SACSIM/05
Activity-Based Travel Forecasting Model for SACOG
Featuring ***DaySim***—the Person Day Activity and Travel Simulator

Technical Memo Number 6
Day Pattern Activity Generation Models
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Prepared for

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Introduction

This memo documents the models in the DaySim system that predict the number and purpose of tours and intermediate stops made by each individual. As shown in Figure 1, this occurs at 4 places in the model hierarchy:

Person-day level:

Model 2.1: **Day Activity Pattern**: The main Activity Pattern model, which predicts whether or not a person participates in tours and intermediate stops for 7 different activity purposes during the travel day, with the possible alternatives being 0 or 1+ tours/stops..

Model 2.2: Exact Number of Tours: For each activity purpose for which Model 2.1.predicts 1 or more tours, this model predicts the exact number of tours made for that purpose during the full day, with the possible alternatives being 1, 2 or 3 tours.

Model 3.2: Number and purpose of Work-based Subtours: For each home-based Work tour predicted by Models 2.1 and 2.2, this model predicts the exact number and primary purpose of Work-based subtours that originate from that tour. This model uses a stop/repeat structure, with 8 possible alternatives: 1 (more) subtour for any of 7 different activity purposes, or No (more) subtours.

Model 4.1: Number and purpose of intermediate stops: For each half-tour on all tours and work-based subtours predicted by models 2.1, 2.2 and 3.2, this model predicts the exact number and purpose of any intermediate stops made along the way between the tour origin and primary destination. This model uses a stop/repeat structure, with 8 possible alternatives: 1 (more) intermediate stop for any of 7 different activity purposes, or No (more) stops.

An important feature of this model system is that we do not predict the number of stops and allocate stops to tours completely at the upper person-day level, as is done in the Portland and SFCTA models, or completely at the tour level, as is done in other models, such as Columbus. Rather, the person-day level pattern model predicts the likelihood that ANY stops will be made during the day for a given purpose, at a level where the substitution between extra stops versus extra tours can be modeled directly (in Model 2.1). Then, once the exact destinations, times of day and modes of tours are known (from Models 3.1, 3.2 and 3.3), the exact allocation and number of stops is predicted using this additional tour-level information in Model 4.1. We feel that this approach provides a good balance between person-day-level and tour-level sensitivities. In particular the allocation of stops to particular tours can be sensitive to where, when and how each tour takes place, and the exact total number of intermediate stops can also vary somewhat according to tour-level sensitivities, but only within limits, as each individual must complete at least one activity for each stop purpose predicted at the person-day level. One way to think of this is in the context of shopping stops. If person has easy access to a number of different stores during the day in the course of their travels, they may spread their shopping across multiple stops, and perhaps multiple tours. If they do not have good access to stores, they will be more likely to concentrate their shopping within fewer stops, but they still need to visit at least one store.

Figure 1—DaySim models (numbered) within the program looping structure

Begin
{Read run controls, model coefficients, TAZ data, LOS matrices,
population controls, and Parcel data into memory}
{Draw a synthetic household sample if specified}
{Pre-calculate destination sampling probabilities}
{Pre-calculate (or read in) TAZ aggregate accessibility arrays}
{Open other input and output files}
{Main loop on households}
{Loop on persons in HH}
{Apply model **1.1 Work Location for workers**}
{Apply model **1.2 School Location for students**}
{Apply model **1.1 Work Location for students**}
{End loop on persons in HH}
{Apply model **1.3 Household Auto Availability** }
{Loop on all persons within HH}
{Apply model **2.1 Activity Pattern** (0/1+ tours and 0/1+ stops)
and model **2.2 Exact Number of Tours** for 7 purposes}
{Count total home-based tours and assign purposes}
{Initialize tour and stop counters and time window for the person-day before looping on tours}
{If there are tours, loop on home-based tours within person in tour priority sequence,
with tour priority determined by purpose and person type}
{Increment number of home-based tours simulated for tour purpose (including current)}
{Apply model **3.1 Tour destination**}
{If work tour, apply model **3.2 Number and purpose of work-based subtours**}
{Loop on predicted work-based sub tours and insert then tour array after current tour}
{Apply model **3.3 Tour mode**}
{Apply model **3.4 Tour primary destination arrival and departure times**}
{Loop on tour halves (before and after primary activity)}
{Apply model **4.1Half tour stop frequency and purpose**}
{Loop on trips within home-based half tour (in reverse temporal order for 1st tour half)}
{Increment number of stops simulated for stop purpose (including current)}
{Apply model **4.2 Intermediate stop location**}
{Apply model **4.3 Trip mode**}
{Apply model **4.4 Intermediate stop departure time**}
{Update the remaining time window}
{End loop on trips within half tour}
{End loop on tour halves}
{End loop on tours within person}
{Write output records for person-day and all tours and trips}
{End loop on persons within household}
{End loop on Households}
{Close files}
{Create usual work location flow validation statistics}
End.

Day activity pattern (Model 2.1)

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, and the occurrence of additional stops during the day for the same seven purposes. 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 (2.1) predicts the occurrence of tours (0 or 1+) and extra stops (0 or 1+) for each purpose, and a simpler conditional model (2.2) predicts the exact number of tours for each purpose.

