Space and Accessibility in the SANDAG Activity-Based Model

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Introduction

This paper describes a unique approach to addressing 'the tyranny of zones' problem in travel demand forecasting models, within the context of an Activity-Based travel demand model (ABM). The existing trip-based modeling system developed for San Diego Association of Governments (SANDAG) utilizes multiple layers of spatial analysis, including a typical Transportation Analysis Zone (TAZ) system for representation of auto times and costs, and a spatial classification scheme of approximately 33,000 polygons for representation of trip ends, transit and non-motorized accessibilities, and land-use data. One of the unique aspects of this system is that transit modal availabilities, times, and costs are explicitly based on the locations of trip ends vis-à-vis the transit stops that serve them. This ensures that the access and egress times to transit stops are consistent with the skimmed in-vehicle times and costs, and allows the model to represent trade-offs between walk time and transfers, as often occurs for feeder bus access to rail. The traditional method of utilizing zonal-based levels-of-service coupled with aggregate zonal percent walk for TAZs is obviated by this approach. The implementation of the Coordinated Travel – Regional Activity-Based Modeling Platform (CT-RAMP) currently under development for SANDAG takes full advantage of this scheme for destination and mode choice, and utilizes this disaggregate data for calculation of accessibility measures. The following discussion addresses the spatial classification scheme, the accessibility measures specified for model estimation and application, and influence of accessibilities in the generation of travel within the context of the ABM.

Space and Transportation Supply

The SANDAG model encompasses San Diego County, which is approximately 4,500 square miles, and was home to 3,173,407 million persons in January 2009. The modeling area is represented by a TAZ system of 4,600 zones, and a finer-detailed spatial system of 33,353 polygons, referred to as Master Geographic Reference Areas (MGRAs), as shown in Figure 1. The TAZ system is used to skim auto networks and assign auto demand. Transit and non-motorized travel is handled differently. The transit network is coded with explicit representation of transit stops as 'dummy zones', or Transit Access Points (TAPs) as shown in Figure 2. TransCAD is used to skim stop-to-stop travel times and costs, including the standard in-vehicle time, first wait, transfer wait, etc. Walk access to/from transit stops is calculated between MGRA centroid and transit stop using GIS methods that take into account physical constraints and slope (Figure 3). Then the utility of travel by each stop-stop combination is computed on-the-fly within the model application software. This approach ensures that the access times that are computed using GIS and used in accessibility calculations are consistent with the in-vehicle times that are calculated using the TransCAD transit skimming procedure. This is a significant improvement over other ABMs that utilize detailed location data which assumes that the nearest transit stop to each parcel is consistent with the level-of-service matrix skimmed at a zonal level. In the SANDAG approach, no such

simplifying assumptions are made, and trade-offs regarding walking distance to transit versus in-vehicle time and transfers are explicit and accurate.

Figure 4 shows an example of the explicit trade-offs that the model considers. In this figure, there is a choice between walking to a bus that offers direct service between the origin and destination MGRA, versus walking a short distance from the origin MGRA to a feeder bus that provides access to an LRT station, versus walking further directly to the origin LRT station. Utilities are calculated for all potential choices in the mode choice application software, as well as auto access utilities (not shown). Auto access times are calculated based on the TAZ of the trip origin (according to its MGRA) and the TAZ of the boarding transit stop/parking lot. Non-motorized utilities, including walking and biking, are also represented at the MGRA level. All of these lower-level calculations are utilized in a nested logit mode choice model (Figure 5), and the logsum of the model is taken for calculation of subsequent multi-modal accessibility measures.

