the exact number of stops for each purpose is a result of the stop level models. Within each half-tour, the stops are modeled one-by-one, first for stops before the tour destination, and then for stops after the tour destination.

Stops before the tour destination are modeled in reverse temporal sequence. First the number, purpose and sequence of stops is modeled. Then, for the last stop before the tour's destination, its location (4.2), departing trip mode (4.3), and time period of arrival at the tour destination (4.4) are modeled. These results also determine the time period in which the trip from the stop location begins, since the trip mode and travel level of service are known. This continues, constructing the trip chain from the tour primary destination to the tour origin in reverse chronological sequence until the trip from the tour origin to the first stop is modeled. The reason for modeling in reverse chronological sequence for the first half tour is the hypothesis that people aim to arrive at the primary destination at a particular time, and adjust their tour departure time so as to enable completion of the desired intermediate stops. After the trip chain for the first half-tour is modeled, the trip chain for the second half-tour back to the tour origin is similarly modeled, but this time in regular chronological order.

Half-tour stop frequency and purpose (4.1)

This is a multinomial choice model in which there is one alternative for each purpose plus a 'no more stops' alternative. For each half-tour, it is run repeatedly until the 'no more stops' alternative occurs. Important explanatory variables include the stop purposes selected in the day pattern model, and the number of stops for each purpose simulated so far in the person's simulated tours. As stop purposes called for by the pattern model are accomplished, the likelihood of additional stops decreases.

Linked escort trips (4.2)—Optional

An important type of joint travel is the case where two or more household members travel together to and/or from an activity location, but do not participate in the same activity there. The most common example is a parent driving a child to school and then either returning home (an escort tour) or else driving on to work (an escort stop on a work tour). The main benefit of explicitly linking these trips is that it makes the timing, mode and destination of the escort consistent with those of the person being escorted. The exact nature of this model is not clear, because an effective method of implementing models to achieve this linkage has never been developed. Implementing this option would involve innovative research and design.

Most existing models, however, do include a separate "escort" purpose, so that the most important special characteristics can be captured—particularly the fact that the mode is nearly always auto, with the exception of infrequent cases of walk escort. Also, children's school locations can easily be included as special alternatives in the parents' escort tour destination choice sets, so that at least the location is accurate, even if the exact trip timing and car occupancy are not matched. So, substantial benefits can be achieved by using implicit linkages of this type.

Intermediate stop location (4.3)

For intermediate stop locations, the main mode used for the tour is already known, so the choice is primarily a tradeoff between the additional deviation and impedance of making another stop by that mode versus the accessibility to additional land use opportunities in alternative parcel/buildings.

As with tour destinations, a sampling procedure is required for the stop location models, and a procedure is used that employs importance sampling with replacement. The exact procedure is different, however, because the sampling problem is more complex. For intermediate stops, the travel impedance affecting choice is a function of three locations instead of two: the intermediate stop location, as well as locations before it and after it in the half tour. This expands the number of relevant impedances geometrically. Therefore, a 3-stage importance sampling procedure is used. For each parcel/building to be drawn, first a stratum is drawn, then a TAZ within the stratum, and finally a parcel/building within the TAZ.

Trip mode (4.4)

The trip-level mode is conditional on the predicted tour mode, but now treats as given a specific tour OD pair and time period, as well as the trip mode for the adjacent, previously modeled trip in the chain. The trip mode alternatives are defined as in Table 7. The tour and trip level mode choice models are estimated simultaneously to ensure the most significant and consistent values for key travel time and cost coefficients.

Trip departure time (4.5)

At this stage, the main tour mode is known. Therefore it is possible to use the travel level-of-service by time of day for the chosen tour mode to help determine the departure times for the intermediate stops. For tours without intermediate stops, the trip timing model is not needed.

Park-and-Ride lot choice (4.6)—Optional

This model is run only for the first park-and-ride trip on a work tour with a tour mode of 'transit with auto access'. The dependent variable identifies whether a park-and-ride lot was used and, if so, which lot. The survey variables used to identify the dependent variable include responses to the questions of the type of parking location, whether it was a park-and-ride lot, and which lot, for the five possible trip segments (ParkA-ParkE, ParkLotA-ParkLotE, ParkWhA-ParkWhE). Important variables explaining the choice include the travel times and costs of the auto and transit legs of the trip. For model application, it will be important to account for fill status of each lot during each time period, to prevent overfilling. This could be accomplished by using a shadow price based on fill status that is updated when the model is iterated to equilibration. After a park-and-ride lot choice is simulated, the trip is split into two trips for purposes of network assignment, one with auto mode for auto assignment, and the other with transit mode for transit assignment.

Park-and-Walk lot choice (4.7)—Optional

The method just described for modeling park-and-ride lot choice might also be an effective way of modeling parking location choice for auto drive trips where the car must be parked at the destination and the traveler walks from the parking location to the activity location. This could be especially valuable in cases where parking congestion and/or parking pricing affect travel choices and are important policy issues. Modeling location choices at the parcel/building level paves the way for such models. However, to our knowledge, this type of model has never been incorporated in a regional forecasting model, and there would be many modeling issues to be worked through. Some of these would be related to the desirability of capturing the affects of capacity, parking prices and parking subsidies on destination, mode and timing choice. Other issues relate to the availability of good parking data for model estimation and application. Because of the innovative nature of this model, it is not a good candidate for the initial implementation, and it would require a substantial design phase. An initial implementation might only deal with work tours to certain high congestion areas such as the CBD, rather than all tours and trips.

Travel Modes

PSRC desires to have 18 distinct transport modes considered explicitly in the mode choice models of the AB model system, as listed in Tables 7 and 8 below. These 18 modes correspond to the current PSRC modes, except PSRC has considered but not yet separated tolled from non-tolled auto modes. It may be advantageous to double the number of Transit-Drive trip modes in order to identify whether the drive portion of the trip occurs before or after the transit portion. Given a trip mode, restrictions on link availability and usage will need to be enforced during highway assignment, transit assignment and skimming, as noted in the Trip Mode table.

Table 7: Trip Modes

	Non-motorized	Abbrev	Link Restrictions
1	Walk	W	
2	Bicycle	B	
	Auto—Free		
3	SOV Free	D1F	0 toll links, 0 HOV2 or HOV3+ restricted links
4	HOV2 Free	D2F	0 toll links, 0 Hov3+ restricted links
5	HOV3+ Free	D3F	0 toll links
	Auto—Toll		
6	SOV Toll	D1T	1+ toll links, 0 HOV2 or HOV3 restricted links
7	HOV2 Toll	D2T	1+ toll links, 0 HOV3+ restricted links
8	HOV3+ Toll	D3T	1+ toll links
	Transit—Walk		
9	Walk-Ferry	FeW	1+Fe link
10	Walk-Commuter Rail	CRW	0 Fe links, 1+CR links
11	Walk-Light Rail	LRW	0 Fe or CR links, 1+LR links
12	Walk-Express Bus	EBW	0 Fe, CR or LR links; 1+EB links
13	Walk-Local Bus	LBW	0 Fe, CR, LR or EB links; 1+EB links
	Transit—Drive		
14	Drive-Ferry	FeD	1+Fe link
15	Drive-Commuter Rail	CRD	0 Fe links, 1+CR links
16	Drive-Light Rail	LRD	0 Fe or CR links, 1+LR links
17	Drive-Express Bus	EBD	0 Fe, CR or LR links; 1+EB links
18	Drive-Local Bus	LBD	0 Fe, CR, LR or EB links; 1+EB links

The tour modes will probably correspond to the trip modes. However, during model development it may be determined that it is better to implement a more aggregate definition of the tour modes. Given a tour mode, restrictions on availability and usage of trip modes on the tour will need to be enforced, as noted in the Tour Mode table.

Table 8: Tour Modes

	Non-motorized	Abbrev	Trip Mode Restrictions and Availability
1	Walk	W	0 non-W
2	Bicycle	B	1+B; 0 auto or transit
	Auto—Free		
3	SOV Free	D1F	1+ D1F; 0 D2F, D3F, D1T, D2T, D3T, or transit
4	HOV2 Free	D2F	1+ D2F; 0 D3F, D1T, D2T, D3T, or transit
5	HOV3+ Free	D3F	1+ D3F; 0 D1T, D2T, D3T, or transit
	Auto—Toll		
6	SOV Toll	D1T	1+ D1T; 0 D2T, D3T, or transit
7	HOV2 Toll	D2T	1+ toll; 1+ D2, 0 D3F, D3T, or transit
8	HOV3+ Toll	D3T	1+ toll; 1+ D3, 0 transit
	Transit—Walk		
9	Walk-Ferry	FeW	1+ FeW; 0 transit-drive
10	Walk-Commuter Rail	CRW	1+ CRW; 0 FeW; 0 transit-drive
11	Walk-Light Rail	LRW	1+ LRW; 0 FeW or CRW; 0 transit-drive
12	Walk-Express Bus	EBW	1+ EBW; 0 FeW, CRW or LRW; 0 transit-drive
13	Walk-Local Bus	LBW	1+ LBW; 0 FeW, CRW, LRW, EBW; 0 transit-drive
	Transit—Drive		
14	Drive-Ferry	FeD	1+ transit-drive; 1+ Fe
15	Drive-Commuter Rail	CRD	1+ transit-drive; 1+ CR; 0 Fe
16	Drive-Light Rail	LRD	1+ transit-drive; 1+ LR; 0 Fe or CR
17	Drive-Express Bus	EBD	1+ transit-drive; 1+ EB; 0 Fe, CR or LR
18	Drive-Local Bus	LBD	1+ LBD; 0 Fe, CR, LR or EB

Accessibility variables

Accessibility measures are discussed separately in this memo for two reasons. First, they are very important because in a hierarchical model system, they capture the sensitivity of activity and travel decisions modeled in higher levels of the model hierarchy to the utility of opportunities associated with conditional (and hence 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. For example, in a destination choice model, a logsum variable can capture the expected utility of the available travel mode alternatives. This is a very important aspect of model integration, and can be called upward vertical integration. Without it, the model system will not effectively capture sensitivity to travel conditions. Second, when there are very many alternatives (millions in the case of the entire day activity schedule model), the most preferred measure of accessibility, the expected utility logsum, requires an infeasibly large amount of computation.

For the PSRC Activity model, we recommend the use of two techniques to supplement the selective use of true logsums, in an effort to achieve upward vertical integrity with a feasible amount of computation. The basic idea of the first technique is to avoid the use of a time of day logsum when applying an upper level model by treating as given a yet un-modeled time of day. The assumed time of day is selected by a Monte Carlo draw using observed time-of-day distributions. Rather than making every simulated outcome sensitive to variability in level of service by time of day, sensitivity is achieved across the population through the variability of outcome in the Monte Carlo draws. In this way, the upper level 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 effects 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 decision-makers, 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 decision-makers 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 and driving age, yielding four socioeconomic classifications (under age 16, household without a car, household with less cars than drivers, household with 1+ cars per driver). Second, it uses three aggregate distance bands for transit walk access (short access, long access, walk access unavailable). Third, sometimes it uses a logsum for a composite or most likely purpose instead of calculating it across a full set of specific purposes; distinct logsums are generated for the following categories: escort, personal business, shop, meal, social visit, recreation, work-based subtour, and composite nonwork purpose. 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 an assumed available time window size and time period combination that is most likely for the particular logsum being calculated. With these simplifications, it is possible to pre-calculate 96 logsums for each TAZ, and use them when needed at any point in the simulation of any person's day activity schedule. These logsums are generated using simplified versions of the tour mode and destination choice model, estimated using only the explanatory variables that distinguish the 96 logsum categories.

The approximate intermediate stop location choice logsums are used in the activity pattern model, tour destination choice, and other models where the choice may be influenced by the convenience of access for intermediate stops on the way to or from the tour destination. 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 (detour) time and zonal attractiveness, and zonal attractiveness is a function of employment and school enrollment, taken from an estimated purpose-non-specific intermediate stop location choice model (simplified version of model 4.3).

Table 9 shows a list of the models in the model hierarchy, with preliminary specification for the measurement of accessibility, including direct measures, true logsums, approximate logsums and simulated outcomes. The measures actually used will likely vary somewhat from what is described here, based on the results of further design work and empirical results of model estimation. But it is important for the implemented models to include most of the accessibility measures identified here.

Urbansim also has a series of accessibility measures used in the long-term choice spatial and economic models. It will be important for these accessibility measures to be evaluated and compared to the proposed mobility model measures so that consistency can be achieved where desired, efficiency can be achieved by calculating these measures only once, and so that advancements in developing these measures can be achieved across all models. One example of a new accessibility measure is the time-space prism accessibility used in the residential location choice models, which measures how much time you need for an activity at the intermediate location given constraints on departure and arrival times.

Table 9: Measurement of accessibility (impedance and spatial attribute effects) in the model hierarchy

	Model	Direct measures of travel impedance	Direct measures of spatial attributes	Disaggregate logsums	Simulated conditional outcomes	Aggregate tour mode-destination choice logsum	Aggregate intermediate stop location choice logsum
1.1	Regular mode to work	All LOS variables	Parking costs, Transit accessibility, Mixed use density, Grid connectivity.		Time of day	At regular workplace	Yes.
1.2	Transit pass		Parking costs, Transit accessibility, Mixed use density, Grid connectivity.	Tour destination			
1.3	Auto availability	distance to transit stop	Parking price near home. Commercial employment near home.	Mode (to work, to school)	Time of day	At home.	
1.4	Auto type	distance to transit stop	Parking price near home. Commercial employment near home.	Mode (to work, to school)	Time of day	At home.	
2.1	Household day pattern			Mode (to work, school)	Time of day	At home	
2.4	Daily Activity Pattern		Mixed use density near home. Intersection density near home.	Mode (to work, school)	Time of day	At home.	Yes.
2.5	Exact number of nours			Mode (to work, school)	Time of day	At home.	
3.1	Tour destination	Distance	Employment, enrollment, households, Parking & employment mix, grid connectivity, Parking costs, Transit accessibility, Mixed use density.	Mode	Time of day	At destination.	Yes.
3.2	Work-based subtour generation (no. & purp, tours to reg. workplace)		Commercial employment near work. School enrollment near work.			At regular workplace.	
3.3	Tour node	All LOS variables	grid connectivity, Parking costs, Transit accessibility, Mixed use density.		Time of day	At destination.	Yes.
3.5	Tour time of day	Travel time and cost					
4.1	Intermediate stop generation (No. & purp)		Grid connectivity X commercial employment at tour destination				For auto-based tour modes.
4.3	Intermediate stop location	Generalized time. Distance. Distance from tour origin. Distance from tour dest.	Employment, enrollment, households. Parking & employment mix.				
4.4	Trip mode	All LOS variables	Parking costs. Transit accessibiity.				
4.5	Trip departure time	Travel time and cost					
4.6	Park-and-ride lot	Travel time and cost	Parking cost, capacity, expected fill level				
4.7	Park-and-walk location	Travel time and cost	Parking cost, capacity, expected fill level				

AB MODEL INPUTS

This and the next section specify the inputs and outputs of the AB model, identifying the requirements for data that must be exchanged among the major components of the integrated model system, namely UrbanSim, the AB-model, and the assignment models (highway and transit). In each of the following sub-sections, a category of data is described, a preliminary set of data items is listed, and possible issues and variations are discussed.

Synthetic Population from UrbanSim

The following variables should be provided as inputs to the AB model. They (nearly) match the variables already specified as input for the new activity generator under development. To be consistent with it, dBase IV file format is preferred, with person records for all members of the households in the sample. Variables SAMPNO to HOURS and EXFAC are PUMS household and person variables, while HTAZ, HPARCEL, UWTAZ, UWPARCEL and UWTYPE are all added by UrbanSIM. The file should be sorted by SAMPNO and then by PNUM within household. The number of person records within any household should be equal to the value of PERSONS. The values of SAMPNO, PERSONS, VEHICL, HINC, HTAZ, HPARCEL and EXFAC are identical for all persons within a household.

As noted above in the description of destination choice models, destination choice sets may be defined in terms of buildings rather than parcels. If this is the case, then HPARCEL, UWPARCEL and USPARCEL should also be defined at the building level instead of the parcel level.

Table 10: Included synthetic sample variables

Label	Definition
SAMPNO	Household ID
PNUM	Person sequence number within HH
PERSONS	# persons in the household
HINC	Household annual income ($)
RELATE	Relation to head of household (PUMS coding)
SEX	Gender (1=male, 2=female)
AGE	Age (years)
STUDENT	Person is a student (0/1)
GRADE	Grade/level in school (PUMS coding)
WORKER	Person is a worker (0/1)
HOURS	Hours worked per week
HTAZ	Residence zone
HPARCEL	Residence parcel/building ID
UWTAZ	Usual work zone
UWPARCEL	Usual work parcel/building ID
UWTYPE	Usual workplace type (-1 = N/A, 1=out of home, 2=at home, 3=none)
USTAZ	Usual school zone
USPARCEL	Usual school parcel/building ID
USTYPE	Usual school type (-1 = N/A, 1=out of home, 2=at home, 3=none)
EXFAC	Expansion factor
VEHICL	PUMS # of vehicles in the household (used for testing purposes)

Parcel/Building Attributes from UrbanSim

Tables 11 and 12 show the complete list of Parcel/Building variables that should be provided by UrbanSim as potential input to the AB model. As noted above in the description of destination choice models, destination choice sets might be defined in terms of buildings rather than parcels. If this is the case, then all of the data items in Tables 11 and 12 should be supplied for each building in the region rather than for each parcel.