If the main pattern model were to include every combination of the 14 binary choice variables, there would be 2^14, or 16,384 alternatives. Based on an examination of the data, however, it is feasible to include only combinations that meet the following criteria:

- There can be no intermediate stop purpose with 1+ stops unless there is at least 1 tour purpose with 1+ tours.
- The maximum number of tour purposes with 1+ tours is 3.
- The maximum number of stop purposes with 1+ stops is 4.
- The maximum number of tour purposes + stop purposes with 1+ is 5.
- There can be no intermediate Work stops or School stops unless there are 1+ Work tours and/or 1+ School tours.
- The pattern cannot include both intermediate Work stops and School stops (if one is 1+, the other must be 0).

Following these rules, the number of alternatives in the model is reduced to 2,080, while approximately 99% of the observed patterns in the household survey data are accommodated.

The “base alternative” in the model is the “stay at home” alternative where all 14 dependent variables are 0 (no tours or stops are made).

The main utility component for each purpose-specific tour or stop alternative is a vector of person-specific and household-specific characteristics and accessibility measures.. No set of variables used in the vector can cover the entire sample, so each characteristic used must have a base group. For the estimation, the following “base” characteristics are assumed to have coefficient 0, with the other person- and household-specific variables estimated relative to these:

- Person type : Full-time worker
- Age group : 36-50
- Gender/role : Male adult with no children under age 16
- HH composition: Family household with 2+ adults and 2+ workers.
- HH income : $45-75K/year

For all alternatives other than the base (stay at home) alternative, which has utility 0, the utility consists of the following components:

U = sum over p(Ip.BPp)

+ BT(NT)

+ BS(NS)

+ C(NT,NS)

+ sum over p,q (Tp.Tq.BXpq)

+ sum over p,q (Sp.Sq.BYpq)

+ sum over p,q (Tp.Sq.BZpq)

Where:

- p and q are indices that range from 1 to 7 for the 7 tour/stop purposes
- Ip is 1 if there are EITHER 1+ tours or 1+ stops for purpose p, otherwise 0
- Tp is 1 if there are 1+ tours for purpose p, otherwise 0
- NT is the sum of Tp across the 7 purposes (1<=NT<=3)
- Sp is 1 if there are 1+ stops for purpose p, otherwise 0
- NS is the sum of Sp across the 7 purposes (0<=NS<=4)

The estimated coefficients are:

- BPp a purpose-specific array of coefficients related to making 1+ tours/stops for a specific purpose p, including a constant.
- BT an array of coefficients related to making more tours, not including a constant (the effect of each variable is proportional to the log of the number of tours)
- BS an array of coefficients related to making more stops, not including a constant (the effect of each variable is proportional to the log of the number of stops)
- C(NT,NS) a set of constants related to making tours for exactly NT different purposes and stops for exactly NS different purposes.
- BX a matrix of coefficients for making tours for BOTH of a given pair of tour purposes. Only a half-matrix is estimated, with the diagonal constrained to 0.

- BY a matrix of coefficients for making stops for BOTH of a given pair of stop purposes. Only a half-matrix is estimated, with the diagonal constrained to 0.
- BZ a matrix of coefficients for making a stop of a given purpose in combination with a tour of a given purpose. Here, a nearly full matrix can be estimated, as all stop purposes and tour purposes can occur together in the same pattern.

The model was estimated, on 8755 person-day observations, and the estimation results are shown in Tables 1 to 4. The model fit statistics are shown below. The overall rho-squared with respect to constants of 0.136 seems very good considering that a model with 2080 alternatives would have 2079 alternative-specific constants!

Observations	8755
Final log likelihood	33234.3
Rho-squared(0)	0.503
Rho-sqiared(constants)	0.136

The main findings that can be seen in Tables 1 to 4 are:

- Many household and person variables have significant effects on the likelihood of participating in different types of activities in the day, and on whether those activities tend to be made on separate tours or as stops on complex tours.
- The significant variables include employment status, student status, age group, income group, car availability, work at home dummy, gender, presence of children in different age groups, presence of other adults in the household, and family/non-family status.
- For workers and students, the accessibility (mode choice logsum) of the usual work and school locations is positively related to the likelihood of traveling to that activity on a given day.
- For workers, the accessibility to retail and service locations on the way to and from work is positively related to the likelihood of making intermediate stops for various purposes.

Table 1: Day Activity Pattern Model Estimation Results (part 1)

