SACSIM/05
Activity-Based Travel Forecasting Model for SACOG

Featuring ***DaySim***—the Person Day Activity and Travel Simulator

Technical Memo Number 4

Mode Choice Models

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Introduction

This memo reports the results of estimation of three sets of mode choice models:

(1) Detailed models at the tour level

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

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

1. Detailed Mode Choice Models

Table 1 shows the number of tours in the estimation data set by tour purpose and mode. There are seven home-based tour purposes (work, school, escort, personal business, shopping, meal, and social/recreation) plus one work-based purpose. There are also eight modes, although some of them are only available for specific purposes. They are listed below along with the availability rules, the same priority order as used to determine the main mode of a multi-mode tour:

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

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

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

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

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

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

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

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

Table 2 shows the observations in terms of percentages of the estimation sample within tour purpose. Transit has less than 1% mode share and Bicycle has less than 2% mode share for all purposes except Work and School.

Table 1: Tour Mode Choice Estimation Data – Mode Choice and Availability – # of Observations

Mode	Code	Home-Based Work		Home-Based School		Home-Based Escort		Work-Based	
		Chosen	Available	Chosen	Available	Chosen	Available	Chosen	Available
Drive to Transit	DT	30	1539						
Walk to Transit	WT	68	1720	55	868			2	362
Shared Ride 3+	S3	208	3063	540	1484	388	877	49	573
Shared Ride 2	S2	480	3063	295	1484	443	877	100	573
Drive Alone	DA	2172	3035	188	504			321	570
Bike	BI	58	2530	80	1429			6	545
Walk	WK	47	1221	157	1191	46	715	95	428
School Bus	SB			169	1484				
TOTAL		3063	3063	1484	1484	877	877	573	573

Mode	Code	HB Pers. Business		Home-Based Shop		Home-Based Meal		HB Social/Recreat.	
		Chosen	Available	Chosen	Available	Chosen	Available	Chosen	Available
Walk to Transit	WT	14	1031	4	926	3	252	3	649
Shared Ride 3+	S3	256	1643	184	1382	127	398	270	1103
Shared Ride 2	S2	511	1643	473	1382	166	398	344	1103
Drive Alone	DA	801	1472	655	1244	81	361	389	881
Bike	BI	18	1539	15	1301	2	378	17	1017
Walk	WK	43	1040	51	1035	19	252	80	719
TOTAL		1643	1643	1382	1382	398	398	1103	1103

Table 2: Tour Mode Choice Estimation Data – Mode Choice and Availability – % of Observations

Mode	Code	Home-Based Work		Home-Based School		Home-Based Escort		Work-Based	
		Chosen	Available	Chosen	Available	Chosen	Available	Chosen	Available
Drive to Transit	DT	1.0%	50.2%						
Walk to Transit	WT	2.2%	56.2%	3.7%	58.5%			0.3%	63.2%
Shared Ride 3+	S3	6.8%	100.0%	36.4%	100.0%	44.2%	100.0%	8.6%	100.0%
Shared Ride 2	S2	15.7%	100.0%	19.9%	100.0%	50.5%	100.0%	17.5%	100.0%
Drive Alone	DA	70.9%	99.1%	12.7%	34.0%			56.0%	99.5%
Bike	BI	1.9%	82.6%	5.4%	96.3%			1.0%	95.1%
Walk	WK	1.5%	39.9%	10.6%	80.3%	5.2%	81.5%	16.6%	74.7%
School Bus	SB			11.4%	100.0%				

Mode	Code	HB Pers. Business		Home-Based Shop		Home-Based Meal		HB Social/Recreat.	
		Chosen	Available	Chosen	Available	Chosen	Available	Chosen	Available
Walk to Transit	WT	0.9%	62.8%	0.3%	67.0%	0.8%	63.3%	0.3%	58.8%
Shared Ride 3+	S3	15.6%	100.0%	13.3%	100.0%	31.9%	100.0%	24.5%	100.0%
Shared Ride 2	S2	31.1%	100.0%	34.2%	100.0%	41.7%	100.0%	31.2%	100.0%
Drive Alone	DA	48.8%	89.6%	47.4%	90.0%	20.4%	90.7%	35.3%	79.9%
Bike	BI	1.1%	93.7%	1.1%	94.1%	0.5%	95.0%	1.5%	92.2%
Walk	WK	2.6%	63.3%	3.7%	74.9%	4.8%	63.3%	7.3%	65.2%