Table 11: Parcel/Building Attributes to be supplied by UrbanSim

Label	Definition
PARCELID	Parcel/Building ID number
X_spf	Xcoordinate – state plane feet
Y_spf	Y coordinate – state plane feet
SQFT	Area – square feet
TAZ	TAZ number
HOUSES_P	Housing units – parcel (x 100)
HOUSES_Q	Housing units – quarter mile radius (x 100)
HOUSES_H	Housing units – half mile radius (x 100)
EMPEDU_P	Education jobs – parcel/building (x 100)
EMPFOODP	Food service jobs – parcel/building (x 100)
EMPGOV_P	Government jobs – parcel/building (x 100)
EMPOFC_P	Office jobs – parcel/building (x 100)
EMPRET_P	Retail jobs – parcel/building (x 100)
EMPSVC_P	Service jobs – parcel/building (x 100)
EMPMED_P	Medical jobs – parcel/building (x 100)
EMPIND_P	Industrial jobs – parcel/building (x 100)
EMPTOT_P	Total jobs – parcel/building (x 100)
EMPEDU_Q	Education jobs – quarter mile radius (x 100)
EMPFOODQ	Food service jobs – quarter mile radius (x 100)
EMPGOV_Q	Government jobs – quarter mile radius (x 100)
EMPOFC_Q	Office jobs – quarter mile radius (x 100)
EMPRET_Q	Retail jobs – quarter mile radius (x 100)
EMPSVC_Q	Service jobs – quarter mile radius (x 100)
EMPMED_Q	Medical jobs – quarter mile radius (x 100)
EMPIND_Q	Industrial jobs – quarter mile radius (x 100)
EMPTOT_Q	Total jobs – quarter mile radius (x 100)
EMPEDU_H	Education jobs – half mile radius (x 100)
EMPFOODH	Food service jobs – half mile radius (x 100)
EMPGOV_H	Government jobs – half mile radius (x 100)
EMPOFC_H	Office jobs – half mile radius (x 100)
EMPRET_H	Retail jobs – half mile radius (x 100)
EMPSVC_H	Service jobs – half mile radius (x 100)
EMPMED_H	Medical jobs – half mile radius (x 100)
EMPIND_H	Industrial jobs – half mile radius (x 100)
EMPTOT_H	Total jobs – half mile radius (x 100)
COUNTY	County ID

PARCELID	Parcel ID number
STUDK12P	Students K-12- parcel/buuilding (x 100)
STUDK12Q	Students K-12– quarter mile radius (x 100)
STUDK12H	Students K-12– half mile radius (x 100)
STUDUNIP	Students University– parcel/building (x 100)
STUDUNIQ	Students University – quart. mile radius (x 100)
STUDUNIH	Students University – half mile radius (x 100)
NODES1Q	1 link nodes– quarter mile radius (all streets network)
NODES1H	1 link nodes– half mile radius (all streets network)
NODES3Q	3 link nodes– quarter mile radius (all streets network)
NODES3H	3 link nodes– half mile radius (all streets network)
NODES4Q	4+ link nodes– quarter mile radius (all streets network)
NODES4H	4+ link nodes– half mile radius (all streets network)
FERDIST	Distance to nearest ferry stop (miles x 100 -1 if none)
CRTDIST	Distance to nearest commuter rail stop (miles x 100 -1 if none)
LRTDIST	Distance to nearest LRT stop (miles x 100 -1 if none)
EXBDIST	Distance to nearest express bus stop (miles x 100 -1 if none)
BUSDIST	Distance to nearest local bus stop (miles x 100, -1 if none)
PARKDY_P	Daily paid parking spaces- parcel
PARKDY_Q	Daily paid parking spaces- quarter mile radius
PARKDY_H	Daily paid parking spaces- half mile radius
PPRICDYP	Avg price daily parking- parcel (cts)
PPRICDYQ	Avg.price daily parking- quarter mile (cts)
PPRICDYH	Avg.price daily parking- half mile (cts)
PARKHR_P	Hourly paid parking spaces- parcel
PARKHR_Q	Hourly paid parking spaces- quarter mile radius
PARKHR_H	Hourly paid parking spaces- half mile radius
PPRICHRP	Avg price hourly parking- parcel (cts)
PPRICHRQ	Avg.price hourly parking- quarter mile (cts)
PPRICHRH	Avg.price hourly parking- half mile (cts)

UrbanSim generates outputs at the parcel and building level that have not generally been available in the past for use in disaggregate demand models. Table 12 identifies potentially useful variables that should be supplied to the AB model, and notes there source.

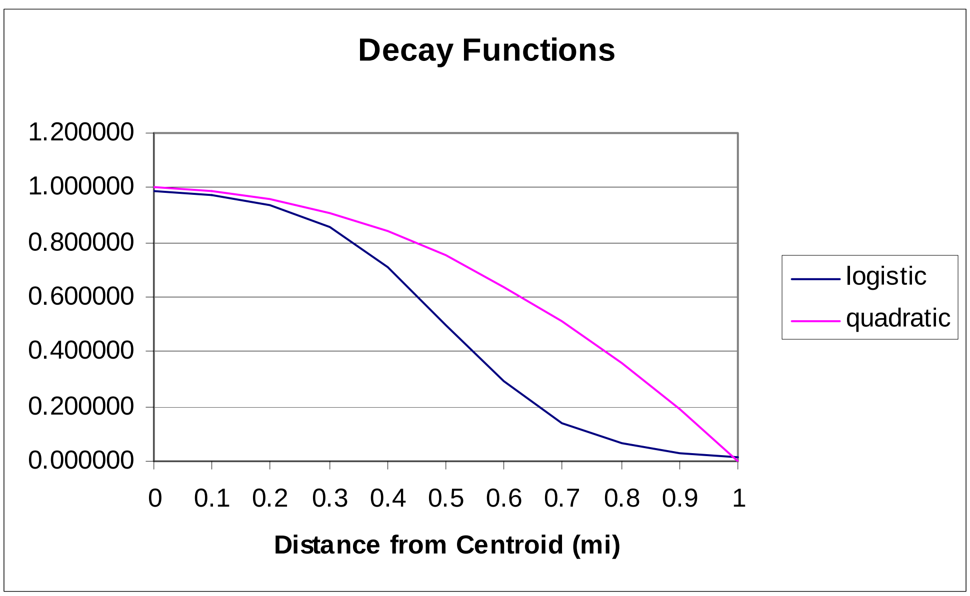
Table 12: Potentially Useful UrbanSim Parcel/Building Variables

Label	UrbanSim Source	Definition
city_id	Parcel table	
is_inside_urban_growth_boundary	Parcel table	
land_us_type_id	Parcel table	
unit_price (per sq ft)	Parcel table	price of land and improvements per sq ft of buildings on parcel (or of parcel for unimproved parcels)
num_building_records	Parcel table	(on building's parcel)
parcel sqft	Parcel table	sq ft of building's parcel (from assessor)
parcel_sqft_in_gis	Parcel table	sq ft of building's parcel (from GIS maps)
plan_type_id	Parcel table	
tax_exempt_flag	Parcel table	
predominant Building_type_id	Buildings table	
non-residential sqft	Buildings table	
residential_units	Buildings table	
sqft_per_unit	Buildings table	
first year_built	Buildings table	earliest year built
last year built	Buildings table	most recent year built

Most of the Table 11 variables occur in three versions: the count within the parcel/building, and the count within two buffer zones surrounding the parcel centroid (quarter-mile and half-mile. We have identified two improvements that could substantially improve the quality of these variables. First, the buffer variables could use walking distances along the street network to capture connectivity effects. This requires use of an all-streets network overlay in GIS (including pedestrian-only) that has already been used in this way in Seattle projects with Larry Frank. PSRC desires to generate variables two ways for model estimation, with and without street-based distance buffers, test them both during model estimation, and decide whether which to use. Either way, the data needs to be generated within UrbanSim and exported to the geodatabase or generated in the geodatabase to provide input for the AB model forecasts.

Second, instead of using uniform weights within the buffer, a distance decay function should be used, with full weight at the parcel/building centroid, declining to a weight of zero at the boundary. Two possible decay functions are quadratic (gradual initial decay, accelerating rapidly as boundary is approached) and logistic decay (gradual decay near centroid, increasing to fast decay partway, then decreasing again near the boundary), as shown in the following chart. In Figure 2 the quadratic function is $weight = 1 - dist^2$, and the logistic function is $weight = 1/(1 + \exp(9(dist - .5)))$. Ideally, it would be nice to test various shapes and widths of buffer zones. However, generating buffer variables can be time consuming, so it would be acceptable to generate only one buffer zone for each variable, perhaps one of the two shown here.

Figure 2: Possible Functional Forms for the Parcel/Building Buffer Variable Weight Decay Functions



Since UrbanSim already keeps track of attributes of grid-cells, it may be efficient to calculate parcel/building buffers as aggregations of grid-cell cell values among grid cells surrounding the parcel/building. This would not preclude using walk-distance buffers or decay functions. They could be based on grid-call distances from the parcel/building location or from the centroid of the grid-cell in which the parcel/building is located.

We have identified several additional considerations that would substantially improve the quality of the parcel/building data.

Third, the **school enrollment variables** would be improved by including pre-K enrollment, subdividing the K-12 enrollment into categories corresponding to the predominant grade ranges of standalone school facilities, such as pre-K, K-5, 6-8, and 9-12, subdividing school enrollment by public and private, and subdividing university enrollment by commuter enrollment and residential enrollment.

Fourth, the **node variables**, which are useful indicators of pedestrian friendliness, should be measured on an all-streets network that includes pedestrian-only links.

Fifth, one of the model design options is to include park-and-ride location choice as a component of the AB model system, so the choice could be modeled at the parcel/building level, and include lot-specific capacities and prices. In that case we would need to have parking capacities and prices for all qualifying parcels/buildings.

Sixth, the parcel/building data could include additional geographic aggregations beyond TAZ. We understand that there are several such categorizations at PSRC, and it may be desirable to put one or two of them in the parcel/building data along with the parcel/building ID and its TAZ ID.

Table 13 lists the employment categories included in Table 11 and recommended for use by PSRC. Table 14 defines them in terms of the existing PSRC UrbanSim employment categories.

Table 13: AB Model Employment Categories

AB Model Employment Category	Est 2000 Jobs	Share
Industrial	609,411	0.33
Retail	203,915	0.11
Office	327,252	0.18
Food	128,233	0.07
Education	109,296	0.06
Medical	181,612	0.10
Services	122,990	0.07
Government	166,860	0.09
Total	**1,849,569**	

Table 14: UrbanSim Employment Categories with Correspondence to Recommended AB Model Employment Categories

ID	Est 2000 Jobs	PSRC UrbanSim	AB Model
1	10,173	Natural resources and mining	Industrial
2	120,316	Construction	Industrial
3	91,188	Aerospace	Industrial
4	109,876	Other durable goods	Industrial
5	24,088	Nondurable goods	Industrial
6	87,430	Wholesale trade	Industrial
7	203,915	Retail trade	Retail
8	68,982	Transportation and warehousing	Industrial
9	2,703	Utilities	Industrial
10	31,542	Telecommunications	Industrial
11	63,113	Other information	Industrial
12	111,783	Financial activities	Office
13	215,469	Professional and business services	Office
14	128,233	Food services and drinking places	Food
15	17,143	Educational services	Education
16	181,612	Health services	Medical
17	122,990	Other services	Services
18	166,860	Government	Government
19	92,153	Education	Education
	1,849,569	**Total**	

Skim data from Assignment Models

OriginZone-to-DestinationZone skim data by time of day are needed for **each** of the 18 trip modes defined for the AB model, as listed in the table below for each category of mode. In addition, we identify two special OD matrices identifying the need for major bridge and ferry crossings that are likely to be important for the destination choice models in the PSRC context

Table 15: OD Skim data items

Non-motorized (2 modes)
distance (miles x 100) or time (minutes x 100)
Auto—Free (3 modes)
travel time (minutes x 100)
travel distance (miles x 100)
Auto—Toll (3 modes)
travel time (minutes x 100)
travel distance (miles x 100)
Toll (cents)
All transit (10 modes)
fare (cents)
in-vehicle time (minutes x 100)
first wait time (minutes x 100)
number of boardings
transfer time (minutes x 100)
Transit-Drive (5 modes)
drive time (minutes x 100)
drive distance (miles x 100)
drive toll (cents)
Bridge and Ferry Indicators
A major bridge crossing is required to get from O to D
A ferry crossing is required to get from O to D

It is desirable to have a flexible software implementation that allows the following characteristics of the skim data to be used in the models:

- To allow time periods as small as 30 minutes corresponding to the time periods of the time-of-day models
- To allow some modes to have different time periods than others
- To allow one skim file to be used for more than one mode
- To allow a skim table to represent the OD direction in some cases and the DO direction in others
- To allow skims for Transit—Drive modes to depend on whether the drive end is at the origin or destination

To do this, we propose to allow the user to input a "roster" table of level of service files. Given a mode, time period and, for Transit—Drive, the drive end of the trip, the roster identifies the prefix of the skim files that supply the skim attribute values, and whether the values are in the OD or DO direction. Table 16 shows an example of a partial table demonstrating the flexibility available for assigning skim files.

Table 16: Example of partially specified skim data input structure

Mode	Start time	End time	Drive End of Drive-Transit	File name prefix	Direction
Walk	300	259		walk	1
HOV2 Free	300	559		HOV1	1
HOV2 Free	600	729		HOV2	1
HOV2 Free	730	859		HOV3	1
HOV2 Free	900	1159		HOV2	2
HOV3 Free	300	559		HOV1	1
HOV3 Free	600	729		HOV2	1
HOV3 Free	730	859		HOV4	1
HOV3 Free	900	1159		HOV2	2
Drive—Commuter Rail	500	959	O	CRD1	1
Drive—Commuter Rail	1500	2159	D	CRD2	1

AB MODEL OUTPUTS

Person-day, Tour and Trip Files from AB Model

The main output of the activity-based model consists of three files: person-day, tour and trip. The person-day file includes one record for the simulated day of each person, consisting primarily of the number and purpose of tours and stops in the person's day. The tour file includes one record for each tour in the person's day, including work-based tours, and the trip file includes one record for each trip in each tour.

Table 17: Person-day file (from AB model)

Label	Definition
SAMPNO	Household ID
PNUM	Person sequence number within HH
HTAZ	Residence zone
HPARCEL	Residence parcel ID
PERSONS	# persons in the household
HHCARS	# vehicles in the household
UWTAZ	Usual work zone
UWCEL	Usual work parcel
USTAZ	Usual school zone
USCEL	Usual school parcel
NTOURS1	Number of work tours
NTOURS2	Number of school tours
NTOURS3	Number of escort tours
NTOURS4	Number of personal business tours
NTOURS5	Number of shopping tours
NTOURS6	Number of meal tours
NTOURS7	Number of social/recreation tours
NSTOPS1	Number of work stops
NSTOPS2	Number of school stops
NSTOPS3	Number of escort stops
NSTOPS4	Number of personal business stops
NSTOPS5	Number of shopping stops
NSTOPS6	Number of meal stops
NSTOPS7	Number of social/recreation stops
WBTOURS	Number of work-based subtours
EXPFAC	Expansion factor (same as EXFAC x subsample

Table 18: Tour file (from AB model)

Label	Definition
SAMPNO	Household ID
PNUM	Person sequence number within HH
TOURNO	Tour sequence number within person day
TOURPURP	Tour purpose (1 to 7, as above)
PRNTTOUR	Work-based subtour “parent” tour ID (0 for
PDTAZ	*Tour primary destination zone*
PDCEL	*Tour primary destination parcel/building*
TIMARRPD	*Tour primary destination arrival time (HHMM)*
TIMDEPPD	*Tour primary destination departure time*
MAINMODE	*Tour main mode*
TRIPSH1	Tour # of trips in first half tour
TRIPSH2	Tour # of trips in second half tour
SUBTOURS	Tour # of subtours
EXPFAC	Expansion factor (same as EXFAC x subsample

Table 19: Trip file (from AB model)

Label	Definition
SAMPNO	Household ID
PNUM	Person sequence number within HH
TOURNO	Tour sequence number within person day
TOURHALF	Tour half (1=outbound, 2=return)
TRIPNO	Trip sequence number within half-tour
OTAZ	*Trip origin zone*
OCEL	*Trip origin parcel/building*
DTAZ	*Trip destination zone*
DCEL	*Trip destination parcel/building*
MODE	*Trip mode*
OPURP	Trip orig act. purp (1-7 as above, or 8=home)
DPURP	Trip dest act. purp (1-7 as above, or 8=home)
DEPTIME	*Trip departure time (HHMM)*
TRAVTIME	*Trip door-to-door travel time (min)*
TRAVCOST	*Trip door-to-door travel cost ($)*
EXPFACT	Expansion factor (same as EXFAC x subsample

Augmented Synthetic Population from AB Model

The AB model will augment the synthetic population with all of the household and person-level mobility decisions modeled within the AB model. Given the dynamic iterative implementation of UrbanSim with the AB model, it might be appropriate to use some of these directly as explanatory variables in UrbanSim models, if a method can be determined for estimating the correct parameters.

Accessibility Data from AB Model

The accessibility data available to UrbanSim is basically the same as the accessibility data described above that is used in the upper levels of the AB model itself. It would be possible to construct a composite logsum that incorporates expected utility across all possible activity patterns, and it has conceptual advantages, but should only be generated if there is a desire to test this kind of variable in particular UrbanSim models.

DATA FOR MODEL ESTIMATION, CALIBRATION AND VALIDATION

Mobility Models

- Regular mode to work
  - Estimation: The household survey, including household attributes, accessibility measures and transportation network levels of service will be the primary sources

for model estimation. The household survey provides information on travel mode to work for each of the 10 days prior to the survey that can be used to infer whether there is a "usual mode" for each worker.

- Calibration / Validation: The household survey will be the source for all calibration and validation target mode shares. No additional data collection is required.

- Auto availability
  - Estimation: The household survey, including household attributes, and work location and mode choice, will be the primary sources for model estimation
  - Calibration / Validation: Calibration and validation targets will be derived from the household survey and the year 2000 Census Transportation Planning Package (adjusted to reflected changes in regional households between 2000 and 2006). These measures will include numbers and shares of households by vehicle availability class and district. No additional data collection is required.

- Vehicle type
  - Estimation: The household survey file, including household and household vehicle attributes, and informed by policy-specific vehicle type classifications, will the primary sources for model estimation.
  - Calibration / Validation: Calibration and validation targets will be derived from the household survey and any other appropriate vehicle fleet composition information, derived from vehicle information provided by the State of Washington Department of Licensing. This information would ideally be for the year 2006, in as disaggregate a form as possible (such as individual vehicle records), stripped of pesonal information but preserving any geographic information.

- Transit pass
  - Estimation: The household survey file, which includes information on transit passholding, auto ownership and the presence of workers, will be the primary source for model estimation.
  - Calibration / Validation data source: Calibration and validation targets will be derived from the household survey and other appropriate sources of transit pass acquisition and usage data, as available from Sound Transit and other regional transit operators. At a minimum, the number of year 2006 passholders would provide a basis for model calibration, though ideally, a coordinated regional transit on-board survey would provide more detailed information about transit travelers. The calibration and validation targets will include shares of workers holding transit passes by household segment (such as income and vehicle availability).

Day-Level Models

- Household day pattern
  - Estimation: The household survey will be the primary source for model estimation.
  - Calibration / validation: The household survey will also be the primary source for model calibration and validation targets. These targets may be adjusted in order to validate the entire model system. No additional data collection is required.

- Person day pattern
  - Estimation: The household survey will be the primary source for model estimation.
  - Calibration / validation: The household survey will be the primary source for model calibration and validation targets. These targets will include tour and stop frequency shares by person type, and may be adjusted in order to validate the entire model system. No additional data collection is required.

- Exact number of tours by purpose
  - Estimation: The household survey will be the primary source for model estimation.
  - Calibration / validation: The household survey will also be the primary source for model calibration and validation targets. These targets will include shares and totals of tours by person type, household income segment, auto sufficiency, and district, and may be adjusted in order to validate the entire model system. No additional data collection is required.

Tour-Level Models

- Tour destination
  - Estimation: The household survey, including household attributes, accessibility measures and transportation network levels of service will be the primary sources for model estimation.
    - Calibration / validation: The household survey, Census data, and employment totals at various levels of geographic aggregation will be the primary sources of calibration and validation targets. Tour destination measures will include average tour distances, tour length and tour duration frequency distributions, and district-to-district flows by tour purpose. These targets may be adjusted to account for discrepancies amongst data sources or to validate the entire model system.