Figure 1: MGRAs and TAZs

Figure 2: Transit Network, Stops, and Transit Access Points

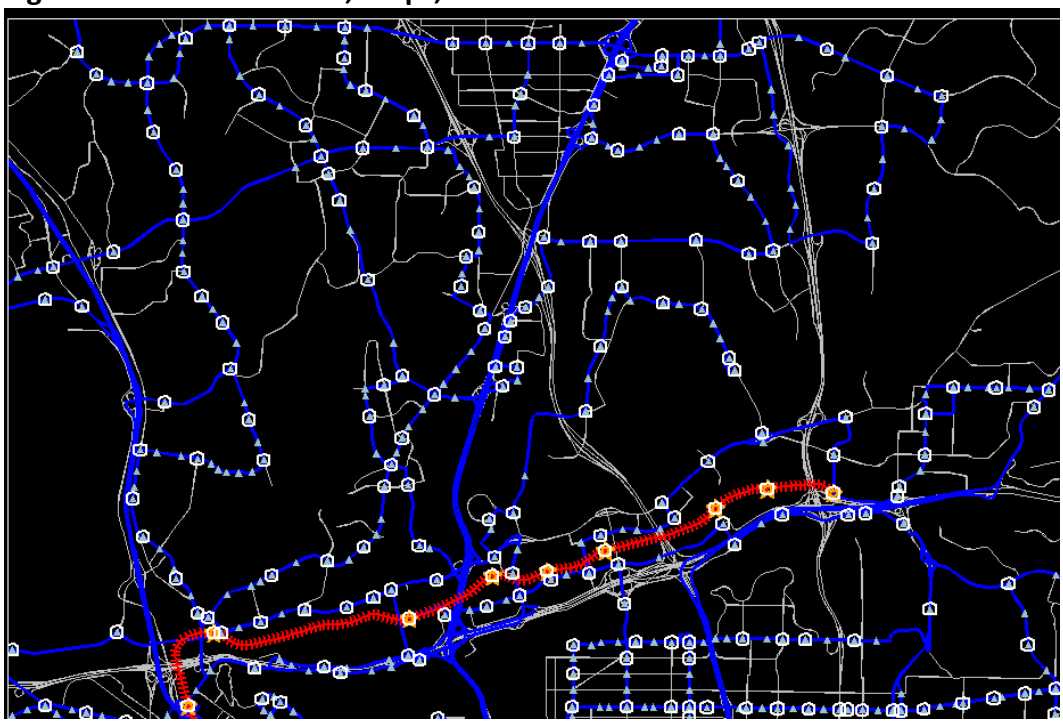


Figure 3: Walking Constraints

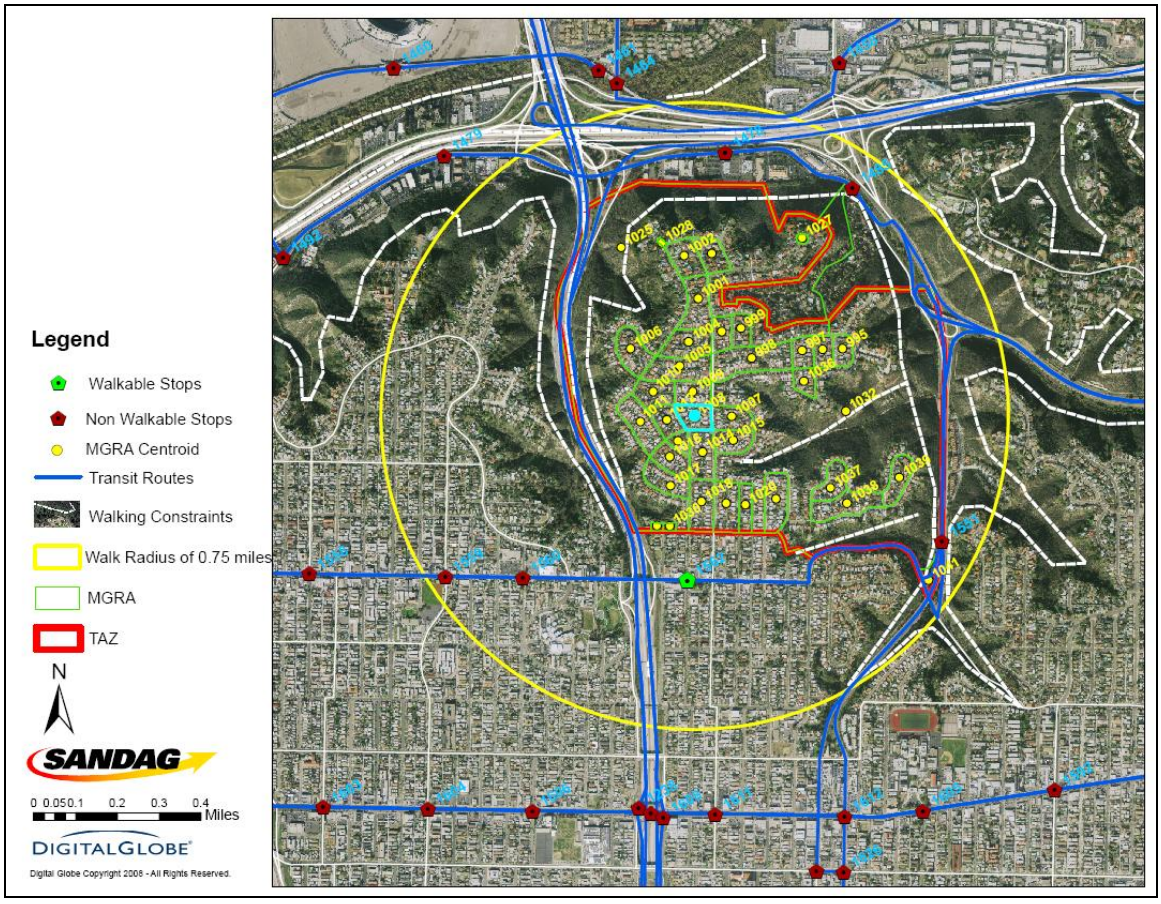


Figure 4: Transit Paths

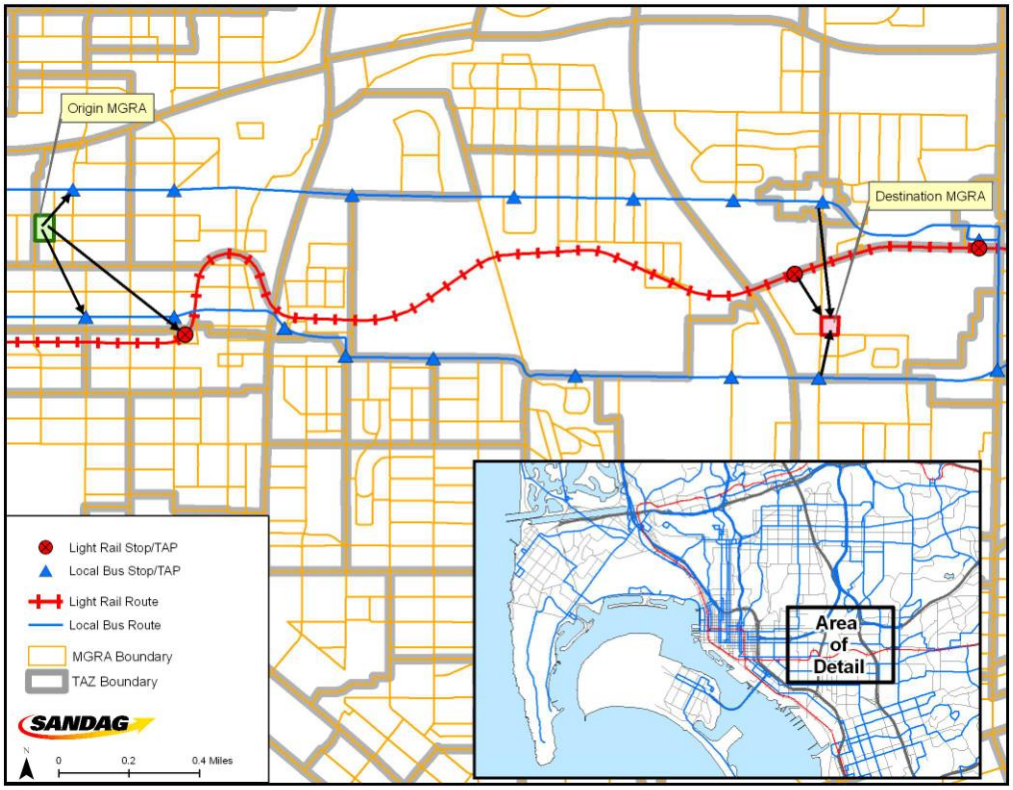
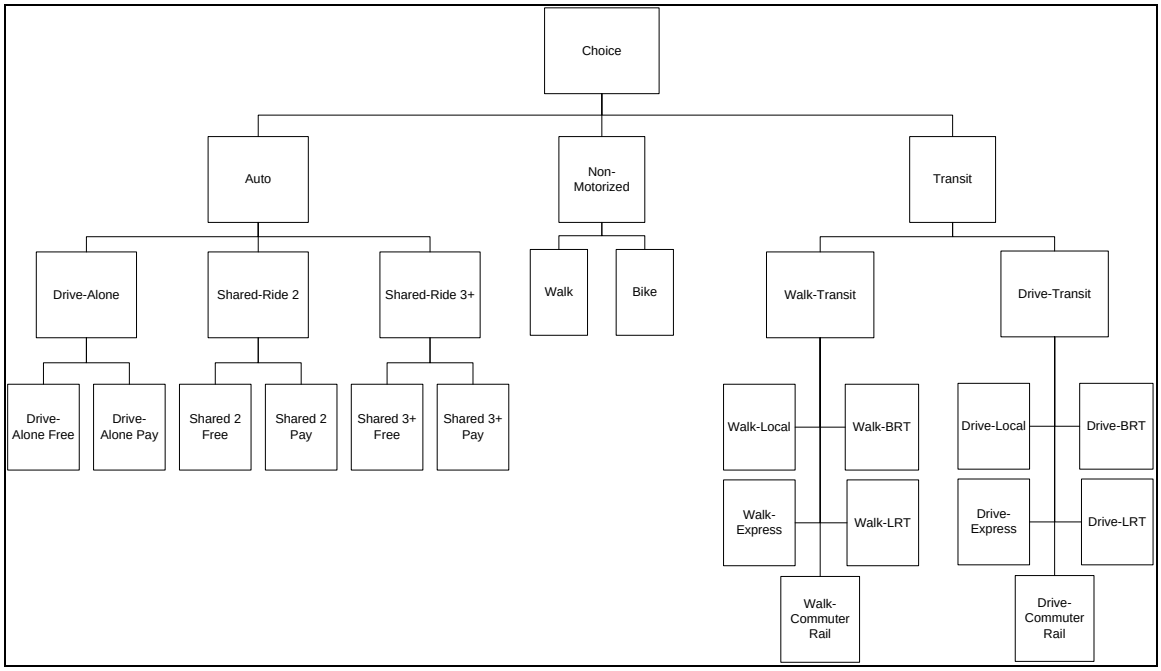