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

Level of service variables: In general, it was possible to obtain significant coefficients for out-of-vehicle times, but not for travel costs or in-vehicle times. This is a typical result for RP data sets, particularly when there are few transit observations. As a result, many of the coefficients for cost and in-vehicle time were constrained at values that met the following criteria: (1) the in-vehicle time coefficients meet FTA guidelines, (2) the imputed values of time are reasonable and meet FTA guidelines, and (3) the values were kept as close as possible to what the initial estimation indicated.

(Note: We had thought of using the transit on-board survey data in combination with the household survey data, but recent experience in other cities has shown that this still does not often give significant LOS coefficients, and can introduce error into the models because on-board survey data tends to contain a large amount of coding error and incomplete data relative to household survey data. Furthermore, the on-board survey data does not contain sufficient information about the tour that the trip is part of, which makes it problematic to use in tour-based model estimation.)

The resulting values of time and out-of-vehicle/in-vehicle time ratios are shown in the following table:

Model	Value of time ($/hr)	Ratio Walk to In-Vehicle	Ratio Wait to In-Vehicle
Home-Based Work	$11.20	2.95	2.50
Home-Based School	$6.00	2.20	2.20
Home-Based Escort	$7.50	3.00	N/A
Home-Based Other	$7.50	2.72	2.72
Work-Based	$7.50	2.84	2.84

The number of transfers was not found to be significant in any of the models, however transfer wait time is included in the out-of-vehicle time coefficients.

Other LOS-related variables are included in the Home-Based Work model. Having an LRT stop as the closest stop to home significantly increases the probability of choosing Walk to Transit. Also, the higher the percentage of time in a Drive to Transit path that is spent in the car rather than on transit, the lower the probability of choosing it. This is a result often found in other cities as well, which serves to discourage park-and-ride choices that include long drives followed by short transit rides.

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

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

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

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

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

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

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

Car availability: There are three separate variables:

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

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

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

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

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

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

Davis: The choice of the Bike mode is much more likely in Davis than in other areas in all of the models. Walk is also more likely in Davis for HBOther tours.

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

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

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

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

(1) Drive to Transit with Walk to Transit

(2) Shared Ride 2 with Shared Ride 3+

(3) Bike with Walk

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

The estimated logsum parameters are 0.51 for Work, 0.86 for School, and 0.73 for Other. For Work-Based tours, it was not possible to obtain a stable estimate, so a constrained value of 0.75 (similar to HBOther) was used.

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

Application

The application of the models in Tables 3 to 7 was programmed, and the code was used for 3 purposes:

- To test the application of the models against the observed shares in the estimation data.
- To calculate mode choice logsums to be used in other models in the system.
- To be implemented in the final model system.

The tables contain the parameter numbers as used in the application code and coefficients file.

Table 3: Home-Based Work Tour Mode Choice Model

Par #	Modes	Variable	Coefficient	T-Stat
		Level of Service		
1	DA,S2,S3,DT,WT	Cost ($)	-0.161	-4.9
2	DA,S2,S3,DT,WT	In-vehicle time (min)	-0.030	Const
3	DT,WT	Wait time (min)	-0.075	Const
7	DT,WT,BI,WK	Walk and bike time (min)	-0.089	-7.3
		Mode-specific		
10	DT	Constant	-4.089	-3.2
11	DT	No cars in HH	-2.000	Const
13	DT	HH fewer cars than workers	-1.563	-2.2
18	DT	Drive time/total in-vehicle time	-3.393	-1.6
20	WT	Constant	-4.195	-3.7
8	WT	LRT walk access	3.552	2.3
168	WT,DT	Mixed use density at destination	0.018	3.8
30	S3	Constant	-3.772	-5.2
38	S3	One person HH	-3.624	-5.1
39	S3	Two person HH	-1.729	-6.5
40	S2	Constant	-3.143	-4.4
48	S2	One person HH	-3.145	-4.8
31	S2,S3	HH # children under age 5	0.744	2.6
32	S2,S3	HH # children age 5-15	0.546	3.6
34	S2,S3	HH # non-working adults 18+	-0.287	-1.3
35	S2,S3	Log of auto distance (miles)	-0.376	-3.5
41	S2,S3	No cars in HH	-5.246	-3.6
42	S2,S3	HH fewer cars than drivers	1.024	3.0
133	S2,S3	Escort stop purpose / # tours in day	6.643	5.3
134	S2,S3	Other stop purposes / # tours in day	0.709	2.3
50	DA	Constant	1.512	2.4
53	DA	HH fewer cars than workers	-1.304	-3.7
54	DA	HH income under $25K	-1.174	-3.0
131	DA	Escort stop purpose / # tours in day	-4.232	-3.9
132	DA	Other stop purposes / # tours in day	0.342	1.3
60	BI	Constant	-5.407	-6.2
61	BI	Male	1.822	2.9
63	BI	Age over 50	-1.369	-2.4
64	BI	Davis zones	4.957	6.6
67	BI	Mixed use density at origin	0.019	3.0
71	WK	Male	-1.487	-2.4
77	WK	Mixed use density at origin	0.013	2.1
99	All	Mode nesting parameter	0.510	7.6