Par#	**Purpose-specific variables *(BP)***	**Work**	***X=1***	**School**	***X=2***	**Escort**	***X=3***	**Per.Bus.**	***X=4***	**Shop**	***X=5***	**Meal**	***X=6***	**Soc+Rec**	***X=7***
		Coeff	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-sta**
X00	Constant-Tour	0.5127	3.2	-4.256	-20.4	-4.077	-16.2	-2.575	-18.4	-2.998	-20.9	-3.671	-20.8	-2.389	-24.1
X01	Constant-Stop	1.19	1.9	-4.623	-6.8	-1.354	-3.3	-0.1647	-0.5	-0.4863	-1.4	-0.6483	-1.8	-0.4726	-1.5
	Person Type														
X02	Part-time worker	-0.784	-7.1	-1.448	-2.0					0.2415	2.2	-0.2599	-2.0		
X03	Retired	-5.769	-23.0	-3.364	-3.3	-0.4971	-3.9	0.5196	5.2	0.3059	3.3				
X04	Other non-worker	-4.465	-26.6	-0.3849	-1.1			0.2516	2.4	0.4258	4.2				
X05	University student	-2.305	-14.7	1.903	9.6										
X06	Student age 16+	-3.136	-13.5	3.897	16.7			-0.3791	-1.9	-0.5627	-2.7	-0.5137	-2.2		
X07	Student age 5-15	-20		4.309	20.7			-0.5406	-3.7	-0.6673	-4.6	-0.9138	-5.0	0.3234	3.0
X08	Child age 0-4	-20		1.896	8.1	0.8636	5.5	-0.5059	-3.1			-0.2058	-1.1	0.5279	3.9
	Adult age group														
X21	Age 18-25			0.8488	4.5	-0.7015	-4.8	-0.425	-3.5	-0.3178	-2.7				
X22	Age 26-35			0.3781	1.6	-0.2772	-2.4	-0.2817	-2.6	-0.2606	-2.5				
X23	Age 51-65			-0.9501	-3.3	-0.254	-2.7	0.1504	2.0	0.1142	1.6			-0.2656	-3.5
	Adult gender/chidren														
X19	Male / age 0-4					0.4954	2.9			-0.3869	-2.3				
X20	Male / age 5-15					1.206	10.6	-0.4442	-4.0			-0.4927	-3.8	-0.5121	-4.0
X16	Female / none	0.1629	2.1							0.1847	3.1	-0.1314	-1.8		
X17	Female / age 0-4	-0.2411	-1.5	-1.124	-2.8	1.35	9.0	-0.3885	-2.5						
X18	Female / age 5-15					1.803	17.6	-0.2761	-2.6			-0.6791	-5.2	-0.5295	-4.5
	Household composition														
X13	Only adult in HH					0.3452	2.9	0.1119	1.4	0.2982	3.7			0.112	1.2
X14	Only worker in HH					-0.4844	-4.4								
X15	Non-family 2+person HH											0.1582	0.9		
	Household income														
X09	Income 0-25K	-0.2439	-2.1	0.4402	3.1	-0.2769	-2.6	-0.1314	-1.6	-0.1888	-2.3	-0.1706	-1.7	-0.4891	-5.3
X10	Income 25-45K	-0.1311	-1.3	0.4486	3.5	-0.1683	-2.0					-0.121	-1.4	-0.25	-3.2
X11	Income over 75K	0.1311	1.6					0.1658	2.8	0.1091	1.8			0.06062	0.9
	Other														
X12	Cars per adult in HH	0.4733	2.9					0.4717	4.0	0.578	4.7	0.4213	2.8	0.1336	1.4
X24	Work at home	-2.542	-16.5											-0.6038	-3.3
X25	Home mixed use density									0.1560	2.1				
X26	Home intersection density														
X27	Home-work/school accessibiiity	0.1976	3.6	1.395	18.0										
X27	Home aggregate accessibility					0.04319	1.8								
X28	Home-work stop accessibility			0.1115	4.2	0.01077	1.1	0.01169	1.4			0.01333	1.4		

Table 2: Day Activity Pattern Model Estimation Results (part 2)

Par #	**Additional constants (*C[NT,NS]*)**	**Coeff**	**T-stat**
1311	1 tour purpose + 1 stop purpose	-2.145	-6.9
1312	1 tour purpose + 2 stop purposes	-3.313	-6.1
1313	1 tour purpose + 3+stop purposes	-3.649	-5.1
1321	2 tour purposes + 1 stop purpose	-1.965	-6.2
1322	2 tour purposes + 2 stop purposes	-3.018	-5.5
1323	2 tour purposes + 3 stop purposes	-3.393	-4.7
1331	3 tour purposes + 1 stop purpose	-1.66	-4.6
1332	3 tour purposes + 2 stop purposes	-2.809	-4.7

Table 3: Day Activity Pattern Model Estimation Results (part 3)

Par #	**Frequency-specific variables**	**LN(Tour purposes)**	***X=8***	**LN(Stop purposes)**	***X=9***
		Coeff	**T-stat**	**Coeff (X=9)**	**T-stat**
	Person Type				
X02	Part-time worker	1.081	7.4		
X03	Retired	0.5032	3.2		
X04	Other non-worker	0.5956	3.8	0.2279	1.8
X05	University student	0.7088	3.6		
X06	Student age 16+	1.106	4.6	1.058	4.2
X07	Student age 5-15	0.5472	2.7	0.6778	3.6
X08	Child age 0-4				
	Adult age group				
X21	Age 18-25	0.48	3.1		
X22	Age 26-35				
X23	Age 51-65	-0.07682	-0.7		
	Adult gender/chidren				
X19	Male / age 0-4	-0.34	-1.5		
X20	Male / age 5-15	0.7031	4.5		
X16	Female / none	-0.2158	-2.3		
X17	Female / age 0-4	-0.7844	-3.8		
X18	Female / age 5-15	0.8024	5.4		
	Household composition				
X13	Only adult in HH				
X14	Only worker in HH				
X15	Non-family 2+person HH				
	Household income				
X09	Income 0-25K				
X10	Income 25-45K				
X11	Income over 75K				
	Other				
X12	Cars per adult in HH				
X24	Work at home	1.011	5.1	0.4993	2.6
X25	Home mixed use density		*		
X26	Home intersection density	0.001968	2.1		
X27	Home-work/school accessibiiity				
X27	Home aggregate accessibility	0.0437	2.5		
X28	Home-work stop accessibility				

Table 4: Day Activity Pattern Model Estimation Results (part 4)