Figure 5: Mode Choice Model Structure



Accessibility Measures for the SANDAG ABM

There are two different types of accessibilities used in the SANDAG ABM:

1) The mode choice logsum, which is the composite utility of travel across all modes from a given origin MGRA to a given destination MGRA, and;
2) The destination choice logsum, which is the composite utility of travel across all modes to all potential destinations from an origin MGRA to all destination MGRAs.

Mode choice accessibilities are needed to ensure that destination choice models reflect modal opportunities between MGRA pairs. Destination choice accessibilities are primarily needed to ensure that the upper-level models in the ABM hierarchy such as car ownership, daily activity pattern (DAP), and (non-mandatory) tour frequency are sensitive to improvements of transportation level-of-service across all modes, as well as changes in land use. They can also be used for location choices (tour primary destination and stop location) as part of the attraction (size) variable, though this formulation has been rare in practice so far. Accessibility indices are similar in nature to density measures and can be thought of as continuously buffered "fuzzy" densities; they reflect the opportunities to implement a travel tour for a certain purpose from a certain origin (residential or workplace). They are needed because it is infeasible to link all travel choices by full logsums due to the number of potential alternatives across all dimensions (activities, modes, time periods, tour patterns, and daily activity patterns). The SANDAG ABM model is one of the few advanced travel models where accessibilities are not represented simply as "flat" area-type dummies or TAZ-based levels of service.

Destination accessibility measures have the following general form:

$$A_i = \ln\left[\sum_{j=1}^{I} S_j \times \exp\left(-\gamma c_{ij}\right)\right], \qquad \textbf{Equation 1}$$

Where:

$i, j \in I$	=	origin and destination zones,
A_i	=	accessibility measure calculated for each origin MGRA,
S_j	=	attraction size variable for each potential destination MGRA,
c_{ij}	=	cost of travel between origin MGRA and destination MGRA,
γ	=	dispersion coefficient.

In this form, the destination choice accessibility measure is essentially a sum of all attractions in the region discounted by the travel impedance. The dispersion coefficient expresses a sensitivity of the given type of activity to travel cost, i.e. travelers' tolerance to longer travel times in order to participate in the given activity. Larger dispersion coefficients reflect a greater sensitivity to travel times and costs, reflecting more localized activity types.

Differentiation of Accessibility Measures

The design adopted for the SANDAG ABM requires destination accessibility indices only for non-mandatory travel purposes since the usual location of work / school activity for each worker / student is modeled prior to the DAP, tour frequency, and tour destination choice for non-mandatory tours.

The set of accessibility measures created for analysis and testing in the SANDAG ABM model is summarized in Table **1**.

Table 1: Accessibility Measures for the SANDAG ABM

No	Description	Model where it is used	Attraction size variable S_j	Travel cost c_{ij}	Dispersion coefficient $-\gamma$
1	Access to non-mandatory attractions by SOV in off-peak	Car ownership	Total weighted employment for all purposes	Generalized SOV time including tolls	-0.05
2	Access to non-mandatory attractions by transit in off peak	Car ownership	Total weighted employment for all purposes	Generalized best path walk-to-transit time including fares	-0.05
3	Access to non-mandatory attractions by walk	Car ownership	Total weighted employment for all purposes	SOV off-peak distance (set to 999 if >3)	-1.00
4-9	Access to non-mandatory attractions by all modes	CDAP	Total weighted employment for all purposes	Off-peak mode choice logsums (SOV skims for ipersons, HOV skims for interaction) segmented by 3 car-availability groups	+1.00
10-12	Access to shopping attractions by all modes except SOV	Joint tour frequency	Weighted employment for shopping	Off-peak mode choice logsum (HOV skims) segmented by 3 HH adult car-availability groups	+1.00
13-15	Access to maintenance attractions by all modes except SOV	Joint tour frequency	Weighted employment for maintenance	Off-peak mode choice logsum (HOV skims) segmented by 3 adult car-availability groups	+1.00
16-18	Access to eating-out attractions by all modes except SOV	Joint tour frequency	Weighted employment for eating out	Off-peak mode choice logsum (HOV skims) segmented by 3 adult HH car-availability groups	+1.00
19-21	Access to visiting attractions by all modes except SOV	Joint tour frequency	Total households	Off-peak mode choice logsum (HOV skims) segmented by 3 adult car-availability groups	+1.00
12-24	Access to discretionary attractions by all modes except SOV	Joint tour frequency	Weighted employment for discretionary	Off-peak mode choice logsum (HOV skims) segmented by 3 adult car-availability groups	+1.00
25-27	Access to escorting attractions by all modes except SOV	Allocated tour frequency	Total households	AM mode choice logsum (HOV skims) segmented by 3 adult car-availability groups	+1.00
28-30	Access to shopping attractions by all modes except HOV	Allocated tour frequency	Weighted employment for shopping	Off-peak mode choice logsum (SOV skims) segmented by 3 adult car-availability groups	+1.00

No	Description	Model where it is used	Attraction size variable S_j	Travel cost c_{ij}	Dispersion coefficient $-\gamma$
31-33	Access to maintenance attractions by all modes except HOV	Allocated tour frequency	Weighted employment for maintenance	Off-peak mode choice logsum (SOV skims) segmented by 3 adult car-availability groups	+1.00
34-36	Access to eating-out attractions by all modes except HOV	Individual tour frequency	Weighted employment for eating out	Off-peak mode choice logsum (SOV skims) segmented by 3 car-availability groups	+1.00
37-39	Access to visiting attractions by all modes except HOV	Individual tour frequency	Total households	Off-peak mode choice logsum (SOV skims) segmented by 3 car-availability groups	+1.00
40-42	Access to discretionary attractions by all modes except HOV	Individual tour frequency	Weighted employment for discretionary	Off-peak mode choice logsum (SOV skims) segmented by 3 car-availability groups	+1.00
43-45	Access to at-work attractions by all modes except HOV	Individual sub-tour frequency	Weighted employment for at work	Off-peak mode choice logsum (SOV skims) segmented by adult 2 car-availability groups (0 cars and cars equal or graeter that workers)	+1.00

The size variable is calculated as a linear combination of the MGRA land-use variables with the specified coefficients, as shown in **Table** 2. The values of coefficients in the table have been estimated by means of an auxiliary regression model that used the LU variables as independent variables and expanded trip ends by travel purpose as dependent variables.