Table 4: Home-Based School Tour Mode Choice Model

Par #	Modes	Variable	Coefficient	T-Stat
		Level of Service		
1	DA,S2,S3,WT	Cost ($)	-0.150	Const
2	DA,S2,S3,WT	In-vehicle time (min)	-0.015	Const
3	WT,BI,WK	Out-of-vehicle time (min)	-0.033	-6.9
		Mode-specific		
10	SB	Constant	-1.294	-3.5
17	SB	Child under age 5	-0.612	-0.5
18	SB	Adult age 18+	-3.011	-2.4
20	WT	Constant	-2.331	-3.4
21	WT	No cars in HH	1.113	1.9
22	WT	HH fewer cars than drivers	0.716	1.8
27	WT	Child under age 5	-5.000	Const
28	WT	Adult age 18+	1.993	4.0
29	WT	Child age 16-17	1.566	3.0
167	WT	Mixed use density at origin	0.013	2.3
168	WT	Mixed use density at destination	0.007	1.4
30	S3	Constant	0.345	1.0
37	S3	One or two person HH	-1.412	-4.8
40	S2	Constant	-0.311	-0.9
38	S2	One person HH	-1.768	-1.6
41	S2,S3	No cars in HH	-2.803	-3.2
44	S2,S3	HH income under $25K	-0.675	-2.5
45	S2,S3	HH income $25-50K	-0.520	-2.6
47	S2,S3	Child under age 5	1.646	2.6
133	S2,S3	Escort stop purpose / # tours in day	2.762	4.3
134	S2,S3	Other stop purposes / # tours in day	0.433	2.5
50	DA	Constant	2.287	4.6
52	DA	HH fewer cars than drivers	-1.111	-3.7
54	DA	HH income under $25K	-1.409	-3.3
56	DA	HH income over $75K	0.583	1.8
59	DA	Child age 16-17	-2.245	-5.7
131	DA	Escort stop purpose / # tours in day	-1.575	-1.5
132	DA	Other stop purposes / # tours in day	0.464	1.8
60	BI	Constant	-2.873	-6.8
61	BI	Male	0.564	1.8
64	BI	Davis zones	3.739	9.0
69	BI	Adult age 18+	0.760	1.9
75	WK	Intersection density at origin	0.009	2.3
99	All	Mode nesting parameter	0.865	7.7

Table 5: Home-Based Escort Tour Mode Choice Model

Par #	Modes	Variable	Coefficient	T-Stat
		Level of Service		
7	S2,S3,WK	Cost ($)	-0.400	Const
7	S2,S3,WK	In-vehicle time (min)	-0.050	Const
7	S2,S3,WK	Out-of-vehicle time (min)	-0.150	-5.8
		Mode-specific		
40	S2	Constant	0.267	0.4
30	S3	Constant	-0.629	-0.8
31	S3	HH # children under age 5	0.915	5.8
32	S3	HH # children age 5-15	0.469	7.1
33	S3	HH # children age 16-17	-0.372	-2.8
41	S2,S3	No cars in HH	-5.914	-3.4
73	WK	Age over 50	-0.703	-1.0
76	WK	Intersection density at destination	0.020	2.9
81	WK	HH # children under age 5	0.986	2.7
82	WK	HH # children age 5-15	0.437	2.3
83	WK	HH # children age 16-17	-1.626	-2.9