Par #	Purpose combination variables	Tour+Tour	*Y=11*	Stop+Stop	*Y=12*	Tour+Stop	*Y=10*
		Coeff	T-stat	Coeff	T-stat	Coeff	T-stat
Y11	Work + Work					-1.469	-2.7
Y12	Work + School	-1.454	-6.8			0.2223	0.4
Y13	Work + Escort	-0.7426	-5.1	-1.028	-5.4	0.5514	4.2
Y14	Work + Per.Bus	-1.22	-9.6	-0.2313	-1.5	-0.1685	-1.4
Y15	Work + Shop	-1.025	-8.2	-0.3903	-2.4	0.04718	0.4
Y16	Work + Meal	-0.2655	-1.8	-0.3467	-2.1	0.1761	1.3
Y17	Work + Soc/Rec	-0.4903	-4.0	-0.8318	-3.9		
Y21	School + Work					-0.4215	-0.9
Y22	School + School					2.625	4.7
Y23	School + Escort	-1.01	-5.3	-0.8321	-2.7	0.5689	4.0
Y24	School + Per.Bus	-0.9665	-5.9	-0.3223	-1.1	-0.3841	-2.7
Y25	School + Shop	-0.8558	-5.1	-1.203	-3.3	-0.3848	-2.6
Y26	School + Meal	-0.4355	-2.0	-0.0102	0.0	-0.4487	-2.6
Y27	School + Soc/Rec	-0.5298	-3.6	-0.05269	-0.2		
Y33	Escort + Escort					2.312	8.9
Y34	Escort + Per.Bus	0.5593	4.2	-0.5243	-4.1	-0.1566	-1.2
Y35	Escort + Shop	0.33	2.4	-0.5016	-3.9	-0.3028	-2.3
Y36	Escort + Meal	-0.04151	-0.2	-0.1916	-1.4	-0.1474	-1.0
Y37	Escort + Soc/Rec	0.4668	3.3	-0.2277	-1.6		
Y43	Per.Bus + Escort					0.3288	2.9
Y44	Per Bus + Per Bus					0.9089	5.6
Y45	Per Bus + Shop	-0.2195	-1.9	-0.03368	-0.3	0.254	2.5
Y46	Per Bus + Meal	0.3488	2.3	-0.3466	-2.8	0.4017	3.5
Y47	Per Bus + Soc/Rec	-0.01914	-0.2	-0.4352	-3.3		
Y53	Shop + Escort					0.179	1.5
Y54	Shop + Per Bus					0.3853	3.8
Y55	Shop + Shop					1.392	8.5
Y56	Shop + Meal	-0.116	-0.7	-0.3225	-2.6	0.06504	0.5
Y57	Shop + Soc/Rec	0.00233	0.0	-0.4836	-3.6		
Y63	Meal + Escort					0.4539	2.9
Y64	Meal + Per Bus					-0.2992	-2.0
Y65	Meal + Shop					-0.1665	-1.1
Y66	Meal + Meal					0.36	1.7
Y73	Soc/Rec + Escort					0.09108	0.8
Y74	Soc/Rec + Per Bus					-0.182	-1.7
Y75	Soc/Rec + Shop					-0.04755	-0.4
Y76	Soc/Rec + Meal					0.4006	3.5

Table 5: Distribution of Exact Number of Tour by Purpose, from Among those Making Tours

	Work	%	School	%	Escort		Per.Bus.		Shop		Meal		Soc+Rec	
Observations	3142		1462		600		1446		1307		399		1080	
1 tour	1390	95.1%	398	66.3%	1193	82.5%	1176	90.0%	383	96.0%	1009	93.4%	1390	95.1%
2 tours	66	4.5%	159	26.5%	221	15.3%	120	9.2%	16	4.0%	67	6.2%	66	4.5%
3+ tours	6	0.4%	43	7.2%	32	2.2%	11	0.8%	0	0.0%	4	0.4%	6	0.4%

Table 6: Exact Number of Tour by Purpose Model Estimation Results (part 1)

Par#		**Work**	***P=1***	**School**	***P=2***	**Escort**	***P=3***	**Per.Bus.**	***P=4***	**Shop**	***P=5***	**Meal**	***P=6***	**Soc+Rec**	***P=7***
	Observations	3142		1462		600		1446		1307		399		1080	
	Final log likelihood	-820.7		-281.8		-442.7		-725.2		-411.4		-47.5		-251.9	
	Rho-squared(0)	0.762		0.825		0.328		0.544		0.713		0.892		0.788	
	Rho-sqiared(constants)	0.114		0.084		0.093		0.054		0.112		0.292		0.092	
	Person//HH variables *(X)*	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
	Person Type														
P01	Full-time worker	0.3705	1.8							0.5642	2.2	-10	*		
P02	Part-time worker			-10	*							-10	*		
P03	Retired			-10	*										
P04	Other non-worker					0.828	3.3								
P05	University student			0.94	2.7							-10	*		
P06	Student age 16+			0.479	1.3			0.7187	1.2			-10	*		
P07	Student age 5-15							-0.9342	-1.6	-0.6396	-0.8	-10	*		
P08	Child age 0-4			-10	*							-10	*	-10	*
	Adult age group														
P21	Age 18-25	-0.4828	-1.6			-1.102	-1.6							0.7688	1.8
P22	Age 26-35	-0.415	-1.9			-0.6103	-1.9			-1.661	-2.2			0.6217	1.1
P23	Age 51-65					-0.4292	-1.6							0.7787	2.7
	Adult gender/chidren														
P19	Male / age 0-4														
P20	Male / age 5-15					0.6455	2.1			1.105	2.8				
P16	Female / none	-0.302	-1.9					0.3141	2.1						
P17	Female / age 0-4	-0.5121	-1.2					0.5371	1.3					-0.8909	-0.8
P18	Female / age 5-15					0.8719	3.6			0.5436	1.7			-1.006	-1.3
	Household composition														
P13	Only adult in HH							0.3596	1.8	0.5404	2.3	-1.428	-1.7	0.7188	2.2
P14	Only worker in HH														
P15	Non-family 2+person HH					-5	*								
	Household income														
P09	Income 0-25K	0.863	3.4	0.9686	3.2	0.8219	3.0	-0.4943	-2.3			1.651	2.8		
P10	Income 25-45K					0.4439	1.8								
P11	Income over 75K									0.3538	1.5				
	Other														
P12	Cars per adult in HH			0.7023	1.4										
P24	Work at home	1.036	3.0			0.925	2.8			0.4937	1.3				
	Logsum variables *(L)*														
P27	Accssibility logsum- 2 tours	1.66	10.4	0.3914	1.5	0.1476	2.1	0.0349	0.6	0.5011	3.9				
P29	Accssibility logsum- 3 tours	2.917	4.5	1.185	1.7	0.2124	2.0	0.0584	0.4	0.9517	1.9				