Table 2: Correspondence of LU variables to travel purposes and relative attraction rate

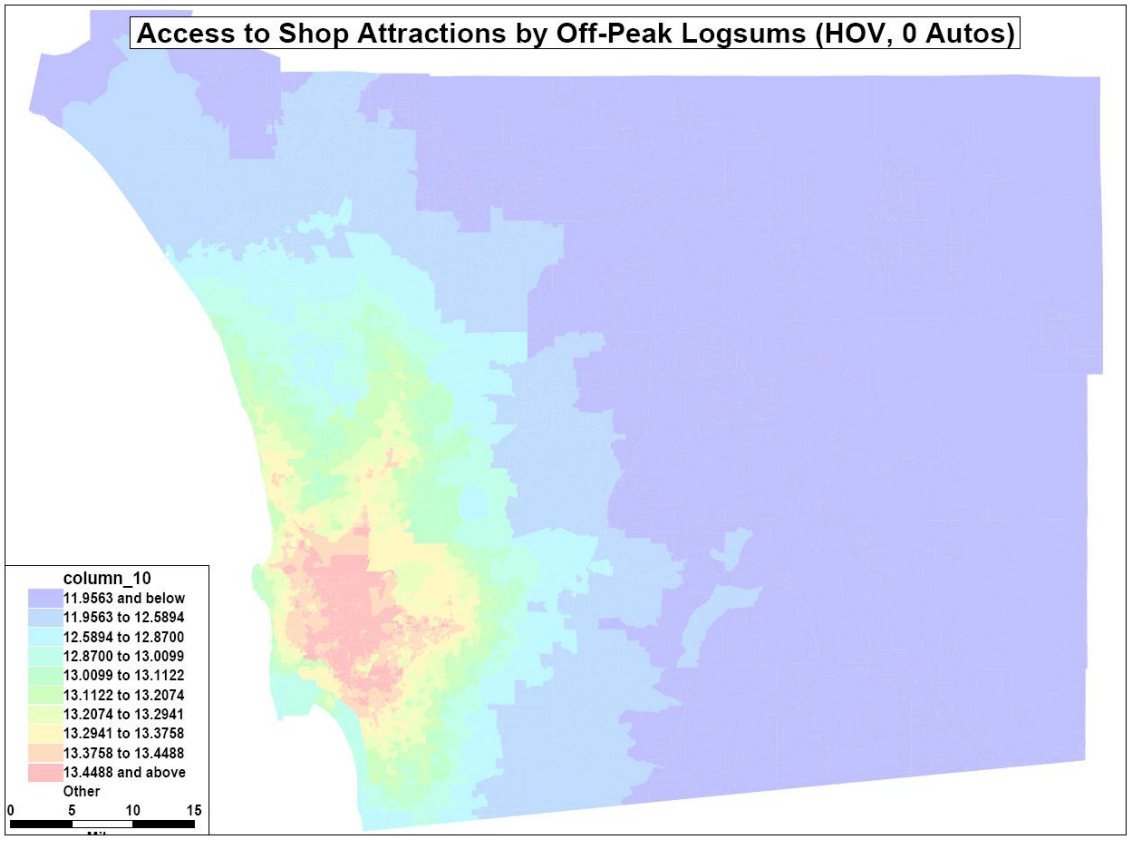
Employment by PECAS Model categories of Industry and other variables		Non-mandatory travel purpose in the ABM							
		4=escort	5=shop	6=main	7=eat	8=visit	9=disc	At-work	All
12	Retail Activity		3.194	0.776	0.325		0.098	0.154	3.970
13	Professional and Business Services			0.243				0.029	0.087
19	Amusement Services				0.089		0.364		0.407
20	Hotels Activity (479, 480)						0.318		
21	Restaurants and Bars		3.081		2.103	0.253	0.769	0.367	8.123
22	Personal Services Retail Based			0.500				0.054	0.999
23	Religious Activity						5.154		7.786
25	State and Local Government Enterprises Activity								
27	Federal Non-Military Activity			1.025					1.313
29/30	State and Local Non-Education Activity								0.214
	Total number of households	1.0				0.105	0.156		0.489

Mode choice logsums are calculated using time and cost coefficients borrowed from existing 4-step models, and mode choice constants estimated from survey data. This is due to the lack of recent on-board survey data and the schedule for ABM development. SANDAG is processing on-board survey data collected in fall 2009 and mode choice model parameters used in destination choice accessibilities will be updated when tour mode choice models are estimated using this data. Travel costs are computed using different combinations of auto and transit modes depending on the accessibility to be

calculated. For example, accessibilities for joint tours are calculated by "turning off" the drive-alone portion of the mode choice model (Figure 5) thereby allowing HOV modes to have a greater impact on accessibilities. Accessibilities for car ownership models include auto only, transit only, and non-motorized-only, in order to reflect the appropriate accessibilities for different auto ownership choices.

An example plot of accessibilities (for shopping attractions, HOV logsums, 0 autos) is given in **Figure** 6.

Figure 6: Accessibility Plot



Accessibility Effects on Auto Ownership and Travel Pattern Generation

The following section describes some of the model estimation results that use the accessibilities described above.

Auto Ownership

The household car ownership model predicts the number of autos available to a household. The model was estimated in a nested logit form using the ALOGIT software. The car-ownership model is applied after the work, university, and school location choices and includes relative auto, transit, and non-motorized accessibilities to both

mandatory activities (at a person level) and non-mandatory activities (at a household level) as explanatory variables. In this model, car sufficiency is used to stratify household composition and educational level variables. Model parameters are given in the appendix in Table 3, and relevant accessibility parameters are described below:

- The positive coefficient for non-motorized accessibility for 0 car ownership is consistent with the expectation that the more accessible a household is to non-mandatory activities by walking or biking, the more likely the household is to own zero autos. For motorized modes, the difference between auto and transit accessibilities has a negative coefficient for 0 car ownership, and this is consistent with the expectation that households with relatively better auto access than transit access to non-mandatory destinations are less likely to own zero cars.

- The negative coefficient on 3 and 4 or more cars for the intersection density variable shows that households in dense urban areas are less likely to have more cars. Population density and retail employment density variables both have positive coefficients for 0 car ownership. This shows household live in dense urban areas are more likely to have 0 cars.