Table 6: Work-Based Tour Mode Choice Model

Par #	Modes	Variable	Coefficient	T-Stat
		Level of Service		
1	DA,S2,S3,WT	Cost ($)	-0.200	Const
2	DA,S2,S3,WT	In-vehicle time (min)	-0.025	Const
3	WT,BI,WK	Out-of-vehicle time (min)	-0.071	-6.1
		Mode-specific		
20	WT	Constant	-3.436	-3.4
30	S3	Constant	-4.748	-3.4
40	S2	Constant	-3.978	-2.8
88	S2,S3	Drive alone to work	2.720	2.1
89	S2,S3	Shared ride to work	3.222	2.4
50	DA	Constant	-4.595	-2.5
54	DA	HH income under $25K	-0.827	-1.3
55	DA	HH income $25-50K	-0.428	-1.3
58	DA	Drive alone to work	5.502	3.1
59	DA	Shared ride to work	4.368	2.5
60	BI	Constant	-12.436	-6.0
61	BI	Male	2.032	1.2
64	BI	Davis zones	10.299	6.3
69	BI	Bike to work	10.000	Const
77	WK	Mixed use density at origin	0.015	4.8
79	WK	Walk to work	7.000	Const
99	All	Mode nesting parameter	0.750	Const

Table 7: Home-Based Other Tour Mode Choice Model

Par #	Modes	Variable	Coefficient	T-Stat
		Level of Service		
1	DA,S2,S3,WT	Cost ($)	-0.200	Const
2	DA,S2,S3,WT	In-vehicle time (min)	-0.025	Const
7	WT,BI,WK	Out-of-vehicle time (min)	-0.068	-8.9
		Mode-specific		
20	WT	Constant	-4.660	-4.3
21	WT	No cars in HH	3.594	3.9
165	WT	Intersection density at origin	0.008	1.3
168	WT	Mixed use density at destination	0.014	2.5
171	WT	Shopping tour	-1.928	-2.1
172	WT	Meal tour	2.000	2.0
30	S3	Constant	-0.643	-1.7
38	S3	One person HH	-4.149	-9.8
39	S3	Two person HH	-1.779	-16.8
40	S2	Constant	-0.650	-1.7
48	S2	One person HH	-2.454	-6.8
31	S2,S3	HH # children under age 5	0.657	3.7
32	S2,S3	HH # children age 5-15	0.127	1.7
34	S2,S3	HH # non-working adults 18+	0.244	3.8
35	S2,S3	Log of auto distance (miles)	0.317	4.5
41	S2,S3	No cars in HH	-1.323	-2.4
43	S2,S3	HH fewer cars than workers	0.439	2.5
133	S2,S3	Escort stop purpose / # tours in day	1.742	3.1
134	S2,S3	Other stop purposes / # tours in day	0.514	2.6
174	S2,S3	Shopping tour	0.243	2.0
175	S2,S3	Meal tour	2.329	7.0
176	S2,S3	Social/recreation tour	0.580	3.9
50	DA	Constant	1.590	3.7
52	DA	HH fewer cars than drivers	-0.432	-2.7
131	DA	Escort stop purpose / # tours in day	-1.020	-1.8
132	DA	Other stop purposes / # tours in day	0.294	1.5
60	BI	Constant	-4.085	-7.1
61	BI	Male	0.911	2.7
63	BI	Age over 50	-0.619	-1.7
64	BI	Davis zones	2.845	5.6
65	BI	Intersection density at origin	0.011	1.9
67	BI	Mixed use density at origin	0.011	2.0
182	BI	Social/recreation tour	0.881	2.2
73	WK	Age over 50	-0.471	-1.9
74	WK	Davis zones	1.367	3.4
75	WK	Intersection density at origin	0.012	4.1
178	WK	Meal tour	1.390	3.2
179	WK	Social/recreation tour	1.349	4.5
99	All	Mode nesting parameter	0.730	8.6