Table 7: Exact Number of Tour by Purpose Model Estimation Results (part 2)

Par#		Work	*P=1*	School	*P=2*	Escort	*P=3*	Per.Bus.	*P=4*	Shop	*P=5*	Meal	*P=6*	Soc+Rec	*P=7*
	Pattern outcomes *(Y)*	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**	**Coeff**	**T-stat**
	Other tours in day														
P31	Work tours (#)					-0.4197	-2.1	-0.7577	-3.7	-2.443	-5.2	-10	*	-1.465	-3.4
P32	School tours (#)**	-0.6543	-1.2			-1.675	-3.3	-1.104	-2.1			-10	*		
P33	Escort tours (#)**	0.6317	2.5					-0.266	-1.6			-10	*	0.6477	2.3
P34	Per.bus tours (#)									-0.2152	-1.1				
P35	Shop tours (0/1+)							-0.5737	-2.9						
	Other stops in day														
P41	Work stops (0.1+)	0.6464	3.5												
P42	School stops (0.1+)			0.7152	1.4										
P43	Escort stops (0.1+)									0.7218	2.7				
P44	Per.bus stops (0.1+)	0.5487	3.5					0.7424	5.1	0.3099	1.5				
P45	Shop stops (0.1+)									0.3513	1.7				
P46	Meal stops (0.1+)	-0.3543	-1.7											0.5485	1.8
P47	Soc/rec stops (0.1+)									0.328	1.2			0.4922	1.6
	Constants *(C)*														
P52	2 Tours	-3.264	-14.1	-4.515	-8.1	-2.802	-4.0	-2.165	-2.9	-7.469	-6.1	-2.416	-6.9	-3.034	-13.9
P53	3+ Tours	-6.72	-12.8	-7.928	-6.8	-4.704	-4.6	-4.379	-2.5	-14.18	-2.9	-20	*	-5.852	-11.0

Exact number of tours (Model 2.2)

A much simple model specification was used to estimate models of the exact number of tours for any given purpose, conditional on making 1+ tours for that purpose.

The specification for this model is:

U(1 tour) = 0

U(2 tours) = C2 + BL2.L + BX.X + BY.Y

U(3 tours) = C3 + BL3.L + BX.X + BY.Y

Where:

- C2 and C3 are estimated alternative-specific constants for 2 and 3 tours, respectively
- L is an accessibility logsum for the purpose
- BL2 and BL3 are estimated accessibility logsum coefficients for 2 and 3 tours, respectively
- X is a vector of person and household characteristics.
- Y is a vector of outcomes from the main pattern model (2.1) and the outcomes for higher priority purposes from this model (2.2)
- BX and BY are vectors of estimated coefficients

Table 5 shows the distribution of the estimation data in terms of those making 1, 2 or 3+ tours for each purpose. For all purposes except for Escort and Personal Business, the number making 3+ tours is less than 1%. (For all purposes, the percent making 4 tours was negligible, which is why the model is capped at 3 tours.). Because there are so few people making 3 tours for a purpose, it was decided not to use different X and Y vectors for the 2 and 3 tour alternatives. So, the only alternative-specific coefficients or variables for the 3 tour alternative is the constant (C3) and the accessibility logsum coefficient (BL3).

The estimation results are shown in Tables 6 and 7. An interesting result is that, compared to the main day pattern model, the person and household variables have less influence, but the accessibility variables have relatively more influence. This result indicates that the small percentage of people who make multiple tours for any given purpose during a day tend to be those people who live in areas that best accommodate those tours. Other people will be more likely to participate in fewer activities and/or chain their activities into fewer home-based tours.

Number and purpose of work-based subtours (Model 3.2)

For each home-based Work tour predicted by Models 2.1 and 2.2, this model predicts the exact number and primary purpose of Work-based subtours that originate from that tour. This model uses a stop/repeat structure, with 8 possible alternatives: 1 (more) subtour for any of 7 different activity purposes, or No (more) subtours, here called the 'quit' alternative. When the model is applied the choice is repeated until the purpose of the third subtour or the quit alternative is chosen, whichever comes first. Three subtours is the limit because that is the maximum number observed in the estimation data set.