- Work-based subtour generation (workers only) – number and purpose
  - Estimation: The household survey will be the primary source for model estimation.
  - Calibration / validation: The household survey will be the primary source for model calibration and validation targets. These targets may be adjusted in order to validate the entire model system. No additional data collection is required.

- Tour main mode
  - Estimation: The household survey, which includes information on household attributes, accessibility measures and transportation network levels of service, transit passholding, and auto ownership, will be the primary source for model estimation.
    - Calibration / validation: The household survey, Census data, and any other appropriate mode choice information potentially derived from a transit on-board survey, Sound Transit and other regional transit operator data collection and other efforts such as the 2000 U-Pass telephone survey, will be the primary sources for calibration / validation targets. Mode shares by purpose will be the

primary targets, and may be adjusted to account for discrepancies amongst data sources or to validate the entire model system.

- Tour vehicle / Vehicle allocation
  - Estimation: The household survey, including information on vehicle type, travel purpose, and time availability will be the primary source for model estimation.
    - Calibration / validation: The household survey will be the primary source for model calibration and validation targets. These targets may include measures of miles of travel, trip length, cold starts and vehicle occupancy by vehicle type. These targets may be adjusted in order to validate the entire model system.

- Tour time-of-day
  - Estimation: The household survey, which includes information on accessibility measures and transportation network levels of service by time-of-day, will be the primary source for model estimation.
    - Calibration / validation: The household survey, traffic and transit counts, and other appropriate data will be the primary sources for model calibration and validation targets. Targets will include shares of tours by purpose and time-period-combination and duration. The household survey can provide information on time-period combinations for tours, while detailed traffic and transit counts (at a minimum resolution of 1-hour intervals) can provide information on overall levels of tripmaking by time-of-day. New data collection or processing may be required to develop or extract the required time-of-day information. These targets may be adjusted in order to validate the entire model system.

Trip/Stop-Level Models

- Intermediate Stop Generation (exact number) – Predict number purpose and sequence of stops
  - Estimation: The household survey, which includes information on the frequency and purposes of stops, will be the primary source for model estimation.
  - Calibration / validation: The household survey will be the primary source for model calibration and validation targets. These targets will include shares and totals of stops by person type, household income segment, auto sufficiency, and district as well as shares of tour/stop combinations, and may be adjusted in order to validate the entire model system. No additional data collection is required.

- Stop location
  - Estimation: The household survey, including accessibility measures and transportation network levels of service by time-of-day, stop frequencies and purposes, and land use information will be the primary sources for model estimation.
  - Calibration / validation: The household survey will be the primary source for model calibration and validation targets. Primary measures will include average trip distances (including “extra distance” on the tour), trip length and duration frequency distributions, and district-level summaries. These targets may be

adjusted in order to validate the entire model system. No additional data collection is required.

- Trip mode choice
  - Estimation: The household survey, including transportation network levels of service by time-of-day, will be the primary source for model estimation.
  - Calibration / validation: The household survey will be the primary source for model calibration and validation targets. Mode shares by purpose will be the primary targets, though these shares will be evaluated in the context of observed roadway and transit counts and may be adjusted to account for discrepancies amongst data sources or to validate the entire model system. Trip mode choice will probably not be validated separately from tour mode choice.

- Trip arrival and departure time
  - Estimation: The household survey, including transportation network levels of service by time-of-day, will be the primary source for model estimation.
    - Calibration / validation: The household survey, traffic and transit counts, and other appropriate data will be the primary sources for model calibration and validation targets. Targets will include shares of trips by time period. As with tour time-of-day, he household survey can provide detailed information on tripmmaking by time period and purpose, while traffic and transit counts can provide information on overall levels of tripmaking by time-of-day. New data collection or processing may be necessary to develop or extract the required time-of-day information. These targets may be adjusted in order to validate the entire model system.

- Park-and-ride Park-and-walk
  - Estimation: The household survey, including transportation network levels of service by mode and time-of-day, will be the primary source for model estimation. This information may enhanced by general parking availability and cost data and park-and-ride information.
  - Calibration / validation: The household survey, as well as PSRC's spatially detailed reports of formal and informal, as well as public and private, park-and-ride lot size, occupancy rates by hour, and costs (both hourly and daily) in Seattle, Tacoma and other areas will be the primary sources for model calibration and validation targets. Additional data collection to provide more detailed information on usage by hour, or supplementary information about parking subsidies, parcel-specific parking availability (or restrictions), and on-street parking would also support model calibation and validation. These targets may be adjusted in order to validate the entire model system.

Network Assignment

The primary means of validating the entire travel model system will be by comparing forecasted to observed roadway and transit volumes and speeds. In order to ensure that the component models and the overall model system are performing reasonably well, a comprehensive count and speed dataset should be developed for roadways, and a transit volume dataset should be developed for transit. This dataset should be based around the year 2006, though it will likely be necessary to include counts and speeds from other adjacent years in order to achieve more robust calibration and validation information.

For roadways, this database would ideally include traffic counts by disaggregate time period such as the half hour time periods used in the tour time of day and stop arrival and departure models. This detail would provide the greatest flexibility in analyzing and defining the more aggregate time periods that are anticipated to be used in the initial roadway assignment models and would also support the analysis of phenomena such as peak spreading. This temporal detail can also support calibration of the tour and stop timing models. In addition, the roadway validation database should include traffic counts that provide a reasonable coverage of the entire four-county region and at critical external boundaries, but that are also focused on critical cordons and screenlines within the region, such as water crossings, county borders, and around the core. In the roadway assignment calibration / validation process estimated and observed traffic volumes will be evaluated by facility type, area type, volume class, district, time-of-day, and at critical cordons.

Roadway travel times or speeds by segment can provide important information to the roadway assignment model (as well as overall model system) calibration and validation efforts. Travel time and speed data should be focused on the most congested facilities during periods of peak congestion, and ideally would incorporate both highway and surface street segments. The State of Washington and the City of Seattle are the most likely sources for this data, as it is not anticipated that new travel time or speed data collection will be undertaken.

The transit volume dataset should at a minimum include transit boardings by route and time period, for all transit operators and services in the region. Ideally, this regional transit database would also include additional information such as transit volumes at critical cordons and screenlines are also essential to validating the tour and trip mode choice and transit assignment models. In addition to providing detailed route-level transit validation data, Automated Passenger Count (APC) and Automated Vehicle Location (AVL) data can also provide essential information about transit passenger flows and the relationship between roadway and transit travel times and speeds. This information can be used to refine roadway and transit network assignment parameters and ensure the reasonableness of mode choice model outputs. Transit on-board survey data can also provide critical insights into the reasonableness of forecast transit travel by providing observed information on transit origin-destination patterns, transfer rates, and access modes.

URBANSIM ENHANCEMENTS

The following enhancements are needed within UrbanSim in order to support integration with the new AB Model

1. The ARC population synthesizer used to generate the base year synthetic population needs to be enhanced to synthesize non-institutionalized group quarters residents.

Optionally, it could also be enhanced to control for more demographic categories than in the current setup.

8. Usual school location choice needs to be modeled for all students in the synthetic population.

9. UrbanSim should be enhanced to evolve the synthetic population so that the joint distribution of household and person characteristics that are used as AB model explanatory variables are as accurate as possible. This is a longer term enhancement that may be developed in parallel to the activity-based model.

10. UrbanSim should be enhanced to account for not subdividing parcels:

    10.1 Destination choice models will use buildings instead of parcels to adequately represent future year development that occurs on a single parcel. No change is required in Urbansim to meet this objective, since new buildings are already forecast by the model.

    10.2 Urbansim should add street network data to the development templates so these can be considered in future developments, without having to create future street patterns for new developments.

11. UrbanSim should be enhanced to generate the parcel/building variables prescribed in the above sections. This should include adding development street patterns to development templates and adding templates for parking.

ADDITIONAL DESIGN ISSUES

Parcel-to-parcel proximity. The following "lesson learned" came from Bruce Griesenbeck of SACOG: "Consider carefully how parcel-to-parcel proximity is to be defined and computed within the model. SACOG blended approach works, and is a huge improvement over taz-to-taz proximity measures, but it has problems, too. E.g. geographic barriers like canals and rivers, false proximity is allowed." The method Bruce refers to is an on-the-fly calculation of proximity that relies only on the xy coordinates of the two parcels in question, so it requires no impossibly big matrices and it is very quick. A much better measure would be walk distance generated from an all streets network. This would need to be generated on-the-fly, or else partial matrices generated in advance with distance to neighboring parcels pre-determined for all parcels in the neighborhood of each parcel. Both of these methods are probably too time-consuming to be practical. We need to decide whether to live with the SACOG approach or call for an attempt to implement a superior approach.

Number of zones. Larry has asked for guidance regarding the number of zones to include in the more detailed zonal system that he is planning to implement. The numbers used in the four regions with active AB models are: SACOG (1300), SFCTA (2336), MORPC (2000), NYMTC (6000). Based simply on these comparisons, it would seem that somewhere in the range of 2500 might be about right. However, such a conclusion is pretty arbitrary, and there are better criteria to use in making a decision to subdivide a zone. The general criterion to use is homogeneity; if a zone is so large that important explanatory variables measured at the zone level mask heterogeneity, then the zone should be subdivided. In taking heterogeneity into consideration, remember the following. First, the new destination choice models will use parcel attributes for attractiveness measures, so heterogeneity of employment, school enrollment and population at the zone level is not so important. Second, the AB models can use reasonably good point-to-point measures of impedance for walk trips, transit access and short auto trips, so zonal heterogeneity in these measures is also okay. Third, the transit access measures just mentioned break down somewhat if a zone has multiple transit access locations with significantly different zone OD transit impedances. For instance, if there are two bus lines in the zone that provide access to different parts of the region, and some parts of the zone are much closer to one line, while other parts of the zone are much closer to the other line, then this zone would be a good candidate to subdivide. Fourth, the most important criterion for defining zones relates to homogeneity of the zone OD attributes generated as network skims from highway and transit assignment. A zone should be subdivided if doing so would yield skims in which transit and/or highway OD LOS (other than walk access) would be substantially different for the two new zones.

Person type definitions. The current Activity Generator departs somewhat from the person type definitions used in soem existing model systems. In particular, after some data analysis, the following rule was introduced. If a college student is in a household with at least one other non-student adult and they are age 22 or less, then they are included as person type 6, Driving age student, instead of 5, University student. In destination choice models, we still know from the Student Type variable that we should send them to a university instead of a high-school, but in other aspects of their behavior and role in the household, they fit better with high school kids. When the model system is implemented, the person types need to be clearly and consistently defined and used. The definitions used in the Activity Generator can likely serve as the definitions for the new model system.

Reporting and Query Subsystem. This design document does not address any specific requirements for generating summary information from the AB model outputs. The Person-day, tour and trip outputs provide a wealth of possibilities for summarizing results in various demographic and geographic categories, because of their disaggregate nature. However, because they are disaggregate, it can be challenging to extract the desired information. A desirable feature of the model system would be an information system that puts the main AB outputs into a database and provides a user friendly interface for generating pre-defined useful reports as well as for generating custom aggregations. The current planning and design project does not have enough resources to design such a reporting subsystem in detail, but we recommend that PSRC seriously consider adding this requirement to the development project and budgeting for it. It should interface with the existing PSRC geodatabase and GIS.

OPTIONAL COMPONENTS

The model system design has identified several optional features that might be considered for implementation. However, these features would add to the project cost and might delay the implementation. It is very important to meet the target implementation schedule, so a desired strategy is to defer optional features until a subsequent enhancement. However, for a very attractive feature that would be much more costly to implement later, it may be better to implement it now.

Therefore, for each optional feature in the design document, we considered factors that may impact the decision of whether to implement now, plan for future implementation or defer consideration of the feature. The factors include:

- Expected benefit. How much might the quality of the model's forecasts increase for policies and scenarios addressing land use, transportation, the environment and justice?
- Risk. How big are the risks of delaying the basic project's schedule, causing excessive operational costs or run times, or failing to model outcomes realistically?
- Expected extra costs of implementing the model as part of the basic project
  - model and software development cost
  - other implementation cost
  - model system run time caused by the optional component
- Expected extra cost of implementing the model component in a separate later project devoted to implementing that component.

After considering these factors, we have put the options into three groups, with a different recommendation for each group:

- Group 1: Implement these options as part of the basic project
- Group 2: Implement these options as part of a planned enhancement
- Group 3: Defer these options for future consideration

Table 1 summarizes the decision factors, organizing the options by Group. **Appendix A** provides a detailed option-by-option discussion of these factors.

Table 1: Summary of Option Considerations

Option	Expected benefit	Risk	Extra model & software cost (%)	Extra other implement-ation cost (%)	Extra run time (%)	Extra cost if done later
GROUP 1 **Recommendation: implement as part of the basic project or implement together with Group 2 options as part of a planned enhancement.** **Focus: beneficial options that save future costs by implementing up front**						
Regular mode to work and transit pass (1.1-1.2)	medium	medium	10-15	2-5	2-5	x4
HH Day Pattern (2.1)	medium	low	10-15	1-3	5-8	x4
Linked escort trips—Implicit (4.2)	medium	low	1-2%	0	0	x5
GROUP 2 **Recommendation: implement as part of a planned enhancement.** **Focus: improving the modeling of vehicles and parking**						
Auto type (1.4)—scenario approach	medium	low	5-10	4-6	1-3	x2-x3
Tour vehicle (3.4)—with HH fleet accounting	high	high	10-20	1-3	5-15	x1-x3
Park and Ride lot choice (4.6)	medium	medium	8-15	5-8	5-50	x1
Park and Walk lot choice (4.7)	high	high	15-35	10-25	5-50	x1-x2
Group 3 **Recommendation: defer for future consideration.** **Focus: improving the explicit modeling of intra-household interactions.**						
Joint tours (2.2-2.3)	low	medium	10-15	1-5	10-30	x4
Linked escort trips—Explicit (4.2)	low	very high	25-50	10-20	10-50	x1-x3

We recommend that the Group 1 options be included in the initial implementation (Implementation 1) along with the components of the basic design, given PSRC's desire to include options in Implementation 1 that can substantially reduce the amount of rework that would be required if they were to be implemented in a separate later project. These options have varying levels of benefit, but they have low to medium risk and would all incur substantially higher development costs if implemented separately later.

The Group 2 options, involving improved modeling of choices related to vehicles and parking, have the potential for very large practical benefits. Some of these options involve significant design work, which will require some time and may identify the need for data collection, giving them medium to high risk, especially for schedule delay. Therefore, we recommend that the Group 2 design and data collection proceed while the basic project is being implemented. With this approach, development could proceed pending a favorable outcome of the design work, and their implementation (Implementation 2) could occur as soon as two years after the first implementation.

An alternative recommendation, if PSRC wants to minimize schedule risk or cost of Implementation 1, is to combine Group 1 options with the Group 2 options in Implementation 2. Such a move would increase the Group 1 costs somewhat (over putting them in Implementation 1), but not nearly as much as implementing Group 1 options in a completely separate implementation.

At this point, uncertainty of benefits and concerns about cost lead us to put the Group 3 options lowest in priority. We recommend that PSRC consider these once Implementation 1 is complete and Implementation 2 is well underway. By that time, there will have been much more to learn from the PSRC experience, as well as the experience of academics and practitioners continuing to work in the field, providing more information about the Group 3 and other new options that we are not thinking of right now.

APPENDIX A—OPTIONAL COMPONENT COST-BENEFIT ANALYSIS

Regular mode to work (1.1)

Benefits. Adding this model would realistically provide better information to the auto availability model and transit pass model, and increase the precision of the accessibility information used in the day activity pattern model. The most likely benefit would be a model system that more accurately distinguishes between short-term and long-term effects of transport scenarios.

Risk. Although this model has not been implemented elsewhere, several factors contribute to its having very low risk. First, the modeling of mode choice is well-understood. Second, the 10-day history of mode choice provides a pretty solid basis for inferring a regular mode-to-work. Third, preliminary analysis indicates that the data are of high quality. Fourth, the model would fit very naturally within the hierarchy identified for the non-optional model system components.

Implementation costs. This would increase the number of models from 11 to 12, and it is probably of average difficulty to develop and implement. Thus it would probably increase model and software development costs by about 7-10%. However, it would probably increase other implementation costs by only 1-3%. If deferred to a later date, existing models would need to be re-estimated, including HH auto availability, day activity pattern, exact number of tours, tour destination, work-based sub-tour generation and tour mode choice. Therefore, model development and software costs attributable to this model would probably quadruple. Calibration and validation costs would be re-incurred, although they could be shared by other enhancements implemented at the same time.

Model operation. The impact on model system run times would probably be less than 3%, because the activity pattern, location choice, I/O and traffic assignment dominate run times.

Preliminary recommendation. Group 1.

Transit pass (1.2)

Benefits. As with the usual mode to work model, the most likely benefit of adding a transit pass model would be a model system that more accurately distinguishes between short-term and long-term effects of transport scenarios. Adding this model would realistically provide better information to the auto availability model and significantly affect the mode choice model. Adding a simple transit pass model as envisioned here—pass vs. no pass—would not enable sophisticated analysis of alternative transit pass programs; they would probably require separate SP analysis.

Risk. Including this model would provide very little risk of cost overrun or delayed schedule. The biggest risk might be that this model might not be appropriately sensitive to transit level-of-service and would nevertheless de-sensitize the LOS sensitivity of the within-day mode choice model because of the strong impact of pass holding on that model. A related risk is that the survey data, which is already stretched to support estimation of mode choice parameters, might not provide adequate information for estimating the LOS parameters.

Implementation costs. This would increase the number of models from 11 to 12, and it is probably of below average difficulty to develop and implement. Thus it would probably increase model and software development costs by about 4-8%. However, it would probably increase other implementation costs by only 1-3%. If implemented with the usual mode to work model, these numbers probably drop to 3-6% and 1-2%. If deferred to a later date, existing models would need to be re-estimated, including HH auto availability, day activity pattern, exact number of tours, tour destination, work-based sub-tour generation and tour mode choice. Therefore, model development and software costs attributable to this model would probably quadruple. Calibration and validation costs would be re-incurred, although they could be shared by other enhancements implemented at the same time.

Model operation. The impact on model system run times would probably be less than 3%, because the activity pattern, location choice, I/O and traffic assignment dominate run times.

Preliminary recommendation. Group 1.

Auto type (1.4)

Benefits. Identifying the vehicle type for each vehicle owned by each household would enhance the ability to forecast air quality impacts and fuel consumption of alternative future scenarios. To achieve this benefit, the vehicle type would need to be defined so as to be useful for policy analysis, while at the same time distinguishing types that represent realistic differences that matter when households acquire vehicles. The vehicle type model would need to be realistically sensitive to the factors that influence vehicle type choice. The benefits would be enhanced if (a) the day activity schedule models were also sensitive to the household's vehicle types, as they are sensitive now to ownership level, (b) the model system included the choice of tour vehicle for each auto driver tour (see model 3.4), and (c) a full accounting of household vehicle use by time of day was included, enforcing time-space constraints on every vehicle in the fleet. Without any of (a)-(c) the presence of this model would make it possible to estimate changes in the distribution of vehicle fleet by various market segments. Adding (b) would enable a specific vehicle to each vehicle trip, significantly improving the ability to provide information for air quality analysis. Adding (a) and (c) would improve the quality of the outputs enabled by (b).