2. Simplified Mode Choice Models

Aggregate accessibility logsums are used for several models in the system. These are mode-destination choice logsums to indicate the accessibility of various zones for non-mandatory activity purposes. To make it feasible to use such measures, they are pre-calculated for a limited number of segments. Those segments are each combination of:

Non-mandatory tour purpose:

(1) Home-based personal business

(2) Home-based shopping

(3) Home-based meal

(4) Home-based social/recreation

(5) Home-based escort

(6) All home-based purposes combined

(7) Work-based

Car availability segment:

(1) Child age under 16

(2) Adult in HH with no cars

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

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

Transit accessibility:

(1) Origin is within ¼ mile of transit stop

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

(3) Walk to transit not available

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

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

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

The resulting estimates are shown in Table 8 below. Where comparable, these estimates are similar to those obtained in the detailed mode choice models above.

The application of these models has been programmed, and incorporated into a routine that calculates mode/destination choice logsums from every possible origin zone for each of the 84 segment combinations (see Tech Memo 11).

Table 8: Simplified Mode Choice Models for Calculating Aggregate Logsums

		All Home-Based		Work-Based		HB Escort		HB Pers.Bus		HB Shop		HB Meal		HB SocRec	
Mode	Variable	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat	Coefficient	T-stat
DA, SR, WT	Cost ($)	-0.1826	-7.2	-0.2008	-4.6	-0.12	*	-0.2361	-5.2	-0.4386	-6.8	-0.1215	-1.1	-0.3194	-5.4
DA, SR, WT	In-vehicle time (min)	-0.025	*	-0.025	*	-0.04	*	-0.02	*	-0.025	*	-0.03	*	-0.025	*
WT, WK	Out-of-vehicle time (min)	-0.07227	-17.5	-0.08339	-9.4	-0.1296	-7.2	-0.05341	-8.4	-0.0757	-9.1	-0.09441	-4.8	-0.06894	-9.6
DA	Constant	-0.5821	-4.5	-1.358	-5.9	-5.619	-10.5	0.4807	1.8	0.03664	0.1	-1.793	-3.2	-0.7357	-3.1
DA	HH fewer cars than drivers	-0.3404	-3.2	-0.5896	-3.3	0.3267	1.1	-0.3777	-1.7	-0.3622	-1.7	-0.4127	-1.0	-0.9187	-3.7
SR	Constant	-0.4841	-3.6	-2.396	-9.6	-1.073	-2.8	-0.03517	-0.1	-0.4242	-1.5	-0.685	-1.2	-1.047	-4.2
SR	Child under age 16	0.2458	1.9	1.033	3.7	1.822	4.0	1.194	2.7	0.3822	1.3	-1.72	-2.8	0.2101	1.0
SR	No cars in HH	-2.518	-9.4	-1.782	-3.5	-5.265	-4.9	-1.73	-3.9	-2.187	-5.0	-2.472	-2.2	-1.933	-2.8
SR	HH fewer cars than drivers	-0.1648	-1.5	-0.1185	-0.7	0.4327	1.6	-0.1929	-0.9	-0.3522	-1.7	-0.4882	-1.2	-0.4833	-2.0
WT	Constant	-3.911	-9.7	-4.792	-5.6	-3.447	-2.7	-2.712	-4.6	-3.0	*	-4.013	-2.9	-3.589	-4.2
WT	Child under age 16	-1.0	*	0.0	*	-1.0	*	-1.0	*	-1	*	-1	*	-1.0	*
WT	No cars in HH	2.722	7.3	2.048	2.9	1.0	*	3.117	5.1	1.91	3.1	2.663	2.4	2.485	2.5
WT	HH fewer cars than drivers	0.7025	2.0	1.226	2.4	0.004716	0.0	-0.1959	-0.4	1.049	2.0	1.798	1.4	-0.2369	-0.3
WT	Walk at origin>0.25 miles	-1.958	-1.6	-1.268	-0.8	-2.0	*	-2.0	*	-2	*	-2.0	*	-2.0	*
	*=constrained														

3. Trip level mode choice model

Table 9 below shows the distribution in the household survey data of valid trip-level mode choice records versus the mode for the tour. According to the hierarchy used to assign the main mode, only a subset of modes may be parts of certain tours. At the extreme end, all 1127 trips that are part of walk tours are walk trips.