For this model, the following activity schedule outcomes are known:

- number and purpose of all home based tours (from models 2.1 and 2.2)
- whether or not there are any stops and/or work-based subtours in the day pattern (but not whether they are intermediate stops or subtours) (from model 2.1). For cases where model 2.1 determines that there are no stops or work-based subtours, then the work-based subtour model is not needed.
- if there are stops and/or subtours, what purposes are included (from model 2.1)

For estimation purposes, the set of observed outcomes includes:

- all observed work-based subtours (in which case the outcome is one more subtour of the observed purpose).
- a record for each work tour where another subtour could have been chosen, but wasn't, representing the 'quit' outcome. This includes:
    - one additional record for each work tour with at least one observed work-based subtour
    - one record for each work tour where no work-based subtour was taken, as long as there was at least one intermediate stop predicted in the pattern model. If there were no intermediate stops and no observed work-based tours, then the outcome of pattern model 2.1 has already determined that there are no work-based subtours.

With choice cases defined this way, the Sacramento survey data provides 2524 cases, with the following distribution of observed choices:

Choice	Frequency	Percent
Quit	1937	76.7
Work	136	5.4
Education	5	0.2
Escort	17	0.7
Personal Business	113	4.5
Shop	79	3.1
Meal	209	8.3
Social/recreation	28	1.1
Total	2524	100

In a given choice case, a subtour purpose is available only if the pattern indicates that at least one intermediate stop or work-based subtour occurs for that purpose. In addition, education subtours are considered unavailable unless the person reported being a student. As a result, every choice case in the estimation data has a restricted choice set. The following table shows the number of cases grouped by the number of non-quit alternatives available for the choice:

Number of non-quit purposes available	Frequency in estimation data	Percent
1	1255	49.7
2	783	31.0
3	387	15.3
4	82	3.2
5	17	0.7
Total	2524	100

Model estimation yielded the following summary results:

Summary statistics	
Number observed choices	2524
Number of estimated parameters	16
Log likelihood w coeffs=0	-2429.0
Final Log likelihood	-530.9
Rho squared	0.781
Adjusted rho squared	0.775

Table 8 shows the details of the estimation results. Parameters 1 through 7 are the alternative specific constants for the purpose alternatives, capturing the tendency to take a tour of a given purpose, given all the other factors affecting choice, with the quit alternative serving as the base case.

Parameters 9 through 14 are factors affecting the tendency to quit, and parameter 15 is one factor affecting the tendency to make an escort subtour. The results indicate that a subtour is less likely if it would be the second subtour of the tour (8), if the pattern has multiple home-based tours (9), and especially multiple home-based work tours (10). Subtours are seldom taken from work locations other than the usual workplace (11), and workers in households with auto limitations take less subtours (12, 13). Subtours of any purpose are more likely if there is a lot of commercial employment within a quarter mile of the work location (14), and an escort subtour is more likely if there is a lot of grade school enrollment within a quarter mile of the work location.

Finally, the model specification is nested logit, with the non-quit alternatives grouped together in a nest separate from the quit alternative. The nesting parameter (16) of 0.749 yields a model in which cross-elasticities among the available purposes is greater than the cross-elasticities with the quit alternative. That is, when attractiveness of a purpose changes, there is a tendency to substitute with other purposes rather than substitute with not having a subtour.

Table 8: Number and Purpose of Work-Based Subtours Estimation Results

Parm ID	Description of utility term	Coefficient Estimate	Std Error	T stat
1	Work subtour constant	0.969	0.5	1.8
2	education subtour constant	0.140	0.9	0.2
3	escort subtour constant	-2.137	0.6	-3.4
4	personal business subtour constant	0.074	0.5	0.1
5	shop subtour constant	-0.181	0.5	-0.3
6	meal subtour constant	0.582	0.5	1.1
7	social/recreation subtour constant	-0.258	0.6	-0.5
8	Quit--second or third subtour	1.116	0.5	2.3
9	Quit--Nat log of no. of HB tours	2.102	0.7	3.1
10	Quit--Pattern has 2+ HB work tours	1.502	0.6	2.5
11	Quit--Work location is not usual workplace	8.766	2.2	4.1
12	Quit--HH has no car	1.216	2.2	0.6
13	Quit--HH has less cars than drivers	0.904	0.5	1.7
14	Quit--Nat. log of (1+commercial employment) within a qtr mile of work location	-0.794	0.2	-4.0
15	Escort subtour--Nat. log of (1+ grade school enrollment within a qtr mile of work location)	0.199	0.1	1.9
16	Nesting parameter (quit vs another subtour)	0.749	0.2	1.4

Number and purpose of intermediate stops (Model 4.1)

For each tour, once its destination, timing and mode have been determined, the exact number of stops and their purposes is modeled for the halftours leading to and from the tour destination. For each potential stop, the model predicts whether it occurs or not and, if so, its purpose. This repeats until the quit alternative is predicted or 5 stops have been made. The five stop limit arises because no halftours in the estimation data have more than five intermediate stops. In model application, for the last modeled tour, the model is constrained to accomplish all intermediate stop activity purposes prescribed by the activity pattern model that have not yet been accomplished on other tours.

The set of observed outcomes for model estimation includes

- all observed intermediate stops
- an additional record for each halftour on which one or more stops occurred
- a record for each halftour on which no stops occurred, unless the pattern model (2.1) determined that the pattern has no intermediate stops or work-based subtours.

The resulting data include 20297 observed choices.

The results of model estimation are shown in Table 9. Many factors affect the choices. Some summary observations can be made:

- The outcomes of this model are strongly conditioned by the outcome of the day activity pattern model, including the presence and purpose of tours and stops.
- Known characteristics of the tour and halftour strongly affect the stop choices, including tour purpose and mode; and type, timing and time available for the halftour
- Outcomes of this model for higher priority tours have significant effects. For example, once a stop purpose has been taken, the likelihood of another stop for that purpose drops considerably.
- Person type and presence of children affect the likelihood and purpose of intermediate stops.
- Accessibility has a small but measurable effect. For auto-based modes, accessibility is measured by the aggregate intermediate stop logsum. For non-auto-based modes, stop tendency depends on street network connectivity and commercial employment density.