Risk. Although the PSRC survey data includes good information about the types of vehicles owned by households in the survey, allowing the dependent variable to be identified, it is unlikely that the survey data contains adequate information to robustly estimate the coefficients of this model. In particular, the data were collected during a period of relatively stable and low fuel prices, so it would be impossible to statistically estimate the effects of fuel price on vehicle type choice. In attempting to estimate this model it would be necessary to assume the fuel price effects, based if possible on evidence collected in existing studies. If insufficient information was available for doing this, then a fallback position could be to implement vehicle type choice probabilities as scenario parameters. Observed vehicle type distributions by household type, income and number of employees could be used as the default probabilities, with the model system user being able to arbitrarily adjust the probabilities according to the assumptions of the scenario.

As the discussion above suggests, there is a substantial risk that the predictions of the vehicle type model would be unrealistic. Additionally, there is some risk that the cost of implementing the model would exceed the estimated implementation costs, because of the challenges associated with defining the vehicle types, trying to achieve realistic price sensitivity, and implementing the fallback procedures for making this scenario-based. However, the cost risk would be minimal if it was decided at the outset to use the fallback option of a scenario-based outcome.

Implementation costs. This would increase the number of models from 11 to 12, and it is probably of above average difficulty to develop and implement, because it is a model that has not been implemented in an AB model system, because of the risk factors described above, and because there would be new explanatory factors to consider in the conditional models of the day activity schedule. Model and software development costs would probably increase as follows: basic fallback scenario approach with enhanced conditional models (5-10%); behavioral model with estimated or imported coefficients (another 5-10%); tour vehicle type choice and vehicle accounting are considered separately below. Implementation costs would probably increase by about 5%. If deferred to a later date, existing models would need to be re-estimated, including day activity pattern, exact number of tours, tour destination, work-based sub-tour generation and tour mode choice, if benefit (a) above were to be achieved. Therefore, model development and software costs attributable to this model might double or triple. Calibration and validation costs would be re-incurred, although they could be shared by other enhancements implemented at the same time.

Model operation. The impact on model system run times would probably be less than 3%, because the activity pattern, location choice, I/O and traffic assignment dominate run times.

Preliminary recommendation. Group 2.

Household day pattern (2.1)

Benefits. The most tangible advantage of integrating the person-day models in this way is that it yields more realistic household day patterns, capturing tendencies for persons in a household to coordinate their schedules. For example, in two-worker households without children, workers might be inclined to work on the same days, whereas in two-worker households without children they might be inclined to not work on the same days, or to stay home when a child stays home. To our knowledge, there is no current evidence that modeling the household day pattern makes the model system more accurately sensitive to transport prices and policies, although it might.

Risk. This type of model has been implemented before, and one member of the current consultant team was involved in that implementation, so the technical risk is low for this model.

Implementation costs. This would increase the number of models from 11 to 12, and it is probably of above average difficulty to develop and implement. Thus it would probably increase model and software development costs by about 10-15%. However, it would probably increase other implementation costs by only 1-3%. If deferred to a later date, most of the existing within-day models would need to be re-estimated. Therefore, model development and software costs attributable to this model would probably quadruple. Calibration and validation costs would be re-incurred, although they could be shared by other enhancements implemented at the same time.

Model operation. The impact on model system run times would probably be around 5-8%. The model has a very large choice set, similar to that of the person day activity pattern, requiring considerable time to run.

Preliminary recommendation. Group 1.

Joint tour generation and participation (2.2-2.3)

Benefits. A potential advantage of including this model is that the conditional models of destination, mode and timing might differ for joint tours than for individual tours. However, it is not clear that explicitly modeling joint tours actually improves the policy sensitivity of the model system.

Risk. This type of model has been implemented before, so the technical risk is relatively low for this model.

Implementation costs. This would increase the number of models from 11 to 13, and they are probably of above average difficulty to develop and implement. The complexity arises in the programming of the data preparation for model estimation, where additional logic is required to identify the joint tours and to provide proper time window constraint information to all the joint and individual tours. Likewise, the programming of the model system application software would become more complex. Thus it would probably increase model and software development costs by about 10-15%. However, it would probably increase other implementation costs by only 1-5%. If deferred to a later date, most of the existing within-day models would need to be re-estimated. Therefore, model development and software costs attributable to this model would probably quadruple. Calibration and validation costs would be re-incurred, although they could be shared by other enhancements implemented at the same time.

Model operation. The MORPC model system is the only existing application that includes these models. It is not clear how much of the run time is attributable to these models, but on the surface it seems that the impact on run times is considerable. We suspect that including them would increase run times by 10-30%.

Preliminary recommendation. Group 3.

Tour vehicle (3.4)

Benefits. The tour vehicle model could not be implemented without also implementing the household auto type model (1.3). Identifying the vehicle type for each auto driver tour would enhance the ability to forecast air quality impacts and fuel consumption of alternative future scenarios.

The benefits would be enhanced if a full accounting of household vehicle use by time of day was included, enforcing time-space constraints on every vehicle in the fleet. A side-benefit of implementing household fleet accounting would be an improvement in the realism of mode choice when viewed from the perspective of a particular household, if the accounting information is used in the mode choice model, as it should be. The model system should more accurately capture sensitivity of destination, mode and time of day choices to policy forecast scenarios because of significantly more realistic time and space constraints on the household's use of vehicles. Implementing fleet accounting is similar to implementing explicit intra-household interactions. However, it is likely that vehicle fleet accounting would provide substantially more benefits than the modeling of explicit intra-household interactions because it has a direct effect on predictions of vehicle use, while at the same time it would probably be less expensive to implement and have less impact on run times.

Risk. Given the types of vehicles available in the household, it would be simple to implement a naïve model that assigns one of those vehicles to every auto driver tour. It would be somewhat harder to estimate a model that accurately captures the factors that cause vehicles in the household's fleet to have different choice probabilities under different conditions. It would also be harder to implement the accounting required to restrict vehicle availability for every such choice according to simulated choices of higher priority tours. Implementing that accounting would need to occur in the survey data set itself prior to model estimation, in order to correctly identify the available vehicles for every tour choice. Also, if the accounting is to be implemented, then it would be advisable to also use that information for mode choice model estimation.

Therefore, there is some risk that model estimation might not yield a very intelligent model of vehicle type choice. If the vehicle accounting system was implemented, there would be risk that the project would be delayed more than anticipated, while the vehicle availability accounting is programmed into the data preparation program.

Implementation costs. Implementing the tour vehicle choice model would increase the number of models from 11 to 12, and it is probably of average difficulty to develop. Thus, without also implementing household fleet accounting, it would probably increase model and software development costs by 5%, and other implementation costs by another 2%. If deferred to a later date, some existing models might need to be re-estimated, but probably very few because this model would be low in the model hierarchy.

Implementing household fleet accounting would probably increase model and software development costs by 10-20%, and would probably add 1-2 weeks to the critical path of the project because of extra work required during data preparation for model estimation. If deferred to a later date, the mode choice models would need to be re-estimated, and probably also the trip-level models, in order to take advantage of the information provided by the fleet accounting. Therefore, model development and software costs attributable to fleet accounting might double. Calibration and validation costs would be re-incurred, although they could be shared by other enhancements implemented at the same time.

Model operation. The impact on model system run times of implementing vehicle type choice would probably be less than 3%, because the activity pattern, location choice, I/O and traffic assignment dominate run times. However, implementing household vehicle fleet accounting might increase system run times by an additional 5-10% because of the additional accounting computations.

Preliminary recommendation. Group 2.

Linked trips for escort purpose (4.2)

Benefits. Another type of joint travel is the case where two or more household members travel together to and/or from an activity location, but do not participate in the same activity there. The most common example is a parent driving a child to school and then either returning home (an escort tour) or else driving on to work (an escort stop on a work tour). The main benefit of explicitly linking these trips is that it makes the timing, mode and destination of the escort consistent with those of the person being escorted.

Risk. Because these types of tours are partly joint and partly independent, it can be very complex to explicitly link them across persons. For that reason, explicit modeling of escort linkages has not been done in any of the applied models or recommended for the models under design. Therefore, the risks of technical problems and/or schedule delays and cost overruns are very high for this model. Most existing models, however, do include a separate "escort" purpose, so that the most important special characteristics can be captured—particularly the fact that the mode is nearly always auto, with the exception of infrequent cases of walk escort. Also, children's school locations can easily be included as special alternatives in the parents' escort tour destination choice sets, so that at least the location is accurate, even if the exact trip timing and car occupancy are not matched.

Implementation costs. Because of the complexities and required innovation of this model, we estimate that it could easily increase the model and software development costs by 25-50%. The innovative aspects would probably also increase the other implementation costs considerably, perhaps on the order of 10-20%. If deferred to a later implementation, this feature might cost substantially more. On the other hand, it might be more efficient to implement such a new feature within an already smoothly running model system.

Model operation. We have no good basis on which to estimate the impact on model system run times. However, the complexity involved would probably necessitate substantial new software logic that could significantly increase run times, perhaps by as much as 50%.

Preliminary recommendation. Implicit treatment—Group 1. Explicit treatment—Group 3.

Park-and-Ride lot choice (4.6)

Benefits. Adding this model, along with automated procedures that account for the capacity constraints of park and ride lots, would enable the model system to be realistically sensitive to the effects of projects that deal with the location, capacity and price of park and ride lots.

Risk. To our knowledge, this type of model has not been implemented yet in any of the existing model systems, so it carries some technical risk. The biggest issue is probably related to dealing with lot capacities. For model estimation, it would be necessary to obtain realistic estimates of lot fill levels by time of day at the time of the household travel survey. For model application, techniques would need to be implemented to account for lot fill status at each time of day.

Implementation costs. This would increase the number of models from 11 to 12, and the model is probably of above average difficulty to develop and implement. The complexity arises in the data preparation for model estimation, and in application software, associated with the handling of lot capacities. Thus it would probably increase model and software development costs by about 8-15%. It would probably increase other implementation costs by 5-8% to validate the filling and emptying of the lots. Since this model is very low in the hierarchy, the cost of deferring this capability to a later enhancement project is very low.

Model operation. It is likely that the accounting for lot capacities would require additional model system iterations in order to properly equilibrate lot fill status by time of day. This could have a very large impact on run time, perhaps increasing it by as much as 50%, associated with additional model system iterations required to equilibrate the parking lot fill levels. However, it is also likely that techniques can be developed to enable equilibration with little or no increase in system iterations.

Preliminary recommendation. Group 2.

Park-and-Walk lot choice (4.7)

Benefits. Modeling park and walk lot choice could be especially valuable in cases where parking availability and/or parking pricing affect travel choices and are important policy issues. If properly implemented and integrated with destination, mode and timing choices, it has the potential of enabling the model system to capture the effects of parking availability, prices and subsidies on destination, mode and timing choices, as well as on traffic flows in highly congested neighborhoods. This could enable the model system to be used for testing the effect of parking and auto restriction policies.

Risk. To our knowledge, this type of model has never been incorporated in a regional forecasting model, and there would be many modeling issues to be worked through. Some of these would be related to the desirability of capturing the affects of capacity, parking prices and parking subsidies on destination, mode and timing choice. Other issues relate to the availability of good parking data for model estimation and application. Still others would relate to the impact on run times of modeling at this level of detail.

Implementation costs. The model is probably substantially above average difficulty to develop and implement. It might increase model and software development costs by about 15-35%. It would probably increase other implementation costs by 10-25%. In addition, it is likely that there would be cost and time required to collect additional parking data for development and validation purposes. The cost of deferring this capability to a later enhancement project would probably be similar to the cost of adding it to the basic initial project. Implementing park-and-ride lot choice and park-and-walk lot choice at the same time would probably yield quality and cost synergies.

Model operation. It is likely that the accounting for lot capacities would require additional model system iterations in order to properly equilibrate lot fill status by time of day. This could have a very large impact on run time, perhaps increasing it by 20-50%.

Preliminary recommendation. Group 2. Because of the highly innovative nature of this model, the likely need for data collection, and the possibility of implementing later without substantially increasing the cost, our preliminary recommendation is to exclude it from the initial implementation. However, since the benefits of this feature could be very substantial, we recommend planning now for future implementation in conjunction with the park-and-ride lot choice feature. Also, since it requires design work that may prescribe additional data collection, it would be good to design this enhancement shortly after the Implementation 1 AB model estimation is complete, so that the needed data collection can begin while the initial implementation is occurring.

APPENDIX B—TASK LISTS

This section provides a brief description and a task list for each stage in Implementation 1, as well as for the Planning stage of Implementation 2. The task list identifies the primary party that will need to do most of the work. It also provides rough estimates of the amount of LU Contractor and PSRC staff person-time required for each task. In some cases, the LU Contractor work could be shifted to PSRC. Each task list is followed by descriptions of the tasks that also identify the main deliverables.

Stages beyond Planning for Implementation 2 are excluded here because the details of their tasks depend on the results of the Planning stage. However, we expect that they will have substantially less, if any, LU Contractor tasks because the Implementation 2 functionality is not expected to change the LU model interface substantially. Also, we expect the preparation work for model validation to be substantially less than in Implementation 1, because much of what was prepared for Implementation 1 would still be valid; the focus of the validation preparation would be to prepare validation data that is needed for new validation tasks related specifically to auto and parking choices.

Stage 1—Prepare for AB Model Estimation (Old Zones)

Stage 1 prepares all the data needed for model estimation, using the existing zone system and EMME2 software. **Table B1** lists the tasks that have been identified for this stage. The Preparation of parcel, skim and zonal data is assigned to PSRC and preparation of survey data for model estimation is assigned to the AB model contractor.

Table B1: Stage 1 tasks

Task	Title	Primary Party	PSRC Hours	LU Contr Hours
1.00	Prepare parcel/buffer data for estimation	PSRC	120	
2.00	Assign parcel IDs to all locations in HH survey data	PSRC	40	
3.00	Enhance zone system and regenerate zonal data	PSRC	120	
4.00	Adapt trip-based model system to use new zones	PSRC	40	
5.00	Generate skims for new modes using new zones	PSRC	40	
6.00	Support PSRC stage 1 tasks	AB Contr		
7.00	Prepare HH survey data for model estimation	AB Contr		
8.00	Determine deployment strategy and design	PSRC	40	40

Task 1 involves preparing all the parcel data described in detail in the sections of Technical Memo 1.2 (Recommended Design Approach) entitled “Parcel Attributes from UrbanSim” and “Parcel Attributes from PSRC Geo-database”. The attribute values should correspond as closely as possible to the conditions that existed at the time that the household activity and travel diaries were collected, and any monetary attributes should be expressed in 2006 units. These data should be supplied in two separate tables, one including the attributes that will be supplied automatically by UrbanSim for forecasting, and the other including all the other attributes. For the production system, the files should probably be in binary format so that they can be read and written quickly. However, for purposes of model estimation, ascii files or DBaseIV format is

acceptable. All data items should be stored in integer format using units identified in Technical Memo 1.2. **Deliverable**: Two parcel attribute tables as described above.

Task 2 involves assigning parcel IDs to all locations in the household survey data and verifying that the parcel assignments in the survey data are consistent with the employment and enrollment values in the parcel database. Every occurrence of an XY coordinate in the Household survey data needs to be accompanied by a parcel ID. These include trip origin and destination, household home parcel and previous home parcel, person school parcel, workplace primary employer parcel and secondary employment parcel. In addition, if the park and ride lot choice model option is elected, then parcel IDs must be assigned to every park and ride location. **Deliverable**: Survey data augmented with parcel IDs.

Once the parcel IDs are assigned, their consistency with the parcel database should be verified. Consistency is essential in order to avoid severe bias in the estimation of the location choice models. For example, the workplace primary employer parcel data item should be aggregated by parcel and the results should be compared to the parcel database employment by parcel. A RMSE measure should be calculated, and the parcels with the largest discrepancies should be investigated. Discrepancies should be corrected. One problem that arose with the SACOG data was that the coordinate system used for survey geocoding was misaligned with the coordinate system used for the parcel database. Re-alignment substantially improved the consistency of the data. The same type of verification should be conducted to match home parcel aggregation by parcel with the parcel database number of households by parcel, and person school parcel aggregation by parcel with parcel database school enrollment by parcel. **Deliverable**: Report of parcel ID consistency validation.

Tasks 3 through 5 involve expanding the zone system and preparing all the skim data described in detail in the section of Technical Memo 1.2 (Recommended Design Approach) entitled "Skim data from Assignment Models". The data should be prepared for the 18 modes shown in "Table 2: Trip Modes" of the Technical Memo 1.2, using the restrictions identified in the same table when skimming for specific modes. The time periods should be as detailed as the PSRC assignment and skimming procedure provides. The documentation should clearly identify the mode(s) and time period(s) for which each data item applies. Any monetary attributes should be expressed in 2006 units. For the production system, the files should probably be in binary format and/or in the internal format used by the network software, so that they can be read and written quickly. However, for purposes of model estimation, ascii files or DBaseIV format is acceptable. All data items should be stored in integer format using units identified in Technical Memo 1.2, "Table 10: OD Skim Data Items". **Deliverable**: Skim data with documentation.

Task 6 represents all AB model contractor activity undertaken in support of PSRC for the completion of tasks 1-5.

Task 7 involves transforming the survey data so that it represents all the modeled outcomes in the form needed for model estimation. **Deliverable**: Survey data transformation program.

Task 8 defines PSRC's plans for the use of the LU-Transport model system, identifying the various users, the required capabilities, and how the model system will satisfy them. The types of capabilities under consideration include various modes of model system operation, such as scenario comparisons for New Starts analysis, travel demand analysis without assignment equilibration, travel demand analysis with equilibration, travel demand analysis involving dynamic iteration with UrbanSim, and extraction of information from available model system results. For each of these, the AB model contractor, PSRC, and the LU model contractor will need to design how the model system will work. The task will also involve detailed planning for the Stage 9 deployment, identifying the capabilities that will be tested during that time and specific plans for completing those tests. This task occurs here so that that the Stage 2 development work can proceed with a clear understanding of the needed capabilities and how they will be implemented. **Deliverable**: Deployment strategy and design document.

Stage 2—Develop models

Stage 2 is devoted to specifying, estimating and unit testing of the model parameters for all the new LU models and the AB models.

Table B2: Stage 2 tasks

Task	Title	Primary Party	PSRC Hours	LU Contr Hours
1.00	Estimate LT location models	LU Contr	20	80
2.00	Estimate AB demand models	AB Contr	80	

In **Task 1** the LU model contractor estimates models for which they are responsible. **Deliverable**: LT model estimation results.

In **Task 2** the AB model contractor estimates models for which they are responsible. **Deliverable**: AB model estimation results.

The role identified for PSRC in both tasks is to review and provide feedback on preliminary estimation results.

Stage 3—Convert assignment software

Stage 3 is required if PSRC chooses to convert from EMME2 software. If this occurs, it will be important to regenerate base year data that this causes to change, so that the AB models can be validated using the new data. Stage 3 must be complete before some of the Stage 4 tasks can begin.