- The mandatory tour auto dependency variable (auto logsum – transit logsum) has negative coefficients for 0 car ownership for both workers and students. This shows that a household is less likely to own 0 cars if workers and students in the household have a strong dependency on using the auto mode for commuting to work and school.

- The positive coefficient of 0 car ownership for percent of mandatory tour travel time by rail mode indicates a greater likelihood to own 0 cars for households of higher use of rail for mandatory tours by workers and students.

Coordinated Daily Activity Pattern Model

The Coordinated Daily Activity Pattern (CDAP) model predicts the activity pattern types for an entire day for all household members. The model was estimated in a multinomial logit form using the ALOGIT software. The alternatives in the model are formed based on the number of household members, with a choice of one out of three daily activity pattern types (mandatory, non-mandatory, or stay-at-home) for each household member (up to a maximum of 5 members chosen based on hierarchical role for household size greater than 5) and a joint travel boolean indicator for the household as a whole. Joint travel is defined as a tour in which two or more household members participate fully in all activities on the tour (escorting tours are not included). Estimation results are shown in the appendix in Table 4, and the relevant accessibility parameters are described below:

- Better accessibilities to non-mandatory destinations improve the chances of making non-mandatory travel for full time workers, non-workers and driving school age children.

- Workers are much less likely to travel for mandatory activities if their usual work location is home. Workers who reported not having any usual work location are less likely to have mandatory travel.

- For a household member with a mandatory pattern, the chances of participating in joint travel are higher with better mode choice accessibility to work/school location, reflecting that these household members are likely to spend less time in work or school travel and therefore have more time for joint travel.

- University students are more likely to travel to mandatory activities if accessibility to university location is high. This likely reflects the increased likelihood of full-time students living close to college campus, rather than strict effects of greater mobility on student travel.

Individual Daily Activity Pattern Model

The Individual Daily Activity Pattern (IDAP) model predicts the number of non-mandatory (escorting, shopping, maintenance, eating out, visiting and discretionary) tours by purpose for each household member. This model is applied after the work-at-home, CDAP, and Mandatory tour frequency model. In the first year of model development, this model is used for predicting both joint and individual trips. However, in subsequent phases, the travel predicted by this model will be handled by a separate allocated (maintenance) tour frequency model and a discretionary tour frequency model. This model is only applied for active household members in terms of travel (who have either mandatory or non-mandatory DAP) and is estimated separately for each person type. Estimation results for workers and students are given in the appendix in Table 5, and the relevant accessibility terms are as follows:

- Escorting, shopping, eating out, maintenance, and discretionary accessibilities are all positive and significant when interacted with their appropriate tour purpose, indicating that more accessible households will tend to generate more non-mandatory tours.

- Work/school mandatory accessibilities (mode choice logsums) are significant and positive, indicating that the less time is spent travelling for mandatory tours, the more time is available to engage in non-mandatory travel, and the greater the likelihood of engaging in such travel.

Conclusions

The CT-RAMP modeling form provides many opportunities to incorporate the influence of accessibility in travel behavior, and the SANDAG method of representing space and network costs in a highly disaggregate manner provides a unique and valuable counter-part to the CT-RAMP system. This paper demonstrates that it is possible to represent space at a very detailed level of resolution with consistent transit and non-motorized travel costs, and that the accessibilities that result from such a representation are significant in explaining variation in travel behavior. The next step in the SANDAG model development process includes testing the effects of accessibility and other model variables in forecasts using the models, and comparing these results to existing trip-based models. In subsequent phases of model development, asserted mode choice models will be replaced with estimated models and the full CT-RAMP model system will be developed.

Appendix: Estimation Results

Table 3: Auto Ownership Estimation Results

Variable	Relevant types	Coefficient & T-Stat by Choice Alternative									
		0 car		1 car		2 cars		3 cars		4+ cars	
		coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat
Number of driving age members	1	-2.721	-1.346	ref	ref	-1.438	-2.357	-2.866	-4.059	-3.763	-4.144
	2	-5.032	-2.416	-3.268	-5.439	ref	ref	-1.207	-2.995	-2.647	-4.041
	3	-4.516	-2.109	-3.695	-5.256	-0.520	-1.223	ref	ref	-0.815	-1.226
	4+	-8.965	-3.294	-5.977	-6.017	-1.401	-2.061	-0.770	-1.114	ref	ref
Number of workers/ drivers	1 drivers	-2.515	-4.448	ref	ref	0.761	3.011	0.761	3.011	0.761	3.011
	2 drivers	-2.515	-4.448	-0.643	-1.681	ref	ref	0.761	3.011	0.761	3.011
	3 drivers	-2.515	-4.448	-0.643	-1.681	-0.643	-1.681	ref	ref	0.761	3.011
	4+ drivers	-2.515	-4.448	-0.643	-1.681	-0.643	-1.681	-0.643	-1.681	ref	ref
Number of young adult/drivers	1 driver	-2.290	-2.434	ref	ref	0	--	0	--	0	--
	2 drivers	-2.290	-2.434	-0.891	-1.780	ref	ref	0	--	0	--
	3 drivers	-2.290	-2.434	-0.891	-1.780	-0.891	-1.780	ref	ref	0	--
	4+ drivers	-2.290	-2.434	-0.891	-1.780	-0.891	-1.780	-0.891	-1.780	ref	ref
Number of school children/drivers	1 driver	-0.513	-1.321	ref	ref	0.157	1.109	0.157	1.109	0.157	1.109
	2 drivers	-0.513	-1.321	-0.030	-0.123	ref	ref	0.157	1.109	0.157	1.109
	3 drivers	-0.513	-1.321	-0.030	-0.123	-0.030	-0.123	ref	ref	0.157	1.109
	4+ drivers	-0.513	-1.321	-0.030	-0.123	-0.030	-0.123	-0.030	-0.123	ref	ref
Number of retiree < age 80/drivers	1 driver	-0.732	-1.256	ref	ref	0.461	1.902	0.461	1.902	0.461	1.902
	2 drivers	-0.732	-1.256	-0.303	-0.671	ref	ref	0.461	1.902	0.461	1.902
	3 drivers	-0.732	-1.256	-0.303	-0.671	-0.303	-0.671	ref	ref	0.461	1.902
	4+ drivers	-0.732	-1.256	-0.303	-0.671	-0.303	-0.671	-0.303	-0.671	ref	ref
Number of 80plus/drivers	1 driver	0.766	0.759	ref	ref	-1.316	-4.143	-1.316	-4.143	-1.316	-4.143
	2 drivers	0.766	0.759	0.342	0.377	ref	ref	-1.316	-4.143	-1.316	-4.143