Table 9: Tour Mode (columns) vs. Trip Mode (rows)

Tour mode / Trip mode	drive-transit-walk	walk-transit-walk	school bus	car-shared ride 3+	car-shared ride 2	car-drive alone	bike	walk	Total
drive-transit-walk	***47***								47
walk-transit-drive	***23***								23
walk-transit-walk	9	***282***							291
school bus	2	3	***293***						298
car-shared ride 3+	7	17	62	***4,024***					4,110
car-shared ride 2	20	37	62	1,085	***5,895***				7,099
car-drive alone	15	13	9	719	1,852	***11,478***			14,086
bike		8		7	12	8	***437***		472
walk	11	58	23	116	113	64	22	***1,127***	1,534
Total	134	418	449	5,951	7,872	11,550	459	1,127	27,960

As shown in Table 10, almost 85% of all trips have the same tour mode and trip mode. The purpose of the trip level mode choice model is to explain the other 15%. The table also shows that the large majority of those remaining trips are either shared ride 2 trips in shared ride 3+ tours, or else drive alone trips in shared ride tours. So, it is up to the trip level mode choice model to explain which trips in shared ride tours are shared ride and which are drive alone. There are also 205 trips (0.7%) that are shared ride trips in transit or (mainly) school bus tours. A further 407 trips are walk trips on non-walk tours (1.5%). This leaves only 0.3% of trips in all other combinations.

Table 10: Summary of tour/trip mode combination types

	Frequency	Percent
Tour mode and trip mode are the same	***23,606***	84.4
Tour and trip modes are different, but both by car	3,656	13.1
Shared ride trip on a transit/school bus tour	205	0.7
Walk trip on a non-walk tour	407	1.5
All other combinations	86	0.3
Total	27,960	100

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

- Walk trips on walk tours were excluded because only one alternative is available
- Trips were excluded when they were the last chronological trip in the tour, and no previous trip in the tour had used the main tour mode. In those cases, by definition, the last trip must be the main tour mode. (This was 423 cases, or about 1.5%)
- Various other trips were dropped when the chosen mode was not available in the networks.

The remaining cases for estimation is 25,080. Model statistics are shown in Table 11.

Table 11: Model Statistics

Alternative	Chosen	Unchosen	Available	Unavailable
drive-transit-walk	50	34	84	24,996
walk-transit-walk	249	188	437	24,643
school bus	261	261	522	24,558
car-shared ride 3+	3,964	2,685	6,649	18,431
car-shared ride 2	6,900	7,418	14,318	10,762
car-drive alone	12,826	8,199	21,025	4,055
Bike	434	23,898	24,332	748
Walk	396	16,991	17,387	7,693
Final log likelihood	-9017.6			
Rho-squared (0)	0.6943			
Rho-squared (constants)	0.4701			

Table 12 shows the estimated coefficients for the model. A key variable was the generalized cost of the trip. To calculate the generalized cost, the all time and cost variables were multiplied by the estimated coefficients for the appropriate tour level mode choice model (Tables 3 to 7 above), assuming that the value of time is the same for all trips along the same tour. For this assumption to hold, the estimated coefficient on the generalized cost variable should be near 1.0, and the estimated result is 1.069, not significantly different from 1. Most of the other mode-specific variables in Table 12 are variables that were also significant in at least one of the tour level models (Tables 3 to 7), and they show similar effects here.

The model also includes three new types of variables that are specific to the trip-level data. A large proportion of the mixed drive alone (DA)/shared ride (SR) tours are tours that contain at least one escort (pick up/drop off) stop. The first set of variables (par # 161-170) attempt to explain which trips are shared ride by looking at both the origin purpose and destination purpose, as well as the time of day. Not surprisingly, trips to work in the morning after dropping someone off and from work in the afternoon before picking someone up are rarely shared ride trips. The opposite side of these are the positive SR coefficients for trips from home to drop off in the AM and trips from pick up to home in the PM. Trips from an escort stop back home in the AM, and to an escort stop in the midday tend not to be shared ride.