Table B3: Stage 3 tasks

Task	Title	Primary Party	PSRC Hours	LU Contr Hours
1.00	Convert current model system to new assignment software	PSRC	??	

Task 1 Deliverables: Skim data with documentation, including data formats for exchange with AB model software.

Stage 4—Develop software

Stage 4 develops the software needed to use the model system. This includes the AB simulator, the demand-assignment scripts, programs to make it easy to use the AB model outputs, the components of the LU model that must be added or changed, new programs to automate the preparation of required data, and the interfaces between the LU model and the transport model.

Table B4: Stage 4 tasks

Task	Title	Primary Party	PSRC Hours	LU Contr Hours
1.00	Design AB demand reporting & query system	PSRC	40	
2.00	Develop AB demand simulator	AB Contr		
3.01	Implement and tune demand-assignment equilibration	PSRC	240	
3.02	Publish demand-assignment user documentation	PSRC	40	
3.03	Advise demand-assignment equilibration	AB Contr		
4.01	Program AB demand reporting & query system	PSRC	160	
4.02	Document AB demand reporting & query system	PSRC	40	
4.03	Help PSRC develop AB demand reporting & query system	AB Contr		
5.00	Integrate LU and transport model systems	LU Contr		
5.01	Develop parcel buffer software (UrbanSim)	LU Contr		80
5.02	Develop parcel buffer software (Geodatabase)	PSRC	80	
5.03	Enhance ARC population synthesizer	AB Contr		
5.04	Enhance ARC population synthesizer	PSRC	40	
5.05	Enhance UrbanSim to accommodate GQ residents and improve quality of forecast population	LU Contr		120
5.06	Add LT location models to UrbanSim software	LU Contr		60
5.07	Develop parcel subdivision software	LU Contr		60
5.08	Develop parcel subdivision software	PSRC	40	
5.09	Integrate parcel buffer software, Demand-assignment equilibration software and AB reporting system into Opus software	LU Contr	80	80
5.10	Advise integration of systems into Opus software	AB Contr		
5.11	Publish LU-transport system user documentation	PSRC	60	40
5.12	Assist with development of LU-transport system user documentation	AB Contr	20	

In **Task 1** PSRC and the AB Contractor together design the information system that puts the main AB outputs into a database and provides a user friendly interface for generating pre-defined useful reports as well as for generating custom aggregations that use the existing PSRC geodatabase and GIS. **Deliverable**: AB demand query system specification.

In **Task 2** the AB model contractor writes the AB demand simulator software. **Deliverable**: AB demand simulator software.

Task 3 involves designing, implementing and testing the demand-assignment equilibration procedures. It is expected that these procedures will use the software platform provided by the assignment software vendor, and incorporate the AB demand simulator produced by the AB demand contractor in this stage. It is expected that PSRC will do most of this work, with guidance from the AB model contractor. **Deliverable**: Travel demand model system software with demand-assignment equilibration.

In **Task 4**, PSRC develops the AB model query system, with assistance from the AB model Contractor and LU model contractor. **Deliverable**: AB demand reporting & query software.

Task 5 integrates the LU and transport model systems. It includes several important subtasks. **Subtasks 5.01 and 5.02** automate the generation of the parcel data required by the AB demand simulator, including those that come from UrbanSim forecasts (5.01) and those that come from the transport scenario geodatabase (5.02). **Subtasks 5.03 through 5.05** involve implementing enhancements that are needed to enable UrbanSim to provide a high quality forecast population to the AB model system. This certainly includes enhancing the population synthesizer to include Group Quarters residents, but may also include enhancing the base year controls that are used for synthesis and enhancing UrbanSim to include more controls and evolve the population more realistically. These enhancements can begin while earlier project stages are underway, and must be completed in Stage 4 so that the enhanced population can be used for model validation. These tasks also need to be coordinated with Subtask 3.01 that implements Demand-assignment equilibration, so that the model system properly uses the enhanced population. **Subtask 5.06** enhances UrbanSim to include all the long-term location choice models, including school location choice. **Subtasks 5.07 and 5.08** implement programs and procedures for subdividing parcels in forecast years to improve the representation of developments forecast by UrbanSim and those determined exogenously as future scenarios. **Subtasks 5.09 and 5.10** complete all integration needed in order to have a fully functional integrated system that can operate in the ways prescribed by the Stage 1 Deployment Strategy and Design Document. Finally, Subtasks 5.11 and 5.12 publish the user documentation for the integrated model system. **Deliverables**: Parcel data generation software; Population Synthesizer; UrbanSim with GQ residents and LT models; Parcel subdivision software; Operational Integrated LU-transport model system; User dcumentation.

Stage 5—Prepare for Base Year Model Validation

Task 1 involves preparing the observed model validation data for the base year (2006). Observed model validation data should at minimum include traffic counts encompassing the entire 24-hour day and reported by detailed time period. The traffic count locations should adequately cover the entire region, and must include critical cordon locations such as major bridges. The model validation dataset should also include transit boarding and other data by operator, transit submode, route, and station/stop disaggregated by detailed time period. Ideally, transit onboard survey data is also available to provide more comprehensive information about transfer rates, origin-destination patterns, travel purposes, and traveler demographics. Finally, it may also be desirable to assemble contemporaneous information on parking lot capacities and usage to support further parking model development. Any monetary attributes should be expressed in 2006 units.

Table B5: Stage 5 tasks

Task	Title	Primary Party	PSRC Hours	LU Contr Hours
1.00	Prepare count data for base year validation	PSRC	120	

Stage 6—Validate with base year data

Task 1 involves first validating all components of the travel demand simulator against household survey data to ensure the proper implementation of the models. Prior to validating the entire model system against observed traffic and transit volumes, it is first necessary in **Task 2** and **Task 3** to expand and validate the synthetic population to include group quarters residents, who comprise approximately 2% of the regional population. Once the full regional synthetic population is created and validated, in **Task 4** all components of the travel demand simulator will be calibrated to match patterns observed in the original household survey data for the base year 2006. Each individual component, including the vehicle availability model, activity generator, and destination choice and mode choice models will be individually evaluated and calibrated. **Task 5** involves running the entire model system including assignment with full equilibration, and validating the results against observed traffic and transit counts by time-of-day. making adjustments to the calibration of individual components, particularly the activity generator, destination choice, and mode choice models. Adjustments to these model targets will be necessary in order to rectify discrepancies between the survey data and observed counts. It is expected that PSRC staff will play an integral role in Task 5 in identifying critical validation targets and supporting the validation process with detailed local knowledge. **Deliverable**: Final Validation Report.

Table B6: Stage 6 tasks

Task	Title	Primary Party	PSRC Hours	LU Contr Hours
1.00	Validate demand simulator on survey data	AB Contr		
2.00	Generate base year UrbanSim pop with GQ residents	LU Contr		20
3.00	Validate base year UrbanSim population	AB Contr		
4.00	Validate demand simulator on synthetic population	AB Contr		
5.00	Validate travel model system--base year	AB Contr	120	

Stage 7—Deploy model system

Stage 7 is envisioned as a one year period in which PSRC puts the new model system through its paces while carrying out the modeling required for the next major planning cycle.

Table B7: Stage 7 tasks

Task	Title	Primary Party	PSRC Hours	LU Contr Hours
1.00	Use model system for first major planning cycle	PSRC	1-2 FTE	
2.00	Enhance user documentation	PSRC	40	
3.00	Field test with first external user(s)	PSRC	40-200	
4.00	Debug, tune, enhance, support & document during first year for AB contractor-developed components	AB Contr		
5.00	Debug, tune, enhance, support & document during first year for LU contractor-developed components	LU Contr	80	120
6.00	Roll out to additional users	PSRC	200	

Task 1 is the major task in Stage 7. In this stage there is not a clear distinction between development and production work, and the work will require many varied tasks spread over most of the one-year period. Part of this work will involve performing sensitivity tests, which will provide an opportunity to debug any problems with model inputs such as the synthesized population and model networks, and will also ensure that the model is performing reasonably when exposed to new inputs such as different

network levels of service. **Deliverables**: Sensitivity test reports; Planning cycle outputs; Issue reports for all issues encountered during model usage.

Task 2 involves enhancing the user documentation based on the results of the validation tasks and early experience using the model system. **Deliverable**: Draft 2 of full system documentation.

Task 3 involves distributing model system capabilities to users other than PSRC modeling staff to the extent that this has been prescribed in the Deployment Strategy developed in Task 8 of Stage 1. The idea here is to deploy capability to a pilot user for each type of usage identified in the strategy, and collect feedback so that the system can be further debugged, tuned and documented. If the strategy calls for extensive and/or sophisticated distribution of capabilities, then Task 3 might be restricted to one or two high priority pilot users. **Deliverables**: Software and documentation version(s) for distributed user community; Issue reports (from users) for all issues encountered during model usage.

Tasks 4 and 5 include the work of the AB and LU contractors for one year beginning when PSRC begins Stage 9 model usage. The work will involve debugging, tuning, enhancements, user support and documentation required in order for PSRC to successfully complete Stage 9 and move into ongoing use of the model system. **Deliverables**: Model system software and documentation patch releases. Issue resolution reports.

Task 6 involves making the model system capabilities available to more users, once PSRC and its pilot users have gained experience in Tasks 1 and 3, and necessary debugging, tuning, etc have been completed in Tasks 4 and 5. **Deliverables**: Enhanced software and documentation version(s) for distributed user community; Issue reports (from users) for all issues encountered during model usage.

Stage 8—Maintenance (annual)

After the first year, in which substantial attention is devoted to getting the first version of the model system deployed and working well, there will still likely be occasions in which PSRC needs to get debugging and support services from the contractors who developed the model system. Since this type of work occurs on an irregular basis and tends to be urgent when it arises, it will work best for PSRC to have maintenance or on-call contracts in place. **Deliverables**: Issue reports; Model system software and documentation patch releases; Issue resolution reports.

Table B8: Stage 8 tasks

Task	Title	Primary Party	PSRC Hours	LU Contr Hours
1.00	Debug and support—annual	AB Contr		

Stage 9—Plan Implementation 2

In Stage 9, the AB Contractor works with PSRC to finalize the desired model system enhancements and develops the design, task list, budget and schedule for implementation. These could be the features already identified for possible Implementation 2, and/or new options that may arise from experience with the model system or from the experience of other agencies as the state of the practice advances.

Table B9: Stage 9 tasks

Task	Title	Primary Party	PSRC Hours	LU Contr Hours
1.00	Review literature and practice related to auto type choice and parking choice	AB Contr		
2.00	Identify desired capabilities	AB Contr		
3.00	Design model system enhancements	AB Contr		
4.00	Specify data collection and preparation requirements	AB Contr		
5.00	Plan subsequent stages of implementation	AB Contr		
6.00	Support AB Contractor in all Design stage tasks	PSRC	40-100	

In **Task 1**, the AB model contractor will review the literature and practice related to auto type choice and parking choice. The objective of this review will be to identify the methods with the most promise for effective implementation within the model system framework.

Task 2 looks at the possibilities from the PSRC perspective, identifying the types of analyses that PSRC would want to do related to vehicle and parking choice, and the related information that would be nice to get from the model system.

In **Task 3**, the possibilities and requirements of Tasks 1 and 2 are transformed into design specifications for the enhanced model system.

Task 4 specifies any additional data required by the design for model development and validation.

Task 5 plans the details of all subsequent stages of Implementation 2.

Tasks 1 through 5 are conducted primarily by the AB model contractor, but require significant input from PSRC. **Task 6** represents the work carried out by PSRC staff in support of the Task 1 through 5 objectives.

APPENDIX C—A LA CARTE OPTIONS

This Appendix describes several a la carte options that can be selected independently of each other. The a la carte options provide PSRC with additional options for controlling the budget and scope of the work done by the AB model contractor.

Option a—AB Contractor implement scripts to integrate AB model with traffic assignment and auxiliary trip models

Option a shifts the responsibility for Stage 4 tasks 3.01 and 3.02 (see Appendix 2) from PSRC to the AB Contractor. These tasks include taking full responsibility, with limited guidance from the AB Contractor, for implementing the Transport Model System shown in Figure 1, except for the AB Household Travel Demand Simulator, the Trip Aggregator and the Reporting and Query System. This includes:

- writing all the scripts needed for the trips arising from special generators, external sources and commercial movements (all trips other than non-commercial trips of residents). It is assumed that this will consist of borrowing scripts already in existence that run for the existing trip-based model system on the software required for the new model system.
- writing all scripts for highway and transit assignment (same assumption about appropriating existing scripts)
- writing all scripts for skimming the networks and providing the outputs to the AB Household Travel Demand Simulator in the proper format
- writing all the scripts needed to incorporate the AB Household Travel Demand Simulator executable, the Trip Aggregator and all the above components into an equilibrating system
- implementing the scripts in such a way as to enable the components of the model system (that can be run in parallel) to be distributed to multiple processors
- specifying the hardware and operating system configuration required for implementing the distributed processing approach
- testing and enhancing the scripts to achieve acceptable convergence to a consistent solution in a timeframe acceptable to PSRC
- documenting the user procedures required to set up and run the Transport Model System

If Option is selected, PSRC will need to provide the AB Contractor with remote access to the PSRC hardware deployed for the initial implementation of the model system.

Option b—AB Contractor participate in deployment strategy and design

Task 8 of Stage 1 is described in detail in Appendix B. Option b includes the AB Contractor as an equal participant with PSRC in the task. Without Option b, the AB Contractor is excluded from the task.

Option c—Test 2 or 3 variations in parcel buffer definitions

The discussion of Parcel Attributes in the AB Model Inputs section of this document describes the desirability of defining variations in the parcel buffer definitions, empirically testing them during model estimation, and then selecting the definition(s) to be kept and used. The variations might involve all-streets-based distance buffers (vs. straight-line-distance buffers) and various definitions of the decay functions.

Option c asks the AB Contractor to test 2 or 3 versions of the buffer definitions, supplied by PSRC, during model estimation. Without Option c, PSRC supplies only one version and the AB Contractor uses it.

Option d—Re-estimate some models based on PSRC review of results

If Option d is selected, the AB Contractor will review the preliminary estimation results with PSRC, receive requests to try certain adjustments in the model, re-estimate models and report the adjusted results to PSRC. The amount of adjustments attempted will be limited by the budget for this option; it may not be possible to try adjustments to all models. PSRC will have the option of increasing the budget in order to request additional adjustments.

Without Option d, the AB Contractor will not include PSRC in the review and enhancement of preliminary model estimation results.

Option e—AB Contractor design and develop AB model output aggregator, and assist in development of reporting and query capability

If Option e is selected, the AB Contractor will be responsible to program the Trip Aggregator (shown in Figure 1) that aggregates the trip output of the AB Household Travel Demand Simulator so it can be combined with the trip matrices for other trips (airport, externals and commercial). The AB Contractor will assist PSRC with the design of the Reporting and Query Subsystem, which is anticipated to be an interactive program with Database and GIS features. The AB Contractor will also program a parameter-driven batch aggregator that can be incorporated by PSRC into the Reporting and Query Subsystem.

Without Option e, PSRC will be fully responsible for the Trip Aggregator and the Reporting and Query Subsystem.

Option f—AB Contractor modify ARC PopSyn program

If it turns out that PSRC needs to have the Population Synthesizer program modified in order to facilitate enhancements needed in UrbanSim to support integration with the new AB model system, then with Option f, the AB Contractor would make the needed program changes. If PSRC chooses Option f, then the AB Contractor will have the opportunity to revise the cost estimate for this option, once the desired changes are identified.

Without Option f, PSRC would be responsible to make any needed Population Synthesizer program changes. The AB Contractor would still be responsible to provide advice to PSRC in making non-programmatic changes to the Population Synthesizer input worksheets, if needed.

Option g—Reprogram AB Household Travel Demand Simulator into another language or make substantial changes for OPUS framework interface

PSRC can select Option g if they want the AB Contractor to translate the AB Household Travel Demand Simulator into a language selected by PSRC, or to make changes to the Simulator program required by integrating it into the OPUS framework. If PSRC requests Option g, then the AB Contractor will have the opportunity to revise the estimate once the requested language and/or modifications are known.

Without Option g, the AB Contractor will supply the AB Household Travel Demand Simulator in a language chosen by the AB Contractor, and PSRC will be responsible for all language translations and/or modifications required for the OPUS integration.

Option h— Refine the approximation of short distance parcel-to-parcel street travel distances

Another optional task would address what has come up as an important issue in the work for SACOG. They see a substantial benefit with the SACSIM model in being able to use parcel-level geography to get better modeling of short distance and intra-zonal trips—not just for walk and bike, but for short car trips as well. However, to make the model feasible to run, it doesn't use a full parcel-to-parcel (or grid cell-to-grid cell) street distance measure. That would involve processing a very large number of parcel pairs using a GIS with an all-streets network to get the actual walking or driving distance, and then storing all of that data in memory. The approach that is used instead is to use an XY-based orthogonal distance, and use a sliding average of that and the TAZ-to-TAZ network distance. For intra-zonals and very short strips, the XY distance is used, for trips over a few miles the network distance is used, and in between it's a function that gives more weight to the XY distance as the parcels are closer together.

One alternative approach option with UrbanSim grid cell geography would be to store the street network distance between each grid cell and each other grid cell within a short distance, say 4 km. If the grid cells are 100 m across, then we would need to store an 8 km square around each grid cell, which would be 80 x 80, or 6400 values for each grid cell .This file would still be infeasibly large, plus creating it would require much GIS-based processing whenever the street network is changed.

Another alternative approach would be to estimate a regression model as follows:

(1) For a fairly large sample of point-pairs (for example, all trips of 3 miles or less in the HH survey data), use GIS with an all-streets network to produce as accurate a distance measure as possible (this could be done twice, once including only the walkable network, and once including only the drivable network).

(2) Estimate a regression model to predict the above distance measure as closely as possible as a function of variables that can be used in model application, including:

-the network zone-to-zone distance,

-the XY-based orthogonal distance

-a zone-to-zone “barrier” matrix that indicates what types of barriers are between zones, such as freeways, railroads, rivers, large restricted areas, etc.

-zone-specific “street orientation” indicators. These indicate what type of street pattern is in a zone – grid, cul de sac, etc., and, if it is a grid, what orientation the streets are in relative to NS/EW (this information indicates how to use XY coordinates to get a more accurate estimate of street distance.

Much of the work in this task would be PSRC staff generating the needed data. The consultant work involved in estimating the regression model and coding it for application would be relatively straightforward.