Table 9: Number and Purpose of Intermediate Stops Estimation Results

Parm ID	Utility variable	Intermediate stop alternative	Estim.	Std Error	T stat
	Quit tendencies by trip and halftour				
1	trip 2 on halftour 1	quit	0.480	0.07	6.6
2	trip 3 on halftour 1	quit	0.478	0.10	4.6

Parm ID	Utility variable	Intermediate stop alternative	Estim.	Std Error	T stat
3	trip 4 on halftour 1	quit	0.392	0.15	2.6
4	trip 5 on halftour 1	quit	1.050	0.26	4.1
5	trip 2 on halftour 2	quit	0.727	0.07	11.0
6	trip 3 on halftour 2	quit	0.920	0.09	10.0
7	trip 4 on halftour 2	quit	0.640	0.13	4.9
8	trip 5 on halftour 2	quit	0.812	0.18	4.4
	Quit tendencies by halftour type				
9	HB tour with subtours	quit	0.298	0.08	3.9
10	secondary tour	quit	-0.147	0.06	-2.6
11	work-based tour	quit	0.747	0.10	7.3
12	before work or school	quit	0.297	0.08	3.7
17	transit with walk access tour mode	quit	-0.747	0.20	-3.7
	Affect of accessibility on quit tendency				
13	Intermediate stop aggregate logsum, tour mode is auto	quit	-0.074	0.01	-5.3
14	Intermediate stop aggregate logsum, tour mode is transit w auto access	quit	-0.184	0.02	-7.4
15	Intermediate stop aggregate logsum, tour mode is school bus	quit	-0.203	0.02	-8.3
16	{Connectivity ratio: (# 3 and 4 link nodes)/(# 1,3,4-link nodes) within a qtr mile} * {Nat. log of (1+commercial employment) within a quarter mile of tour destination}, tour mode is transit with walk access, wlk or bike	quit	-0.089	0.03	-3.0
	Stop purpose tendencies by tour purpose				
33	work or education tour	work	-3.648	0.31	-11.7
34	work or education tour	education	2.011	0.77	2.6
35	work or education tour	escort	-3.215	0.25	-12.8
36	work or education tour	pers. business	-0.733	0.20	-3.6
37	work or education tour	shop	-0.910	0.19	-4.7
38	work tour	meal	-0.757	0.26	-2.9
39	work or education tour	social/ rec	-0.844	0.24	-3.6
40	education tour	quit	0.468	0.07	6.4
46	education tour	meal	-0.270	0.32	-0.8
47	escort tour	work	-30.000		
48	escort tour	education	-30.000		
49	escort tour	escort	-4.816	0.27	-17.6
50	escort tour	pers. business	-2.220	0.26	-8.4
51	escort tour	shop	-2.145	0.26	-8.4
52	escort tour	meal	-1.460	0.36	-4.1
53	escort tour	social/ rec	-1.318	0.33	-4.0
54	personal business tour	work	-4.173	0.39	-10.6
55	personal business tour	education	1.316	1.10	1.2
56	personal business tour	escort	-3.467	0.26	-13.5
57	personal business tour	pers. business	-0.970	0.21	-4.6
58	personal business tour	shop	-1.061	0.20	-5.4
59	personal business tour	meal	-0.920	0.29	-3.2
60	personal business tour	social/ rec	-1.223	0.26	-4.7
61	shop tour	work	-5.375	0.61	-8.8
62	shop tour	education	0.659	1.04	0.6
63	shop tour	escort	-3.807	0.26	-14.4