Table 12: Trip mode choice model coefficients

Par #	Variable	Coefficient	T-statistic
1	Generalized cost (using coef from tour mode choice)	1.069	17.2
10	DT- constant	0.365	0.8
12	DT- cars < household drivers	-1.054	-2.0
20	WT – constant	0.060	0.2
22	WT- cars < household drivers	-0.845	-3.1
30	S3- constant	1.574	6.9
36	S3- One person household	-0.215	-8.5
37	S3- Two person household	0.095	2.7
40	S2- Constant	-1.180	-6.4
38	S2- One person household	-0.362	-4.1
32	SR- Household members age 5-15	-0.931	-8.5
34	SR- Household non-working adults	1.032	4.9
41	SR- No cars in household	-1.094	-3.6
149	SR- work tour	-1.250	-15.4
150	SR – school tour	-0.974	-6.6
152	SR – escort tour	-0.951	-9.0
153	SR – shopping tour	0.276	3.0
154	SR – meal tour	0.833	4.8
155	SR – social/rec tour	0.151	1.4
50	DA- constant	1.514	7.7
52	DA- cars < household drivers	-0.275	-4.7
54	DA- household income <$25000	-0.521	-5.4
55	DA- household income $25-45000	-0.128	-1.8
59	DA – age 16-17	-0.955	-4.6
60	BI- constant	-1.870	-4.8
61	BI- male	1.065	4.0
62	BI – age under 35	0.611	2.0
64	BI – Davis origin/destination	2.122	7.1
65	BI – origin intersection density	0.006	2.5
147	BI - work-based tour	-1.771	-1.8
72	WK – age under 35	0.647	3.9
75	WK – origin intersection density	0.002	1.9
78	WK – destination mixed use density	0.006	4.1
141	WK – work tour	0.463	2.9
142	WK – school tour	0.863	4.5
161	SR - escort to work trip / am peak period	-1.860	-9.5
162	SR – work to escort trip / pm peak period	-1.768	-8.4
163	SR – home to escort trip / am peak period	1.883	11.8
164	SR – home to escort trip / midday period	-1.771	-11.8
165	SR – home to escort trip / pm peak period	-0.167	-0.7
166	SR – home to escort trip / evening period	-1.522	-7.0
167	SR – escort to home trip / am peak period	-2.771	-14.6
168	SR – escort to home trip / midday period	-0.105	-0.6
169	SR – escort to home trip / pm peak period	1.634	7.3
170	SR – escort to home trip / evening period	-0.975	-5.3

Table 12: Trip mode choice model coefficients (continued)

Par #	Variable	Coefficient	T-statistic
100	All – Same as tour mode	2.183	11.7
102	All- same as tour mode – only outbound trip	0.788	10.8
103	All- same as tour mode – only return trip	0.677	9.1
104	All- same as tour mode – first of 2+ outbound trips	-0.159	-1.9
105	All- same as tour mode – first of 2+ return trips	0.041	0.5
106	All- same as tour mode – last of 2+ outbound trips	0.102	1.1
107	All- same as tour mode – last of 2+ return trips	-0.110	-1.3
112	SB – DT tour	-2.104	-2.0
113	SB – WT tour	-3.326	-4.3
114	S3 – DT tour	-1.596	-3.6
115	S3 – WT tour	-2.559	-6.4
116	S3 – SB tour	0.884	2.7
118	S2 – WT tour	-1.325	-3.8
119	S2 – SB tour	1.392	4.3
120	S2 – S3 tour	1.666	7.2
121	DA – DT tour	-1.723	-4.7
122	DA – WT tour	-3.253	-7.5
124	DA – S3 tour	0.537	2.1
125	DA – S2 tour	0.557	2.3
127	BI – WT tour	-2.004	-4.2
129	BI - S3 tour	-2.246	-4.9
130	BI - S2 tour	-1.910	-5.0
131	BI – DA tour	-2.579	-4.5

Parameters 100-107 are mainly positive coefficients for the likelihood that the trip mode is the same as the tour mode, regardless of mode. This is particularly true when the half tour only has one trip (no intermediate stops). In cases where the half tour has 2+ trips, the mode for the first outbound trip and last return trip are the least likely to be the same as the tour mode, although these effects are not strong.

Finally, parameters 112-131 apply to specific trip mode/tour mode combinations, all relative to the "base" trip mode of walk. The general pattern in these coefficients is:

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