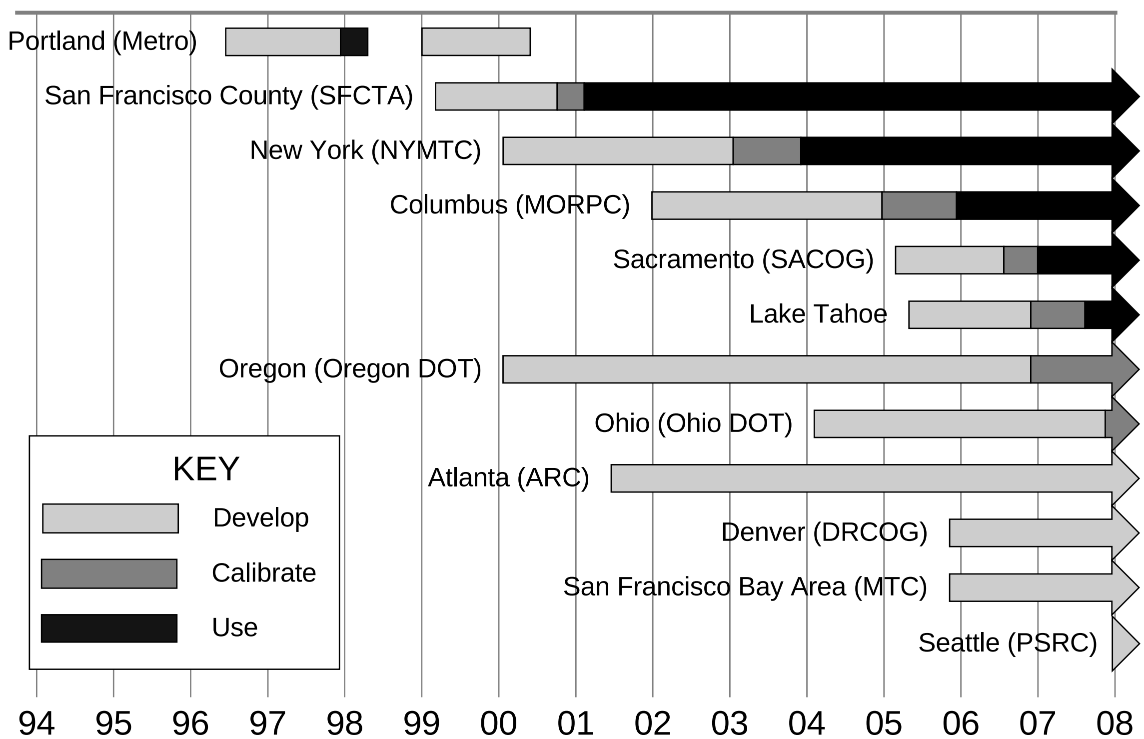
APPENDIX D—STATE OF THE PRACTICE

The purpose of this technical memorandum is to gather information that will be useful in designing the proposed PSRC activity-based (AB) model system. It includes a historical overview of the development for practical use of AB models in the United States, a comparative summary of their features, lists of lessons learned by the current project team and by US agencies currently using their AB model for policy analysis, and a list of requirements and assumptions that PSRC has already identified to guide their model development.

Development History

Figure D1 shows a timeline of the development and use of AB models. It includes only US projects, where a sponsor expressed the intent to implement and use the model, and development has started. This section briefly describes the innovations that have been implemented in these projects.

Figure D1: Timeline of Activity Based Model Implementations in the United States



The Metro model was the first to be implemented and used for policy analysis. It was based directly on the Bowman and Ben-Akiva activity schedule approach developed at MIT, using a full-day activity pattern, conditional tour models, and sensitivity at the day level via logsums from the tour models. It introduced work-based subtours, at-home activities and detailed activity purposes, and integrated the AB model with the traffic and transit assignment models.

The San Francisco County model used the same basic design. It was the first of the models to be calibrated, and then used on an ongoing basis for policy analysis. Along the way, innovative procedures were developed for doing that analysis. In a recent major project, the SFCTA model was enhanced to support road pricing, expand its geography, and add mode and temporal detail. It continues to be enhanced.

In New York, a different approach was used for integrating the tour models. Within each household, the simulated tour choices explicitly depended on the purpose of tours already simulated for this and other persons in the household. The NYMTC model has also been used for innovative analyses, some of which would not be possible with a traditional 4-step model.

The Columbus model started with the NYMTC framework and enhanced it substantially, with a strong emphasis on implementing explicit household interactions and detailed time of day modeling.

The Sacramento model also used the Bowman and Ben-Akiva activity schedule approach. It reformulated the day activity pattern, introduced parcel-level spatial resolution, demonstrated the possibility of rapid development and deployment, and used innovative techniques for rapid equilibration of AB microsimulation models.

The Lake Tahoe project was the first implementation for a small MPO, and the first to transfer and recalibrate a model built for another region (MORPC).

The Oregon model was the first activity schedule model to be implemented for an entire state, and it was also integrated into a land use model system.

Ohio imported the Oregon statewide model and enhanced it to include long distance inter-regional trips.

The Atlanta model, which will be based on the MORPC design, hasn't been fully implemented yet, but they have implemented a flexible population synthesizer, and the design includes other innovations.

DRCOG, MTC and PSRC are the most recent locations where new development projects are under way. PSRC is the first staged implementation in which the first stage involves integrating a day activity pattern model with the existing trip-based model system.

A Comparative Summary of Features

This section provides a concise summary of important design features of various AB model systems that have been implemented or have recently been designed for planning agencies in the U.S. The models described are those mentioned in the previous section, with a few exceptions. Lake Tahoe is excluded because it is essentially a clone of MORPC, and Oregon and Ohio are excluded because they are statewide models. A model for Dallas (CEMDAP) is included because, although no agency has expressed a commitment to use it, it is in an advanced state of development. We have also excluded the FAMOS model for Tampa Bay, which is still primarily a laboratory project, and the TranSIMS model, for which the AB component is not well developed. Finally, we have included the PSRC model system with the Activity Generator incorporated because of its importance to PSRC, even though it remains in part a trip-based model system.

- Except for the PSRC model system, all of the model systems described in this section are similar in several important aspects: represent an entire day of activities and travel for each member of a synthetic population, using stochastic microsimulation
- consist of an integrated system of econometric models
- include traditional traffic and transit assignment components

In addition, the integrated econometric model systems are similar in overall structure, with a hierarchy of levels from “top” to “bottom”, where lower level choice predictions are conditioned by those at higher levels, and higher level choices are influenced by accessibility measures that capture the effect of choice opportunities occurring at lower levels. The levels are:

- Population synthesis (geographic allocation of households)
- Longer term decisions: auto ownership and (in some cases) work and school locations
- Person/household-day level: choices that span the entire day for one or more persons in the household
- Tour-level: The main destination, travel mode, begin and end times, and number of stops for each tour
- Trip-level: Intermediate stop location, and the mode and departure time of each trip

Within this structure, there are several important design features and other aspects that distinguish the models, and these are summarized in Table D1 below. At the time of this writing, the Bay Area (MTC) and Denver (DRCOG) models are in the development stage, and the San Francisco model is undergoing a major upgrade, so the design characteristics shown for those models may be in a state of flux. Each paragraph below is a more detailed annotation of a row in the comparison table.

Implementation status: The Metro model was implemented and used once without complete calibration, and subsequently not used. Four of the models, San Francisco (SFCTA), Sacramento (SACOG), New York (NYMTC) and Columbus (MORPC) are in ongoing use, with ongoing maintenance and improvement. The Dallas model (CEMDAP) has been implemented for validation purposes in a laboratory setting. The remaining models are in various stages of development.

Controls/categories for population synthesis: All of the model systems simulate persons one by one, and require a representative sample of households and persons for the base year and forecast years. All of the regions use zone-level data and forecasts of household size and income as control variables for sampling households from the regional PUMS households. In addition, most of the regions have used the number of workers in the household as a third control variable, both because it is important behaviorally, and because CTPP Table 1-75 provides a useful 3-way joint distribution of household size, number of workers and income for 2000. The Portland (METRO) and San Francisco (SFCTA) models have also used age of head of household as a control variable, and Atlanta (ARC), Bay Area and Denver are all considering using age or age-related variables as well (e.g. presence of children and/or senior citizens). San Francisco (SFCTA) is also using controls for presence of children, single vs multi-family dwelling, race/ethnicity, and is explicitly synthesizing residents in group quarters housing. The sample generation software created for Atlanta has a flexible system for designating and combining control variables, as well as facilities for testing how well the synthetic population matches other variables which have not been explicitly controlled. SFCTA, MTC, DRCOG, MTC and PSRC are all using derivatives of the ARC population synthesizer.

"Usual" work & school locations modeled at the top level: There is a recognition that the choice of where to work and where to go to school are longer-term decisions that are not adjusted day to day, similar to the choice of residence (which is implicitly modeled in the synthetic sample). In most of the models, and all of the more recent ones, the "usual" work and school places are modeled at the "top" level, meaning that these are predicted before predicting any choices specific to the travel day. The home location is typically one of the alternatives in the choice set, for people whose main workplace is at home or who are home-schooled. Note that certain types of individuals such as construction workers or traveling salespeople may not have a "usual" workplace. Also note that this model formulation requires that data be collected on each worker's most frequent work location, even if that person does not visit that location on the survey diary day(s). The destination for any particular work tour will most often be the "usual" work location, but may be another location instead (a business meeting, for example), and that choice is modeled accordingly at the tour level. School tours nearly always go to the usual school location, so school location should be modeled as a long-term choice and a separate school tour destination model may not be needed. In the future, it would be ideal for the population synthesis and longer term models to be replaced by a dynamic, integrated land use model that includes joint prediction of residential and workplace (re)location decisions.

Number of out-of-home activity purposes: The simplest purpose segmentations are in the San Francisco model, with 3 purposes (work, school, other). Most other model systems have included at least 7 activity purposes, being work, school, escort (serve passenger), shopping, meals, personal business (or "other maintenance"), and social/recreation (or "other discretionary"). In some cases, social visit has been separated from recreation. The main reasons for splitting out the meal activity are that it tends to be done at certain types of locations, and has very specific time-of-day and duration characteristics. The escort activity also tends to be to specific locations at specific times in terms of driving children to and from school. Note that in tour-based models we do not need to treat non-home-trips as if they are separate "purposes", although all of the systems do have separate tour level models for work-based tours (often called "subtours" because they are tours within tours). In most of the model systems, the division of the school purpose into university, K-12 and pre-school is made in the lower level models based on the age and enrolment type of the particular person in the sample.

Number of in-home activity purposes: In the Portland models, in-home activities are distinguished between 3 purposes (work/school, maintenance and discretionary), but this distinction is only made for the "primary" activity of the day, and is only predicted in cases when the person has no out-of-home activities. None of the other models distinguish between types of in-home activities. Some of the models predict which people work primarily at home, providing some substitution between in-home and out-of-home work. They do not, however, handle the phenomenon of part-time telecommuting, which is the focus of some TDM policies. As a result, there is some interest in predicting work-at-home as a separate activity type in the Bay Area model if the data will support it.

Day pattern type linked explicitly across HH members: All of the models treat linkages across household members implicitly through the use of a wide variety of person type and household composition variables. However, some of them have begun to use explicit linkages between the predicted activities and travel of different members of the same household, which makes microsimulated activity and travel itineraries more consistent among household members. This and the following three paragraphs are concerned with the modeling of these explicit linkages. One of the key linkages is a fairly simple one. If each person's full day activity pattern is classified into three main types—stay at home, go to work/school, or travel for some other purpose—then we see strong similarities between the patterns of members of the same household, even stronger than the similarities that would be predicted indirectly. The Columbus model system includes a sequential model of these linkages, simulating children first, and then adults conditional on what the children do. The Atlanta model system includes a similar model that is estimated simultaneously across all household members, avoiding the need to assume the order in which they are simulated and thus the direction of causality. A similar model is planned for the Bay Area system.

Joint activities linked explicitly across HH members: Joint activities are cases in which two or more household members travel together to and from an activity location, and participate in the same activity while at that location. In the lower level models such as mode and destination choice, it is best to model such cases as a single joint decision, rather than as independent decisions made by different people. The Columbus and Atlanta model systems include models of household joint activity generation and participation. The application of the Columbus model has shown that predicting joint travel can have significant implications for mode choice, so this type of model has been recommended for the Bay Area model. However, in a wider sense the "jury is still out" as to what extent the additional accuracy of explicitly modeling household interactions will merit the additional complexity. For that reason, such models will not be included in the Denver system, at least in the initial version.

"Escort" trips linked explicitly across HH members: Another type of joint travel is the case where two or more household members travel together to and/or from an activity location, but do not participate in the same activity there. The most common example is a parent driving a child to school and then either returning home (an escort tour) or else driving on to work (an escort stop on a work tour). Because these types of tours are partly joint and partly independent, it can be very complex to explicitly link them across persons. For that reason, explicit modeling of escort linkages has not been done in any of the applied models or recommended for the models under design. Most of the models, however, do include a separate "escort" purpose, so that the most important special characteristics can be captured—particularly the fact that the mode is nearly always auto, with the exception of infrequent cases of walk escort. Also, children's school locations can easily be included as special alternatives in the parents' escort tour destination choice sets, so that at least the location is accurate, even if the exact trip timing and car occupancy are not matched.

Allocated activities divided explicitly among HH members: Certain types of activities such as grocery shopping, escorting, and some other "maintenance" chores, are likely to be allocated across individuals in a household, showing a negative correlation of frequencies and duration across household members within a household-day. The Columbus and Atlanta model systems assume that activities for certain purposes are conducted on behalf of the household, and include explicit models of the generation of these activities at the household level and then allocation to particular individuals. In the Atlanta case, this model was estimated jointly with the household joint travel generation model. Compared to explicitly linking people who make joint tours together, predicting which people within a household perform allocated activities appears less important to the model results—we are not changing anything fundamental about the tours, just which person makes them. So, these models seem less crucial than the joint travel models. In addition, it is difficult to reliably determine, from existing surveys, which activities are most likely to be allocated. For example, grocery shopping is mainly an allocated activity, while shopping for a good book to read is an individual activity, but both are usually coded the same. So, without better survey data designed to distinguish activities by whether they achieve household or personal objectives, the quality of models that attempt to allocate household activities is questionable.

Level at which intermediate stop purpose and frequency are modeled: When ordering the models in an AB system from "top" to "bottom", it is not always clear which decisions should be modeled conditional on which other decisions. A prime example is the generation of intermediate stops made during tours. Are activities planned and combined into trip chains when a person is planning their day, in which case the mode, timing and location of the tours may depend on which stops they contain? Or, conversely, do people make tours, and then decide during the tour how often and where to make stops depending on their mode and location? Clearly, both of these describe real behavior, and which description is more accurate depends on the particular person and the types of activities they are carrying out. The Portland and San Francisco models follow closely the original Bowman and Ben-Akiva day pattern approach, in which the presence (and, in the case of Portland, basic purpose) of intermediate stops are predicted at the person-day level. In contrast, the Columbus, New York and Atlanta models predict only the number and purpose of tours at the person-day level, and then the presence, number and purpose of intermediate stops on any particular tour are predicted at the tour level once the tour destination, time of day and main mode are known. In the Sacramento models, another approach is used. Some information about stop-making is predicted at the person-day level, predicting whether or not any intermediate stops are made for each activity purpose during the day (7 yes/no variables). These are predicted jointly with the choice of whether or not to make any tours for each of the activity purposes (7 more yes/no variables), thus capturing some substitution effects between the number of tours and the number of trips per tour. Then, when each tour is simulated, the exact number and purpose of stops on each tour are predicted conditional on the mode and destination of that tour and conditional on what types of stops still need to be simulated to fulfill the person-day level prediction. There is no proven behavioral reason for this structure, but it "balances" the model sensitivities between the two types of behavior described above. A similar approach is being used for Denver (and has been implemented in the initial Activity Generator for PSRC).

Number of network zones used: This and the next two paragraphs discuss spatial aspects of the model systems. In all cases, the zone system used for model development and application is the same as was also used for trip-based models. The auto and transit networks and assignments are also the same as used in the trip-based models. This fact has facilitated the transition to AB models, but at the same time, the microsimulation framework can also be used with more detailed spatial systems, and would support more accurate traffic simulation methods as well.

Smaller spatial units used below zones: Because the microsimulation framework is not tied as strongly to zone definitions, it is possible to use the zones only to provide the road and transit path level of service variables, while variables related to land use, parking, and walk access (which do not need to be stored as matrices) can be specified at a finer level. The Portland model uses such an approach for roughly 20,000 "block faces", while the Sacramento models use over 700,000 parcels. In both of these model systems, this fine level of disaggregation is used to define the destination choice alternatives and their attractiveness, to provide detailed mode choice information at the trip-ends related to accessibility of transit, and level-of-service for non-motorized modes and intra-zonal trips. Denver is going to use "utility hookup points" instead of parcels, but primarily for modeling mode choice. With these two-level systems, the importance of very small traffic assignment zones is lessened. But the size of zones still needs to be small enough to achieve homogeneity of travel times and costs for the motorized portion of inter-zonal trips, as well as the availability and nature of transit and highway access points.

Simultaneous mode and destination choice model estimation: It has become a sort of tradition in modeling to condition mode choice upon a known destination, sometimes using a sequential nested structure where the mode choice logsum is used in the destination choice model. That is probably appropriate for purposes such as work and school. For purposes such as shopping, however, the choice of store may sometimes depend more upon the mode used than vice-versa. Simultaneous estimation of mode and destination choice allows the modeler to test different nesting hypotheses.

Such an approach was used in the Portland model, but has not been use since by any of the implemented model systems.

Modeled time periods and time-constrained scheduling: Most 4-step models only use two times of day—peak and off-peak, and use fixed time-of-day factors. All of the AB models contain tour time of day models that allow some sensitivity of time of day choice to network conditions. All of the models have used at least 4 highway assignment periods—AM peak, midday, PM peak and off-peak. In some cases, free flow conditions are assumed for off-peak, so no traffic assignment is needed for that period. In some models, a fifth period has been added by splitting the off-peak period into early morning and evening/night. The more recent models, beginning with Columbus, use more precise time windows in order to schedule each tour and trip consistently during the day. This involves keeping track of the available time windows remaining after "blocking out" the time taken by each activity and associated travel. The time windows can also be used in the activity generation models. The Sacramento model and perhaps other models are moving to half-hour periods to provide even more detail. The main constraint on how small the time periods can be is the adequacy of the self-reported times in the diary survey data. There is evidence that people often round clock times to 10, 15 or 30-minute intervals. The effectiveness of modeling time at a detailed level is hampered by the use of no more than four or five time periods for traffic assignment, increasing the pressure to use more time periods for traffic assignment, and to move to dynamic traffic assignment. Denver is implementing 8 assignment time periods, and SFCTA and PSRC have implemented an assignment procedure that takes the equilibrated results of two 3-hour peak period assignments and generates differentiated level-of-service skims for each half hour within the peak.

Tour time of day relative to mode and destination choice models: It is not obvious whether activity and departure times should be predicted before mode and destination choice, between them, or after both. There is some empirical evidence that shifts in time of day occur at two levels: the choice among broad periods of the day (e.g. morning, afternoon, etc.) is made fairly independently of accessibility, while smaller shifts of up to an hour or two are more sensitive to travel times and costs—the peak-spreading effect. Since all of the models use broad network time periods, the tendency has been to model the choice of these periods for tours at a fairly high level above mode and destination choice (although in most cases the usual destination for work and school tours has already been predicted). In some models, time of day choice is predicted between the destination and mode choice levels, which allows the use of destination-specific mode choice logsums in the time of day model, but requires that the destination choice model assume (or stochastically select) a specific time of day for the impedance variables. SACOG models time of day below destination and mode. For DRCOG, the data support modeling tour TOD above mode choice for work and school tours, but below mode choice for other tour purposes.