	3 drivers	0.766	0.759	0.342	0.377	0.342	0.377	ref	ref	-1.316	-4.143
	4+ drivers	0.766	0.759	0.342	0.377	0.342	0.377	0.342	0.377	ref	ref
HH Income	<30k	4.000	9.653	0.947	5.493	ref	ref	-0.914	-3.174	-1.413	-2.904
	30-60k	1.391	3.096	0.513	3.558	ref	ref	-0.462	-2.583	-0.407	-1.582
	100k+	-0.661	-3.824	-0.661	-3.824	ref	ref	0.136	1.003	0.219	1.126
Education Non high school graduate indicator	1 driver	1.117	1.736	ref	ref	-0.258	-1.062	-0.258	-1.062	-0.258	-1.062
	2 drivers	1.117	1.736	0.636	1.208	ref	ref	-0.258	-1.062	-0.258	-1.062
	3 drivers	1.117	1.736	0.636	1.208	0.636	1.208	ref	ref	-0.258	-1.062
	4+ drivers	1.117	1.736	0.636	1.208	0.636	1.208	0.636	1.208	ref	ref
Zonal accessibility	Non-motorized	0.091	0.410	0.060	0.956	ref	ref	-0.080	-1.881	-0.153	-2.632
	Auto-transit	-0.303	-4.259	-0.013	-0.873	ref	ref	0	--	0	--
4Ds	Intersection density	0	--	0	--	ref	ref	-0.474	-1.694	-0.474	-1.694
	Population density	0.068	4.028	0.034	3.900	ref	ref	0	--	0	--
	Retail density	0.114	2.115	0.044	1.842	ref	ref	0	--	0	--
Residence Type	detached	-2.676	-8.184	-0.794	-6.594	ref	ref	0.638	4.151	0.807	3.288
Man auto dependency	worker	-0.074	-0.237	-0.253	-2.349	ref	ref	0.137	1.865	0.137	1.865
	student	-1.761	-2.290	-0.187	-0.726	ref	ref	0	--	0	--
Mandatory tour rail mode	worker	0.262	1.438	0.262	1.438	ref	ref	-0.307	-1.701	-0.307	-1.701
	student	0.393	0.729	0.393	0.729	ref	ref	0	--	0	--

Table 4: Coordinated Daily Activity Pattern Model Estimation Results

Utility Terms	FW- Full Time Worker		PW-Part Time Worker		US- University Student		NW- Non-Worker		RT- Retiree		SD- Driving School Child		SP- Pre-Driving School Child		PS- PreSchool Child	
	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat
Constants																
Mandatory	2.9114	18.00	2.9274	7.90	1.7642	3.19	-3.1521	-7.43	-2.7055	-5.57	3.2036	6.08	7.0644	6.67	1.1000	3.15
Non-Mandatory	-0.7695	-0.34	1.3675	3.81	-0.3138	-0.53	0.5130	0.19	0.9234	5.19	-3.4315	-0.34	2.5740	2.39	0.6017	2.18
Home all day																
Age																
Age 0-1, Mandatory															-1.5151	-4.17
Age 0-1, Non-Mandatory															0.3702	1.30
Age 4-5, Mandatory															3.2965	6.60
Age 4-5, Non-Mandatory															1.1392	2.19
Age 13-15, Mandatory													-0.8582	-2.96		
Age < 35 yrs, Mandatory			-0.7095	-2.07												
Age < 35 yrs, Non-Mandatory	-0.1450	-0.93	-1.4213	-3.86												
Household Income																
Mandatory																
Less than 30K	-0.7201	-3.76	0.1285	0.52	0.4359	1.00							1.2007	1.74		
Between 30 and60K																
Between 60 and100K															0.2952	1.27
More than 100K									-0.1418	-0.13					0.2952	1.27
Home All day																
Less than 30K	-0.5331	-1.81											1.8947	2.38		
Between 30 and60K																
Between 60 and100K					0.6352	1.14										
More than 100K					0.6352	1.14	-0.2468	-1.00	-0.2388	-1.31						
Gender																
Female, Mandatory	0.3032	1.86	0.0610	0.19	1.2429	2.18			-0.7751	-1.14						
Female, Non-Mandatory	0.7718	4.09	0.4176	1.28	2.2549	3.48	0.1475	0.74	-0.3729	-2.71	0.7991	1.35				

Utility Terms	FW- Full Time Worker		PW-Part Time Worker		US- University Student		NW- Non-Worker		RT- Retiree		SD- Driving School Child		SP- Pre-Driving School Child		PS- PreSchool Child	
	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat
Car Sufficiency																
Mandatory																
Zero Cars	-0.3377	-2.02													-0.5917	-1.00
Fewer Cars than Workers	-0.3377	-2.02													-0.4778	-0.77
Cars Equal to Worker																
More Cars than Workers											0.0988	0.20				
Non-Mandatory																
Zero Cars															-1.4389	-2.48
Fewer Cars than Workers															-0.5259	-1.01
Cars Equal to Worker																
More Cars than Workers	-0.0870	-0.66					0.2122	1.09	0.8642	5.14						
Accessibility and Others																
Mandatory																
Work/School Accessibility					0.0243	0.09										
Usual Work Place is Home	-2.4147	-12.39	-2.8801	-11.02												
No Usual work location	-0.3777	-1.79	-0.6869	-2.17												
Non-Mandatory																
Work/School Accessibility																
Usual Work Place is Home	0.8762	4.55														
Retail Accessibility	0.0445	0.29					0.0069	0.04			0.1570	0.24				
Dwelling Type																
At Home																
Detached HH	0.1538	0.96	0.0862	0.27					0.7415	5.05			2.0230	2.10		
Two Person Interactions																
Mandatory																
Full Time Worker																
Part Time Worker																
University Student	0.0627	0.35	0.5967	1.66	0.3881	0.74										