Parm ID	Utility variable	Intermediate stop alternative	Estim.	Std Error	T stat
64	shop tour	pers. business	-1.005	0.21	-4.8
65	shop tour	shop	-0.507	0.20	-2.6
66	shop tour	meal	-0.418	0.30	-1.4
67	shop tour	social/ rec	-0.817	0.26	-3.2
68	meal tour	work	-6.297	1.05	-6.0
69	meal tour	education	-30.000		
70	meal tour	escort	-4.067	0.29	-13.9
71	meal tour	pers. business	-1.681	0.29	-5.7
72	meal tour	shop	-1.662	0.30	-5.6
73	meal tour	meal	-3.229	0.66	-4.9
74	meal tour	social/ rec	-0.973	0.30	-3.2
75	social/ recreation tour	work	-6.274	1.05	-6.0
76	social/ recreation tour	education	2.638	1.00	2.6
77	social/ recreation tour	escort	-3.900	0.27	-14.5
78	social/ recreation tour	pers. business	-1.569	0.23	-6.7
79	social/ recreation tour	shop	-1.168	0.22	-5.4
80	social/ recreation tour	meal	-0.538	0.31	-1.7
81	social/ recreation tour	social/ rec	-0.757	0.25	-3.0
	Stop purpose tendencies by halftour				
82	halftour 1	work	0.384	0.17	2.3
83	halftour 1	education	-0.089	0.37	-0.2
84	halftour 1	escort	-0.347	0.09	-3.8
85	halftour 1	pers. business	-0.425	0.08	-5.3
86	halftour 1	shop	-1.116	0.08	-13.7
87	halftour 1	meal	-1.059	0.12	-8.8
88	halftour 1	social/ rec	-0.779	0.12	-6.6
	Affect of prior stops upon stop tendency for the same purpose				
89	no. of intermed. work stops already chosen in this pattern	work	-0.019	0.08	-0.3
90	no. of intermed. educ stops already chosen in this pattern	education	-4.826	0.57	-8.4
91	no. of intermed. esco stops already chosen in this pattern	escort	-0.534	0.06	-8.5
92	no. of intermed. perb stops already chosen in this pattern	pers. business	-0.608	0.06	-10.6
93	no. of intermed. shop stops already chosen in this pattern	shop	-0.721	0.06	-11.7
94	no. of intermed. meal stops already chosen in this pattern	meal	-4.606	0.31	-14.8
95	no. of intermed. socr stops already chosen in this pattern	social/ rec	-1.925	0.13	-14.5
96	no. of intermed. work stops already chosen in prior halftours	work	-0.591	0.17	-3.5
97	no. of intermed. educ stops already chosen in prior halftours	education	1.841	0.64	2.9
98	no. of intermed. esco stops already chosen in prior halftours	escort	-0.514	0.11	-4.7
99	no. of intermed. perb stops already chosen in prior halftours	pers. business	-1.128	0.10	-11.6
100	no. of intermed. shop stops already chosen in prior halftours	shop	-1.121	0.10	-10.9
101	no. of intermed. meal stops already chosen in prior halftours	meal	1.162	0.34	3.4
102	no. of intermed. socr stops already chosen in prior halftours	social/ rec	-0.732	0.19	-3.9
	Affect of remaining tours in pattern upon stop tendency, by stop purpose				
103	HB tours remaining to model, including this one	work	-0.248	0.08	-3.1
104	HB tours remaining to model, including this one	education	-0.988	0.25	-3.9
105	HB tours remaining to model, including this one	escort	-0.332	0.04	-8.5
106	HB tours remaining to model, including this one	pers. business	-0.630	0.04	-14.1
107	HB tours remaining to model, including this one	shop	-0.603	0.05	-12.7
108	HB tours remaining to model, including this one	meal	-0.666	0.07	-9.1
109	HB tours remaining to model, including this one	social/ rec	-0.778	0.07	-10.5

Parm ID	Utility variable	Intermediate stop alternative	Estim.	Std Error	T stat
	Affect of available time upon stop tendency, by stop purpose				
110	hours available for stops on halftour	work	0.168	0.02	9.5
111	hours available for stops on halftour	education	0.039	0.05	0.8
112	hours available for stops on halftour	escort	0.057	0.01	5.9
113	hours available for stops on halftour	pers. business	0.060	0.01	6.7
114	hours available for stops on halftour	shop	0.078	0.01	8.4
115	hours available for stops on halftour	meal	0.080	0.01	5.7
116	hours available for stops on halftour	social/ rec	0.090	0.01	6.6
	Affect of hour in which primary activity begins (halftour 1) or ends (halftour 2) upon stop tendency, by stop purpose; 5PM-7PM is base				
131	9AM-5PM	work	1.139	0.15	7.5
138	7PM-9AM	education	-2.535	0.48	-5.3
146	7AM-9AM	escort	0.689	0.11	6.4
147	9AM-5PM	escort	0.505	0.08	6.1
154	7PM-9AM	pers. business	-0.693	0.12	-5.6
155	9AM-5PM	pers. business	0.422	0.10	4.3
162	9PM-9AM	shop	-0.609	0.12	-5.1
164	11AM-5PM	shop	0.184	0.07	2.7
170	11PM-9AM	meal	-0.699	0.20	-3.4
171	11AM-3PM	meal	0.861	0.11	7.8
172	7PM-9PM	meal	0.739	0.19	4.0
173	11PM-9AM	social/ rec	-0.702	0.18	-4.0
174	11AM-5PM	social/ rec	0.318	0.10	3.1
	Affect of person characteristics and tour mode upon stop tendency, by stop purpose				
175	adult male	work	0.463	0.13	3.5
181	adult female with children in HH	escort	0.288	0.07	4.2
183	car shared ride 2	escort	2.119	0.14	15.0
184	car shared ride 3+	escort	2.750	0.14	19.3
195	one-person household	pers. business	0.155	0.09	1.8
196	car shared ride 2	pers. business	0.198	0.07	2.7
197	car shared ride 3+	pers. business	0.402	0.09	4.5
207	adult female with children in HH	shop	0.212	0.08	2.5
209	car shared ride 2	shop	0.439	0.07	6.2
210	car shared ride 3+	shop	0.426	0.09	4.6
221	one-person household	meal	0.348	0.15	2.3
222	car shared ride 2	meal	0.420	0.12	3.4
223	car shared ride 3+	meal	0.746	0.15	5.1
226	part-time worker, retired or driving age child	meal	-0.299	0.13	-2.3
228	non-working adult or child age 0-15	meal	-0.479	0.14	-3.5
235	car shared ride 2	social/ rec	0.291	0.11	2.6
236	car shared ride 3+	social/ rec	0.546	0.12	4.7
	Stop purpose tendency for first modeled stop on halftour				
237	first modeled trip on halftour	education	-2.134	0.35	-6.2
238	first modeled trip on halftour	escort	0.414	0.09	4.4
239	first modeled trip on halftour	meal	-0.350	0.12	-2.9
	Summary statistics				
	Number observed choices	20297			

Parm ID	Utility variable	Intermediate stop alternative	Estim.	Std Error	T stat
	Number of estimated parameters	126			
	Log likelihood w coeffs=0	-20505.9			
	Final Log likelihood	-13530.9			
	Rho squared	0.340			
	Adjusted rho squared	0.334			