Departure time choice modeled separately at the trip level: Perhaps the placement of the model that predicts the choice of times for the overall tour is not as crucial if there is a separate model that predicts the departure time for each trip to the more detailed periods, conditional on the mode, origin and destination of each trip. Some of the model systems include such a model as the "lowest" model in the system. It is also possible to include such a model for car trips only, in order to predict the shape of the demand profile within the broader peak periods.

Accessibility measures in the upper level models: The issue of how to include accessibility and land use effects in the upper level models is extremely important, because it determines the accuracy with which the models represent sensitivity of activity, tour and trip generation and patterns to transport level of service and the distribution of activity attractions. Calculation of full logsums across all possible nests of lower level alternatives is infeasible with so many levels of choices. The earliest Portland models came the closest to including "proper" individual-specific logsums, but the structure of that model was relatively simple, and the effect on model run-time was severe. Initially, the San Francisco model included mode-specific measures with set boundaries, such as the number of jobs accessible within 30 minutes by transit. The rather arbitrary cutoff boundaries in such measures can cause unexpected sensitivities when applying the models. It has recently been enhanced to use logsum-based accessibility measures. The New York and Columbus models use mode-specific travel time decay functions that approximate the logsum from a simple destination choice model. Such measures perform better, but still have the problem that they are mode-specific, and that auto and transit accessibility tend to be correlated, so it is difficult to estimate model parameters for both of them. A method that solves this problem and is more consistent with discrete choice theory is to approximate joint mode/destination choice logsums. However, the mode choice logsums tend to vary widely across the population, so it is best to calculate different accessibility measures for different population segments. The Sacramento models use such an approach, with aggregate accessibility logsums for each combination of 7 travel purposes, 4 car availability segments, and 3 walk-to-transit access segments—as those tend to be the most important segmentation variables in the mode choice models. Both DRCOG and PSRC are using aggregate accessibility logsums similar to those used by SACOG.

Network model platform: One attractive aspect of the AB modeling framework used in the existing models is that it is fairly independent of the network modeling software platform. AB models have been implemented to work with Emme2, Cube/TP+ and TransCAD, although three of the four ongoing US AB model systems use Cube/TP+.

AB model software: As the number of AB model implementations has begun to increase, attention to the nature of the software implementation has begun to increase as well. The first implementations, in Portland, San Francisco and NYMTC all employed custom software developed primarily by the model developers themselves, in conjunction with the network modeling platform chosen by the client agency. The software was required for transforming survey data into a form usable for model estimation, and for running the AB components of the implemented model system. Subsequent implementations by those modelers have tended to use and enhance the software from the initial implementations. SACOG and the new PSRC activity generator use software called DaySim, written by Bradley and Bowman in Borland Delphi, a compiled language derived from Pascal that is similar to C++. The SFCTA application uses C++ and Pascal. NYMTC, MORPC, ARC and MTC use Java implementations derived by Parsons Brinckerhoff from their growing common modeling framework (CMF). DRCOG has chosen to develop their own database-oriented custom application with the assistance of a Cambridge Systematics programming team.

Table D1: Features of Various Activity-Based Model Systems

Feature	Portland Metro	San Francisco SFCTA	Sacramento SACOG	Denver DRCOG	Seattle PSRC with Activity Generator	New York NYMTC	Columbus MORPC	Atlanta ARC	Bay Area MTC	Dallas (CEMDAP)
Implementation Status	Discontinued	In use	In use	Development	Development	In Use	In Use	Development	Development	Laboratory
Controls / # categories for population synthesis	4 hh size 4 income 4 age	4 hh size 3 # workers 4 income age, children	4 hh size 4 # workers 4 income	4 hhsize, 3 # wkrs, 4 inc, #adlts, kids, 3 holder age	similar to ARC	5 hh size 4 # workers 4 income	5 hh size 4 # workers 4 income	100+ comb. of hh size, # wkrs, inc, age, children	4 hh size 4 # workers 4 income Age (?)	
Population synthesizer	Custom	ARC PopSyn	Custom	ARC PopSyn	ARC PopSyn (base year)	Custom	Custom	ARC PopSyn	ARC PopSyn	UT CEMDAP
"Usual" work & school locations at top level?	Yes	Yes	Yes	Yes	Work	No	No	Yes	Yes	Yes
Number of out-of-home activity purposes	8	3	7	7	7	4	7	8	7 or 8	11 for adults 3 for children
Number of in-home activity purposes	3	1	1	1	1	1	1	1	1 or 2	1
Day pattern type linked explicitly across HH?	No	No	No	No	No	No	Sequential	Simultaneous	Simultaneous	Sequential
Joint intra-HH activities?	No	No	No	No	No	No	Yes	Yes	Yes	Parent & child
Linked intra-HH "escort" trips?	No	No	No	No	No	No	No	No	No	Yes
Allocated HH activities?	No	No	No	No	No	No	Yes	Yes	No	Yes
Level where stop purpose and frequency are modeled	Person-day	Person-day	Person-day and tour	Person-day and tour	Person-day and tour	Tour	Tour	Tour	Person-day and tour	Person-day and tour
Network assignment zones	1,250	2,336	1,300	2,800	938	6,000	2,000	2,500	1,600	
Smaller spatial units used?	20K blocks	No	700K parcels	Points for mode choice transit access	No (parcels in next version of models)	No	No	No	No	
Mode and destination model estimation	Simultaneous	Sequential	Sequential	Sequential	Sequential trip-based	Sequential	Sequential	Sequential	Sequential	
Network time periods	5 per day	5 per day (12 ½hr peak subperiods)	4 per day	8 per day	5 per day (12 ½hr peak subperiods)	4 per day	5 per day	4 per day	5 per day	
Modeled time periods	5 per day	30 min (new)	30 min	30 min	30 min	4 per day	1 hour	1 hour	30 min	
Scheduling constrained by available time windows?	No	No	Yes	Yes	No	No	Yes	Yes	Yes	
Tour time of day relative to mode and destination	Above	Above	Below	Above for non-work	Below	Between	Between	Between	Between	
Departure time modeled separately at trip level?	No	Yes (auto peak trips)	Yes, lowest model	Yes, lowest model	Yes (auto peak trips)	No	No	Yes, lowest model	Yes, lowest model	
Accessibility measures in upper level models	Person-specific mode / dest logsums	Jobs reached by zone/ mode/time band,logsums	Mode & dest logsums by zone / segment	Mode & dest logsums by zone / segment	Mode & dest logsums by zone / segment	Dest choice logsums by zone / mode / segment	Dest choice logsums by zone / mode / segment	Dest choice logsums by zone / mode / segment	Mode & dest logsums by zone / segment	
Network model platform	Emme2	Cube/TP+	Cube/TP+	TransCAD	Emme2	TransCAD	Cube/TP+	Cube/TP+	Cube/TP+	TransCAD
AB model software	DaySim Precursor	Custom C++	DaySim	Custom C#	DaySim	PB CMF	PB CMF	PB CMF	PB CMF	UT CEMDAP

Lessons Learned

Insights from the Project Team

The model systems from San Francisco, New York, Columbus and Sacramento are notable because they continue to be used and enhanced over time. We cite six reasons for their initial and ongoing success, based on our own experience and observations:

- **Workable design framework**. Although there is substantial variation among these model systems, they all share the similarities described at the beginning of the previous section. While other frameworks may some day be even more successful, the basic framework on which these model systems are built is clearly workable.

- **Trusted instigating advocate**. For every project, someone who is trusted by the sponsor must step forward and say, "Let's go for it". At SFCTA, Jose Louis Moskovitch played that role in tandem with the support of several consultants. Gordon Schultz of PB deserves much of the credit for convincing NYMTC, ARC and MORPC. At SACOG, Gordon Garry was the advocate.

- **Motivated sponsor**. A third key ingredient is sponsorship. This includes an adequate stream of funds to see the project through to completion. Each of these projects has its own important story of how that sponsorship came about and was sustained. However, to a great extent we have learned this lesson through two counter-examples. Under the leadership of Keith Lawton, Metro was the first agency to take the plunge into AB model development. However, when it came time to calibrate and validate the model, the MPO was struggling financially. Lifesaving federal funds became available from TranSIMS, so the development money and staff resources were dedicated to the TranSIMS project; funds and staff resources were never appropriated for the calibration and validation of the AB model. In the case of ARC, a cautious top management chose to invest at a very slow rate in the development effort. They also became pre-occupied with a major geographic expansion of their MPO region from 13 to 20 counties. For these two reasons, ARC didn't commit a large enough concentration of resources for the project to advance effectively. Fortunately, that situation appears to have changed and with a major investment pending in 2008, ARC may now have the needed sponsorship.

- **Powerful internal champion**. The project also needs an internal champion to build and maintain sponsor support. The emphasis here is that advocacy must be sustained continuously over time, and must come from within the organization. In some of the cited success stories, the initial advocate was not within the organization and is no longer on the scene. In others, the internal champion left the organization. But in all cases, there has always been someone carrying the role of internal champion.

- **Capable innovative developers**. When these successful AB models were first developed, the practice of AB modeling was in its infancy, and so it was necessary for the projects to be implemented by developers who could develop and implement innovative features in the context of real-world model system development. Although the state of the practice has matured considerably since those projects started, the modeling framework seems to have yet-untapped potential, and desirable improvements continue to arise. It would be possible now to implement a model system just like one of the existing models, but it is desirable to continue embedding a measure of creative research and development into the fabric of new development projects, and this requires capable innovative developers.

- **Capable user staff**. Finally, capable staff is needed, for the same reasons that capable developers are needed. Although these AB models are very similar in many respects to the trip-based models that precede them, they introduce new data and procedural requirements, and the operating procedures are not well established within the organization. So, it takes a capable and dedicated staff that can participate in the development, break in new features, respond to unforeseen challenges, and initiate ongoing improvements.

Insights from Agencies Using the Models

In order to identify lessons that the four agencies currently using AB models have learned, we submitted a questionnaire to each one. An appendix provides the complete text of the questionnaires and responses. Here we provide a consolidated and edited list of comments that seem especially relevant to PSRC.

Parcel-based model system

1. Determine up front how each parcel-level data item used by the AB model will be forecasted. (SACOG)

2. Try to improve on the parcel-to-parcel proximity techniques used by SACOG, to deal better, for example, with geographic barriers. (SACOG)

UrbanSim integration and synthetic population input

3. Make sure the synthetic population accurately represents the number and location of university students. (SACOG)

4. SFCTA's model does not rely on UrbanSim to generate the synthetic population or to simulate the long term choice outcomes (although it may do so in future integrations). (SFCTA)

Intra-household interaction

5. Intra-household interaction features are intuitively appealing, and can improve the realism of the itineraries across household members. As implemented by MORPC, they seem not to substantially increase run times. However, users are unable to cite evidence that they improve aggregate predictions. (MORPC)

Traffic and transit assignment

6. Improve highway assignment, and transit networks and assignment to take advantage of AB model capabilities. (SACOG, NYMTC)

6.1 Use more than four highway assignment periods and two transit assignment periods in order to provide better information for the time-of-day models. (SACOG)

6.2 If you use PA transit assignment, switch to OD assignment to fit better with the AB model. (SACOG)

6.3 Design transit assignment and the interface so as to supply the AB model with fares by person-type, and use this information in the mode choice model so that it is sensitive to fare schemes that differ for different people. (SACOG)

Model design and calibration

7. Pay attention to how well the model system distributes trips to zones; this includes the AB model's location choice models as well as the handling of special generators. (MORPC)

8. It has been a challenge to deal with the diversity of the region and the particularities of Manhattan (NYMTC).

Hardware, software, run time and model operation

9. Model run time is a major issue. Use a software and hardware implementation that effectively distributes the AB model and the traffic assignment to multiple processors (The distributed processing in the MORPC AB model is clunky and prone to break down.) Plan for post-implementation work to improve model run times. (MORPC, NYMTC)

10. Extra software products used by the AB model software, such as Excel, ESRI Avenue, and even the assignment software, cause problems because the installation requires these products and because the version used will become out-of-date. (MORPC)

Using the model and model system outputs

11. Include in the development project the design and implementation of databases and data flows for generating desired performance measures that take advantage of the AB model and parcel level data/results. (SACOG)

12. Good model documentation has lagged the implementation (SFCTA, NYMTC).

13. Formal training has been required for stakeholders, including decisionmakers (1 day) and model users (3-5 days and more) (NYMTC).

14. There is a need to improve the user interface, online help and documentation for model users (NYMTC)

Implementation schedule

15. Don't implement during an MTP or other major statutory function. (SACOG)

16. Validate your trip-based model system because the AB model implementation will take longer than the original schedule. (MORPC)

17. Be sure to have specific milestones in the work plan, and a schedule for completion that all parties agree to. Establish a system of "point releases" of code that is workable and testable, which is separate from the constant stream of development updates which exist in an open-source collaborative project like UrbanSim. (SFCTA)

18. Expect it to take twice as long as envisioned (SFCTA).

Maintenance and enhancement

19. It is difficult to make big adjustments to the model without assistance from the consultant who established it. (MORPC)

Requirements Specific to PSRC

The following list of specific requirements and assumptions has been developed in discussions with PSRC project team members and UrbanSim developer, Paul Waddell:

1. **Spatial detail for demand models**. We will assume that the demand models should use parcel data. Our design work related to parcel geography will focus on how to do it.

   September 2008 adjustment: There are some measurements that may use grid cells to improve processing times.

2. **Spatial detail for traffic assignment**. PSRC intends to increase the number of zones, probably into the range from 2000-4000. The change will probably be implemented late in 2008.

3. **Temporal detail for demand models**. We will assume the use of a quasi-continuous approach in the time-of-day models, implemented via discrete choice models, with time periods of 30 minutes.

4. **Equilibrium assignment**. For the AB model implementation, we will assume traditional traffic and transit assignment models, at least for the initial application.

5. **Assignment model software**. PSRC is considering a change from Emme3, partly because of license cost increases associated with the number of zones, and partly because of functionality issues. If a change is made, it will probably occur in late 2008.

6. **Highway assignment time periods**. Highway assignment is carried out using five time periods with iterative demand feedback. After convergence, the two 3-

hour peak period assignments are split into twelve 30-minute periods for final assignment. The design needs to take advantage of the availability of distinct LOS skims for 15 different time periods.

7. **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			

8. **Interface with UrbanSim.** PSRC desires to have model outcomes that are longer term than one day to come from UrbanSim rather than the AB model, so that they can interact more flexibly with the other long term model outcomes. These include, at least, residential location of households and non-institutional group quarters residents, usual work location of workers, usual school location of students and household auto ownership.

9. **OPUS framework.** The travel forecasting model system needs to operate within the Opus software framework used by UrbanSim.

   September 2008 addition: The implementation should include the capability to re-estimate and apply models within the OPUS framework.

APPENDIX E—AGENCY STATEMENTS OF LESSONS LEARNED

This appendix contains the interview memos sent to agencies requesting feedback about lessons learned, as well as the text of the agency responses, indicated by italic font.

SACOG—Bruce Griesenbeck

Interview document with interspersed April 21 responses:

To: Gordon Garry and Bruce Griesenbeck (BGriesenbeck@sacog.org)

From: John Bowman (617-232-8189)

Date: April 8, 2008

Subject: Lessons learned in implementing, enhancing and using the SACOG activity based model

At the request of Puget Sound Regional Council (PSRC), I am conducting interviews to learn from the experience of folks now working with activity-based models. They want to know what lessons you have learned that will help them be more successful as they begin planning and design for their own model development. My questions are quite general, leaving it wide open for you to zero in on the insights that you think are most important. Despite the generality of my questions, I hope that your answers will be quite specific, so as to be as helpful as possible.

Parcel-based model system. I am especially interested to get your insights regarding the parcel basis of the activity- based model. This is because PSRC has already decided to implement a parcel-based model and you are the only example of a parcel-based model that is up and running. They are not so much interested in hearing whether they should go this way or not. Rather, they would really benefit from learning how to go about it. As you think about what it was like to implement such a model, and now that you are using it, what specific advice would have to offer PSRC?

Consider how parcel-level land uses in future will be forecasted. Consider it very carefully. Do not over-rely on existing observed data and inventories in estimation, only to discover that a powerful explanatory variable in estimation is impractical/impossible to forecast.

Consider carefully how parcel-to-parcel proximity is to be defined and computed within the model. SACOG blended approach works, and is a huge improvement over taz-to-taz proximity measures, but it has problems, too. E.g. geographic barriers like canals and rivers, false proximity is allowed.

Integrated Land Use-Transport model. They are planning to implement their model system with UrbanSim, so any advice regarding the issues surroundign this would also be very helpful.

Other lessons learned. Beyond these two specific aspects of the model system, I would like you to address the question of what important lessons have you learned about implementing and using an AB model? These could be related to management issues, such as sponsorship, funding, scheduling, etc. They could also be related to technical issues, such as important features, problematic features, design problems, data issues, application issues, etc. It could be mistakes that were made and should not be repeated, or decisions that you are really glad you made. Or anything else where, upon reflection, you think PSRC might benefit from your experience.

Don't implement the model during development of an MTP or other major statutory function—its a bit like tuning a stock car from inside the car during the Daytona 500.

AB modeling + parcel level data provides vast horizons for diving into modeling results and examining land use/transportation/demographic inter-relationships which are impossible to approach with a conventional 4-step, aggregate, taz-based model. It would be extremely useful to plan ahead on what performance measures will be used and build the databases and data flows needed to generate those into the model.

Building synthetic populations and allocating them to parcels merits lots of consideration and planning. In Sacramento, we only had county level, single dimension forecasts of key demographic "marginals" for variables like income, age, and household size. Obviously, there are an infinite number of variations for matching a series of single-dimension marginals with a reasonably detailed synthetic population. Along those same lines, plan on controlling location and number of university students in the synthetic population.

SACOG used 4 time periods for defining highway level-of-service, and 2 for transit. This is insufficient to "fuel" a time-of-travel choice model. We are busy adapting shoulder LOS for both AM and PM peaks, and adapting transit to mirror the number of time periods used in highway. FYI, transit is only 2 currently due to P>A assignment, which doesn't fit well in AB modeling. Plan on doing O>D assignment in transit.

While you are at it, build into the AB model a method of attaching the "correct" transit fare and skim by person type. With AB+synthetic population, you can account for some of the basic variations in fares by person type. E.g. seniors, students pay discounted fares, some portion of lower income may get fare subsidies, etc. Build that into your transit skims, and account for it in mode choice estimation.

Thanks for your help. I'm sure PSRC will greatly appreciate it!

MORPC—Rebekah Anderson (Technical Services, Ohio DOT)

April 8 email response cover memo, followed by interview memo with interspersed responses to interview questions:

John,

I copied Nick Gill and Zhuojun Jiang at MORPC as MORPC is the end user of the model. While we run their model when needed for the Newark MPO or for other ODOT needs, they run the model for projects, their long range plan, TIP, air quality, or other needs. You will probably want their answers and at a minimum to have them on the conference call.