Utility Terms	FW- Full Time Worker		PW-Part Time Worker		US- University Student		NW- Non-Worker		RT- Retiree		SD- Driving School Child		SP- Pre-Driving School Child		PS- PreSchool Child	
	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat
Non-Worker																
Retiree																
Driving School Child			0.0000								0.6854	0.86				
Pre-Driving School Child	0.1434	1.41	0.4024	1.79	0.2755	1.09					0.3692	1.41	0.7729	2.59		
Pre-School Child	0.3851	2.54	0.4453	1.49	0.4148	1.02					0.5467	0.85				
Non-Mandatory																
Full Time Worker	0.1500	0.64														
Part Time Worker																
University Student																
Non-Worker																
Retiree					0.8526	2.22										
Driving School Child	1.0053	2.24			0.9678	1.00	0.7134	1.26								
Pre-Driving School Child	0.3041	0.90	0.3248	0.56			0.8509	2.54			1.8265	3.95	2.5719	5.09		
Pre-School Child	0.0000		0.9231	3.07	0.9241	2.31	1.1721	5.19			1.1744	1.00	0.7036	1.52	0.4338	1.22
Home All Day																
Full Time Worker	0.7511	2.04														
Part Time Worker	0.0000		0.7897	1.07												
University Student			1.6170	2.13												
Non-Worker			1.1606	2.22	0.6370	0.80	1.2214	2.98								
Retiree	0.6692	2.26	0.7915	2.02	0.1955	0.20	0.8544	2.97	1.0484	5.40						
Driving School Child	1.3472	2.77			2.2375	3.40	1.1160	1.62			3.1920	2.20				
Pre-Driving School Child			1.8203	1.80			1.9740	3.56					5.6222	7.75		
Pre-School Child	0.7797	1.90	1.7547	3.35	1.7118	2.87	2.1615	6.54	1.9117	5.20			2.8078	3.91	3.2327	7.40
Three Person Interactions																
Mandatory																
FWxFW	0.2980	2.03	0.2032	1.22												
FWxPW			-0.6279	-1.33									-0.0432	-0.31	-0.0432	-0.31
FWxKD*													-0.1301	-1.17	-0.1301	
PWxPW													-0.1524	-0.32	-0.1524	-1.43
PWxKD													-0.1259	-0.54	-0.1259	-0.89

Utility Terms	FW- Full Time Worker		PW-Part Time Worker		US- University Student		NW- Non-Worker		RT- Retiree		SD- Driving School Child		SP- Pre-Driving School Child		PS- PreSchool Child	
	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat	Coeff	Tstat
KDxKD													-0.0112	-0.06	-0.0112	-0.06
Non-Mandatory																
FWxFW													-0.5454	-0.87	-0.5454	-0.87
FWxPW													-1.7459	-1.76	-1.7459	-1.76
FWxNW							-0.9496	-0.88					-0.1659	-0.65	-0.1659	-0.65
FWxKD													0.4687	1.64	0.4687	1.64
PWxPW			1.8781	1.52												
PWxNW																
PWxKD													-0.6913	-1.12	-0.6913	-1.12
NWxKD													-0.4894	-1.41	-0.4894	-1.41
KDxKD													-0.0582	-0.11	-0.0582	-0.11
Home All Day																
FWxPW							1.5072	1.87					0.8382	1.08	0.8382	1.08
FWxNW													0.4246	0.42	0.4246	0.42
FWxKD													0.1548	0.26	0.1548	0.26
PWxKD													-0.7547	-0.98	-0.7547	-0.98
NWxNW													-2.2535	-1.72	-2.2535	-1.72
NWxKD													-0.9024	-0.87	-0.9024	-0.87
KDxKD													-1.3723	-2.27	-1.3723	-2.27
** KD is for Pre-Driving School Child and Pre-School Child*																

Table 5: Individual Daily Activity Pattern Model Estimation Results for Workers and Students

Utility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Constant by Tour Frequency						
Number of Non-Mandatory Tours =0						
Number of Non-Mandatory Tours =1					-0.7556	-1.35
Number of Non-Mandatory Tours =2	1.0913	6.75	1.0849	4.15	-0.7579	-0.80
Number of Non-Mandatory Tours =3	1.9830	7.14	1.5772	3.75	-0.7579	-0.80
Number of Non-Mandatory Tours =4	2.9392	7.01	2.8374	4.70	-0.7579	-0.80
Number of Non-Mandatory Tours =5+	-999		2.8374	4.70	-0.7579	-0.80
Constant by Tour Purpose						
Escorting Tour	-7.4629	-3.17	-6.7430	-2.00	-3.0190	-2.39
Shopping Tour	-7.8325	-3.53	-2.8982	-0.73	-2.0214	-3.38
Maintenance Tour	-5.5015	-2.86	-7.2800	-2.34	-2.0846	-3.40
Eating out Tour	-12.7521	-3.32	-6.6874	-1.15	-7.9948	-1.27
Visiting	-3.4043	-20.79	-4.3377	-12.13	-3.9562	-2.18
Discretionary	-3.4146	-7.38	-3.1142	-4.26	-10.2788	-1.27
More than 2 tours of same purpose						
Escorting Tours	0.9034	4.59	0.7886	2.73	2.3371	3.61
Shopping Tours	-0.2099	-0.87	-0.8405	-2.17	-0.9990	-1.17
Maintenance Tours					-1.2216	-1.04
Discretionary Tours	-0.5445	-2.02	-0.8835	-2.48	-1.3205	-1.19
For Persons with Mandatory DAP						
Number of Non-Mandatory Tours =1						
Number of Non-Mandatory Tours =2	-1.2847	-6.90	-1.260	-5.56	-0.8376	-1.72
Number of Non-Mandatory Tours =3	-1.5120	-5.11	-1.260	-5.56	-2.7876	-2.45
Number of Non-Mandatory Tours =4	-3.4987	-3.29	-2.043	-3.60	-2.7876	-2.45
Number of Non-Mandatory Tours =5+	-3.4987	-3.29	-2.043	-3.60	-2.7876	-2.45
Household Income						
Escorting, Low Income (<30K)					0.2598	0.58
Escorting, Medium Income (30-60K)					0.2598	0.58
Escorting, Medium Income (60-100K)						
Escorting, High Income (100-150K)	-0.0074	-0.06			-0.2282	-0.41
Escorting, High Income (>150K)	-0.0795	-0.48	-0.1707	-0.68	-0.2282	-0.41
Shopping, Low Income (<30K)			-0.6335	-1.78		
Shopping, Medium Income (30-60K)			-0.3037	-1.04		
Shopping, Medium Income (60-100K)						
Shopping, High Income (100-150K)	0.1436	1.20	0.2211	0.92	0.6090	1.16
Shopping, High Income (>150K)	0.1436	1.20	0.2211	0.92	0.6119	0.71
Maintenance, Low Income (<30K)	0.1377	0.69				