That said, my answers are attached. The attached power point is one I've sent around with run times in it. There are 3 systems to which MORPC and ODOT have access to run the model, and they are detailed. Note the dates in the top left of the run time slides. We bought Cube Cluster to distribute the cube scripts across multiple processors between May and Oct 2006. Cluster is only implemented in the ODOT system times. Therefore, the MORPC systems run faster than shown in the slides due to network scripts now being distributed. Also note the notes section of the ppt. I had originally made these slides for an oral presentation, so they may be hard to follow. Also I believe that MORPC was also combining the MORPC and COTA system computers, so the model now runs faster at MORPC as there are more processors.

Also, as you are aware, we will hopefully have a research project to compare the MORPC tour model with a new trip model. We have been having issues getting a signed contract, so that project still has not started. However, the trip model is almost finished. (I need to find time to calibrate the mode choice models.) ODOT is withholding judgement on what type of model we want to develop for Cincinnati and Cleveland until that project is finished. (Or if there are situations where a trip model will give you an appropriate answer and the tour model is not needed.) That project is also supposed to note the benefits and deficiencies of both types of models. We are running before and after scenarios for 2 large highway projects, and general transit system changes over 1990, 2000, and 2005. It might be interesting to note that we are using the same networks and network algorithms (assignment/skims) and the 2000 highway validation is essentially identical. (As in, the same network adjustments were needed for both demand models.)

Let me know if you have any other questions.

Rebekah Anderson
Ohio Department of Transportation
Office of Technical Services
614-752-5735
rebekah.anderson@dot.state.oh.us

To: Greg Giaimo and Rebekah Anderson

From: John Bowman (617-232-8189)

Date: April 8, 2008

Subject: Lessons learned in implementing, enhancing and using the MORPC activity based model

At the request of Puget Sound Regional Council (PSRC), I am conducting interviews to learn from the experience of folks now working with activity-based models. Some of the questions are matters of fact and others ask for opinions. For facts, it would be nice to get one answer, but for opinions, I would like to receive independent answers from each of you. I have a couple fairly specific questions related to your implementation:

1. How long does the full model system require to equilibrate to full convergence? And how many processors are at work in parallel?

There are 3 full iterations of the model. It may need more iterations to actually converge, however it appeared to converge pretty well in 3 iterations during calibration. Perhaps one day we will actually test what adding a 4th or 5th iteration will do, however, that's not on the short term list. The number of processors varies depending on the computer cluster. See presentation for computers and run times.

2. Intra-household interactions. PSRC needs to decide whether to choose a design that includes explicit household interactions, such as a joint model of primary activity purpose among household members, or joint tours, or school escort trips.

   2.1 Which explicit household interaction features have been of most value in the MORPC model, and why?

My personal opinion is that household interactions have the most value in the activity pattern model. I think that presence of child travel affects adult travel patterns. But, this is just my opinion and we have not actually tested this.

   2.2 Which explicit household interaction features have been of least value and why?

   2.3 What have been the clearest benefits of implementing intra-household interactions?

Unknown. In comparison to a trip model, you can actually have parents drop children off at the same zone as the children are going to school. It is extremely hard to get this relationship into a trip model. I also don't believe you'd be able to get this into a tour model that does not account for joint travel.

   2.4 I suspect that representing intra-household interactions causes the model to perform more slowly. What insight do you have that would sharpen my understanding? For example, maybe this is not really true, or maybe certain interaction features take more time and others don't.

The joint travel models only take ~12 minutes per iteration, or ~36 minutes total out of 11-20 hours. I don't think that it takes any more time in the pattern model as they are logit based, and it's just an additional term.

3. Satisfaction.

   3.1 What are you most satisfied with about the model, and why?

AECOM's review said that it is one of the best distribution models they have seen.

   3.2 What are you least satisfied with about the model, and why?

Run time, for obvious reasons. That it is in java, as it is more opaque than if it were in cube.

Beyond these, I would like you to address the question of what important lessons have you learned about implementing and using an AB model? These could be related to management issues, such as sponsorship, funding, scheduling, etc. They could also be related to technical issues, such as important features, problematic features, design problems, data issues, application issues, etc. It could be mistakes that were made and should not be repeated, or decisions that you are really glad you made. Or anything else where, upon reflection, you think PSRC might benefit from your experience.

I typically tell people to validate their old model first as the development of a new model will take much longer than the schedule states.

Thanks for your help. I'm sure PSRC will greatly appreciate it!

MORPC—Greg Giaimo (Technical Services, Ohio DOT)

Email response, April 9, 2008:

1. answered by Rebekah

2.1 As you should be able to tell from Rebekah's response, we haven't explicitly taken advantage of the intra-HH interaction component of the model. At this time we can only speculate that it provides a more realistic response to changing conditions. We might be able to start exploring that with the sensitivity research project (if the lawyers can ever agree on the contract language).

2.2 I suppose you could invert my response to 2.1 to get my response to this one.

2.3 I guess I 'd switch this around a bit a refer to Rebekah's response to 3.1, a better distribution pattern gives more confidence in the transit projects that were analyzed with this model. Other than that the model has only been used to analyze traditional highway projects and the long range plan (primarily for conformity purposes), thus a 4 step model could have done that. Again I'll refer back to my answer to 2.1 and say there could be some unknown benefit on the model's sensitivity to change which we have yet to quantify.

2.4 answered by Rebekah

3.1 Besides what Rebekah said, I'd say I've gained some satisfaction by the simple fact that this model pushes the envelope a bit. When this model type was proposed by PB we had no idea of the potential benefits and costs (have a good handle on costs now, not so much on benefits) but we agreed to go along with it in the spirit of innovation. Thus I've always seen the MORPC model as something of a test bed so we could learn by doing. Thus for me the measure of success was: could we build a model that could do everything a 4 step could (for about the same cost) and at the same time explore something new? In that respect it is quite successful.

3.2 I'll second Rebekah's comments and add in a few of my own. First there is my pet peave that the particular developers of this model like to build into the delivered application whatever their favorite proprietary software du jour is (I've had to fight to keep statewide model only in Java and Cube, each developer on their team always wants to add in something else like Python, R, SAS, Excel, GISDK etc etc). The MORPC model suffered from having some inputs in Excel (a currently out of date version of Excel of course) and ESRI Avenue. In addition, it seems the way they implemented *distributed processing in the demand models is quite clunky and prone to break down (which was made all the more obvious to me when we obtained the distributed version of Cube which runs across multiple processors quite smoothly by comparison). Also, this particular model didn't address the attraction end very well (there are only a few categories of employment and they feed into some size terms in the destination choice but there didn't seem to be much effort to look at how many trip ends different businesses/zones were attracting, indeed there wasn't even an ability to define special generators which is now being rectified). I could critique the actual model implementation all day, it certainly has various issues (for example the stop frequencies/locations should be better integrated with the rest of the tour decision making rather than an after thought, the resolution of time should be finer, it shouldn't use AM peak skims for decisions made in the PM peak etc. etc.), however, for a first stab it seems pretty good.*

Only follow on comment I can think of is to design your model before you collect surveys. Compromises had to be made in the model based on the available data, for example on the transit side because of lack of an on-board survey (which is now being rectified).

MORPC—Nick Gill

April 9 email response cover memo, followed by interview memo with interspersed responses to interview questions:

John,

Our, MORPC, thoughts on your questions (building from Rebekah's).

Let us know if you want to discuss further.

Thanks

Nick

Nicholas T. Gill PE
Assistant Director, Transportation
Mid-Ohio Regional Planning Commission
Phone: 614-233-4151
Fax: 614-233-4251

To: Greg Giaimo and Rebekah Anderson

From: John Bowman (617-232-8189)

Date: April 8, 2008

Subject: Lessons learned in implementing, enhancing and using the MORPC activity based model

At the request of Puget Sound Regional Council (PSRC), I am conducting interviews to learn from the experience of folks now working with activity-based models. Some of the questions are matters of fact and others ask for opinions. For facts, it would be nice to get one answer, but for opinions, I would like to receive independent answers from each of you. I have a couple fairly specific questions related to your implementation:

4. How long does the full model system require to equilibrate to full convergence? And how many processors are at work in parallel?

The COTA cluster (residing at MORPC) currently takes about 15 hours and 23 hours to complete a 3-full-interation model run, respectively for years 2000 and 2030. The time savings compared to Rebekah's slides are due to using the Cube cluster. There are 5 computers in COTA cluster including 10 processors. As Rebekah mentioned, 3 iterations seem to be sufficient so far. To decide the "optimal" numbers of the full iterations, we may also need to consider the convergence criteria for the UE traffic assignment, since the skims are the main input for the feedback part.

5. Intra-household interactions. PSRC needs to decide whether to choose a design that includes explicit household interactions, such as a joint model of primary activity purpose among household members, or joint tours, or school escort trips.

   5.1 Which explicit household interaction features have been of most value in the MORPC model, and why?

In the MORPC model, two explicit household interactions are included: personal daily activity pattern model and the joint travel model. I believe that the two models would be the most distinguishing feature in the MORPC model compared to a traditional trip-based model.

   5.2 Which explicit household interaction features have been of least value and why?

   5.3 What have been the clearest benefits of implementing intra-household interactions?

Implementing intra-household interactions is theoretically more correct of modeling the real world. However, in practice, the benefit is unclear due to the lack of data to test if models with intra-household interactions would outperform the models without intra-household interactions in terms of predicting kind of "aggregated" travel data in the transportation systems.

   5.4 I suspect that representing intra-household interactions causes the model to perform more slowly. What insight do you have that would sharpen my understanding? For example, maybe this is not really true, or maybe certain interaction features take more time and others don't.

In the MORPC model, the intra-household interaction models take a small portion of running time compared to other models. It is due to smart design of the linkage across household members in the Daily Activity Pattern model and a sequence of 3 choice sub-models for the Joint Travel Model.

6. Satisfaction.

   6.1 What are you most satisfied with about the model, and why?

   6.2 What are you least satisfied with about the model, and why?

Difficult to make big adjustments to the model without the assistance from the consultant who established the model.

Beyond these, I would like you to address the question of what important lessons have you learned about implementing and using an AB model? These could be related to management issues, such as sponsorship, funding, scheduling, etc. They could also be related to technical issues, such as important features, problematic features, design problems, data issues, application issues, etc. It could be mistakes that were made and should not be repeated, or decisions that you are really glad you made. Or anything else where, upon reflection, you think PSRC might benefit from your experience.

Thanks for your help. I'm sure PSRC will greatly appreciate it!

SFCTA—Billy Charlton

April 25 email response cover memo, followed by interview memo with interspersed responses to interview questions:

Hi John,

I've filled out your form rather quickly since I'm short on time. Sorry about that, but I hope it gives the gist of what you're looking for. I've also attached some unfinished documentation written by Paul, but the most interesting sections are still missing. I think there's a lesson in there somewhere.

I'm happy to talk about this more with PSRC if they are interested in our experiences. However, as I stated in my talk at TRB, I consider myself a neophyte in all this land use modeling and I really don't feel I have the expertise to say much about the model structure -- Paul is really the person to talk to about that.

Thanks for your patience with me on this.

- Billy

To: Billy Charlton (SFCTA)—415-522-4816

From: John Bowman

Date: April 8, 2008

Subject: Lessons learned in implementing, enhancing and using your AB model

At the request of PSRC, I am conducting interviews to learn from the experience of folks now working with activity-based models. I have a couple fairly specific questions related to your UrbanSim implementation and your Population Synthesizer, since they want to integrate with UrbanSim.

7. UrbanSim. I understand that you are integrating UrbanSim with the AB model.

   7.1 What inputs does the AB model use from UrbanSim?

UrbanSim produces a land use datafile in the same format required for input into SF-CHAMP. Specifically, it creates a TAZ-level file of zonal household data (households, *population, and employed residents) and employment data (office, retail, industrial, visitor, medical, and institutional employment). This data is fed into the TAZ data processor and population synthesizer of SF-CHAMP.*

7.2 What inputs does UrbanSim use from PopSyn? Is there detailed documentation of this, such as listing the exact measures used in specific UrbanSim models?

The documentation I have that is specific to the SF implementation will be sent along with this form. Beyond that there is extensive documentation at the UrbanSim website, which I've never had time to read.

UrbanSim doesn't read in data from the synthetic population generator. Our implementation has an externally-produced county target for population and employment. UrbanSim uses the output skims by mode from the travel model in its computations of accessibility.

7.3 Does the AB model use a synthetic population supplied by UrbanSim?

The CHAMP model uses TAZ-level forecasts of population and employment that are created by UrbanSim. These forecasts are used to produce the synthetic population using our ARC-based methodology.

7.4 Does UrbanSim supply control values for the AB model's PopSyn? If so, what controls? *Yes, see above.*

7.5 Does UrbanSim determine the usual work location of the synthetic workers? *No, that is all done in the CHAMP travel model.*

8. Population synthesizer. I understand that you implemented the ARC Population synthesizer and it synthesizes non-institutional GQ residents in addition to households. (My reference for this is an undated CHAMP3 Synthetic Population document that I received from Joe Castiglione.)

8.1 Is this procedure used to generate group quarters folks for the AB model even after integration with UrbanSim? Will that be changing?

Yes; as stated above, the ARC pop syn generator is still used for the CHAMP model. This is an area that we are still evaluating. I wish I had more expertise in this field because I'm not even sure what the trade-offs here are.

8.2 How has this worked for you?

So far things seem to be working well. We are still evaluating the results of the model, though.

Beyond these, I would like you to address the question of what important lessons have you learned about implementing and using an AB model? These could be related to management issues, such as sponsorship, funding, scheduling, etc. They could also be related to technical issues, such as important features, problematic features, design problems, data issues, application issues, etc. It could be mistakes that were made and should not be repeated, or decisions that you are really glad you made. Or anything else where, upon reflection, you think it would be helpful for PSRC to think about as they move into a serious design and planning stage for activity-based model development, and integration of that model system with UrbanSim.

*I feel that this linkage has tremendous potential and I am very much looking forward to completing the model integration this summer. It has absolutely been worth the effort so far. However, due to a lack of pressing *need* for the integration, and limited buy-in and modeling prowess from our partners at the SF Planning Department, the project has never received the level of effort that it's deserved.*

Lessons learned: (1) Commit the resources to do it properly. (2) Be sure to have specific milestones in the work plan, and a schedule for completion that all parties agree to. (3) Establish a system of "point releases" of code that is workable and testable, which is separate from the constant stream of development updates which exist in an open-source collaborative project like UrbanSim. (4) Assume it's going to take twice as long as you envision.

In summary, I am very excited to have this prototype working, even though there is still a lot to do. UrbanSim is a natural fit for our model stream and it has been working well for us.

NYMTC—Kuo-Ann Chiao

Interview document, followed by April 25, 2008, response cover email and document produced in response to the interview questions.

To: Kuo-Ann Chiao

From: John Bowman (617-232-8189)

Date: April 8, 2008

Subject: Lessons learned in implementing, enhancing and using the NYMTC model

At the request of Puget Sound Regional Council (PSRC), I am conducting interviews to learn from the experience of folks now working with activity-based models. They want to know what lessons you have learned that will help them be more successful as they begin planning and design for their own model development. My questions are quite general, leaving it wide open for you to zero in on the insights that you think are most important. Despite the generality of my questions, I hope that your answers will be quite specific, so as to be as helpful as possible.

I would like you to address the question of what important lessons have you learned about implementing and using an AB model? These could be related to management issues, such as sponsorship, funding, scheduling, etc. They could also be related to technical issues, such as important features, problematic features, design problems, data issues, application issues, etc. It could be mistakes that were made and should not be repeated, or decisions that you are really glad you made. Or anything else where, upon reflection, you think PSRC might benefit from your experience.

Thanks for your help. I'm sure PSRC will greatly appreciate it!

Hi, John:

Attached is our response to your questions. Please let me know if you have any questions.

KA

Kuo-Ann Chiao
Director of Technical Group
NY Metropolitan Transportation Council
199 Water Street, 22nd Floor
New York, NY 10038

212-383-7212 (office)
917-796-0841 (cell)
212-383-2439 (fax)

Lessons learned in implementing, enhancing and using the New York Best Practice Model (NYBPM)

Modeling Issues

- *The needs for different level of details of modeling documentation*
- *A gap between the availability of proper documentation and the completion of the models*
- *Lack of full integration of Transit and Highway networks*
- *Lack of integration of Land use model and its proper feedback to NYBPM*
- *Long processing time (it was 7 days originally, with current improvements NYBPM runs in 4 days)*

Modeling Environment

- ***Diversity of the large region (9,738 Sq. Mile)***
  - *Diversity in size, population, and employment of each zone*
  - *Variation of available mode choices and connections*
  - *Variation of Travel behavior and patterns of different population subgroups*
  - *"Manhattan Syndrome" … Something hard to explain*
- ***Software Issues***
  - *Change of TransCAD Version*
    - *NYBPM modules not compatible with newer version of TransCAD*
    - *Users have different versions of TransCAD*

    - *Compatibility of various software packages.*
- ***Hardware Issues***
    - *Nearly 9 million households in base year*
        - *Journey productions file over 500 Meg*
    - *Mode destination choice stops model processes over 25 million paired journeys by 8 trip purposes*
        - *Output files over 300 Meg*
    - *6 highway classes and 4 transit trip tables for each of 4 time periods*
        - *Combined file size about 2.5 Gig*
    - *Hardware: 2 GB RAM / Dual Processor / 1.5 Ghz / 80+ GB Hardrive*

Users Training

- ***Providing training to various stakeholders***
    - *One-day training for decision makers.*
    - *Three/five day training for individuals with some modeling background.*
    - *A hands-on training spanning over several weeks for staff of member agencies who will use the model for specific project analysis*

Staffing Issues

- *Lack of trained and experienced modeling staff*
- *High turnover rate*
- *Hiring Constraint*

Institutional Issues

- ***Working with Stakeholders***
    - *Define the model needs and applications*
    - *Model Calibration and validation*
    - *Model usage and improvements*
- ***Getting Consensus***
    - *Definition of zonal system*
    - *Survey design*
    - *Forecasts and calibration results*
    - *Adopting the SED at County level*

Future Model Improvements

New wave of Data Collection

- *Household Travel Survey*
- *Airport Survey*
- *Taxi Survey*
- *Work Place Survey*

- *Transit O/D Surveys*
- *Bridge/Tunnel O/D Survey*
- *Cordon Survey*
- *Travel Time Survey*
- *Traffic Counts/Occupancy Survey*

Future NYBPM Improvements

- *Better Highway -Transit Connection*
- *Improve transit models*
- *Integrate NYBPM with the Land Use Model*
- *Web Applications*
    - *Model output analysis*
    - *Model runs*
- *Distributed Process (to get results overnight)*
- *Better GUI (flowchart-based, on-line help & document)*
- *More project applications*
- *NYBPM User's Group Support & Meetings*

Long-Term Challenges

- *Advanced and flexible modeling framework created*
- *No limitations:*
    - *Further travel/population segmentation*
    - *Adding decision-making components and rules*
- *Addressing long-term trends and tendencies:*
    - *Evolution of travel habits and needs (surveys 1996 and 2007)*
    - *New transportation technologies & policies (area pricing)*
    - *Growing income and changing perception on travel time & cost (willingness to pay)*