Utility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Maintenance, Medium Income (30-60K)	0.0702	0.42				
Maintenance, Medium Income (60-100K)	0.0000					
Maintenance, High Income (100-150K)	-0.0605	-0.37			-0.5281	-0.88
Maintenance, High Income (>150K)	-0.5353	-2.23			-0.5281	-0.88
Eating Out, Low Income (<30K)	-2.6959	-2.65	-1.5883	-2.03		
Eating Out, Medium Income (30-60K)	-0.1275	-0.47	-0.5205	-1.11		
Eating Out, Medium Income (60-100K)	0.0000					
Eating Out, High Income (100-150K)	0.0000				1.8420	1.43
Eating Out, High Income (>150K)	0.8148	3.38	0.7248	1.66	1.8420	1.43
Visiting, Low Income (<30K)	-1.0201	-2.23			0.5460	0.72
Visiting, Medium Income (30-60K)					0.5552	0.79
Visiting, Medium Income (60-100K)						
Visiting, High Income (100-150K)					-0.4675	-0.51
Visiting, High Income (>150K)					-0.4675	-0.51
Discretionary, Low Income (<30K)	-0.5934	-2.04	-0.6393	-1.70		
Discretionary, Medium Income (30-60K)	-0.1232	-0.65	-0.2041	-0.74		
Discretionary, Medium Income (60-100K)	0.0000		0.0000			
Discretionary, High Income (100-150K)	0.0770	0.47	0.2723	1.19	0.9022	1.83
Discretionary, High Income (>150K)	0.2353	1.27	0.2723	1.19	0.9022	1.83
Gender						
Female, Escorting Tour	0.1023	0.95	0.7700	2.97	0.0871	0.24
Female, Shopping Tour			0.6112	2.50	0.9918	2.08
Female, Maintenance Tour					0.7078	1.42
Female, Visiting			-0.4403	-1.28	1.2503	1.83
Household Interactions						
Escorting						
Number of Full-time workers	0.1542	1.90	0.0924	0.68	-0.1580	-0.70
Number of Part-time workers	-0.0804	-0.54	-0.1795	-0.79	-0.4451	-1.20
Number of University Students	0.2372	1.41	0.3996	1.01	0.4494	1.32
Number of Non-Workers	-0.4659	-2.90	-0.2595	-0.78	-0.4451	-1.20
Number of Retirees	-0.4996	-2.30			-0.8595	-1.67
Number of Driving Age School Children	0.4763	4.44	0.5084	2.92		
Number of Pre-driving School Children not at home	0.6307	12.59	0.7923	9.01	0.8500	4.90
Number of Pre-School Children not at home	0.3148	3.59	0.4869	3.72	0.5200	2.45
Shopping						
Number of Full-time workers			-0.3377	-2.02	-0.5624	-1.92
Number of Part-time workers			-0.3377	-2.02	-0.3736	-0.75
Number of University Students					-1.7086	-1.65
Number of Non-Workers			-0.3377	-2.02	-0.2524	-0.46
Number of Retirees						
Number of Driving Age School Children	-0.0739	-1.27				
Number of Pre-driving Age Children	-0.0739	-1.27				

Utility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Maintenance						
Number of Workers	-0.0981	-1.24	-0.1923	-1.42	-0.1629	-0.65
Number of University Students	-0.0981	-1.24			-0.5773	-0.78
Number of Non-Workers	-0.0981	-1.24	-0.6033	-1.62	-0.1629	-0.65
Number of Driving Age School Children	0.0940	1.76				
Number of Pre-driving School Children	0.0940	1.76				
Number of Pre-School Children	0.0940	1.76				
Discretionary						
Number of University Students					0.2747	0.55
Number of Driving Age School Children	0.1498	2.36	0.2234	2.32		
Number of Pre-driving School Children	0.1498	2.36	0.2234	2.32		
Number of Pre-School Children	-0.1361	-1.10	-0.2585	-1.31		
Eating Out	-0.2861	-1.97	-0.3857	-1.32		
Number of Full-time workers	-0.2861	-1.97				
Number of Part-time workers	-0.2861	-1.97				
Number of University Students	-0.2861	-1.97				
Number of Non-Workers	-0.2861	-1.97				
Number of Retirees	-0.2861	-1.97				
Number of Pre-driving School Children	-0.0708	-0.61				
Number of Pre-School Children	-0.0708	-0.61				
Visiting						
Number of Part-time Workers			0.5630	1.94		
Number of University Students	-0.3859	-1.89				
Number of Non-Workers	-0.3859	-1.89				
Number of Retirees	-0.3859	-1.89	0.9409	3.54		
Number of Driving Age School Children			0.1939	1.40		
Number of Pre-driving Age Children (SP,PS)			0.1939	1.40		
Car Sufficiency						
No Cars						
Number of Non-Mandatory Tours =1						
Number of Non-Mandatory Tours =2	-0.5024	-0.89	-2.4269	-2.20		
Number of Non-Mandatory Tours >=3	-0.5024	-0.89	-2.4269	-2.20		
Cars Less than Workers						
Number of Non-Mandatory Tours =1						
Number of Non-Mandatory Tours =2	-0.4768	-1.53	-1.1113	-2.34		
Number of Non-Mandatory Tours >=3	-0.4768	-1.53	-1.1113	-2.34		
Cars More than Workers						
Number of Non-Mandatory Tours =1					0.3197	0.68
Number of Non-Mandatory Tours =2					0.3197	0.68
Number of Non-Mandatory Tours >=3	0.0109	0.04			0.3197	0.68
Escorting						

Utility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
No Cars	-0.9741	-1.37	0.3898	1.05		
Cars Less than Workers	0.5180	2.31	-0.2705	-1.48		
Cars More than Workers						
Shopping						
Cars Less than Workers			0.9171	2.41		
Cars More than Workers			-0.4751	-2.11		
Education						
College Education						
Visiting Tour	-0.4788	-2.30				
Discretionary Tour	0.4731	3.53	0.3717	1.86		
Less than High School						
Visiting Tour	0.5329	1.27				
Discretionary Tour			-0.6811	-0.89		
Accessibilities						
Escorting, Escorting Accessibility	0.2644	1.62	0.2044	0.87		
Shopping, Shopping Accessibility	0.3637	2.30	0.0415	0.15		
Maintenance, Maintenance Accessibility	0.2144	1.41	0.3990	1.63		
Eating Out, Eating Out Accessibility	0.7319	2.45	0.3121	0.70		
Discretionary, Discretionary Accessibility					0.6322	1.03
Walk Accessibility						
Escorting Tour					0.0248	0.21
Eating out Tour					0.3466	0.51
Visiting Tour					0.0431	0.24
Discretionary Tour	0.0359	0.72	0.0783	0.99		
Work/School Accessibility for Persons with Mandatory Pattern						
Number of Non-Mandatory Tours =1	0.3136	3.55	0.4793	2.10	0.7596	2.29
Number of Non-Mandatory Tours =2	0.5485	3.03	0.7695	2.58	0.7596	2.29
Number of Non-Mandatory Tours >=3	0.5485	3.03	0.8721	2.37	0.7596	2.29
Usual Work Place is Home						
Number of Non-Mandatory Tours =1	0.4221	1.79				
Number of Non-Mandatory Tours =2	0.6652	2.32				
Number of Non-Mandatory Tours >=3	1.0048	2.85				
Population Density at Home Location						
Visiting Tour			0.0496	3.08		
Dwelling Type - Detached Home						
Escorting Tour	0.2992	2.32	0.2809	1.33		
Eating out Tour			-0.1225	-0.33		
Discretionary Tour					-0.5836	-1.37

Utility Terms	Full-time Worker (FW)		Part-time Worker (PW)		University Student (US)	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
Number of Observations	3,180		711		226	
Likelihood with Constants only	-4972.73		-1750.78		-414.45	
Final likelihood	-4569.71		-1593.05		-367.31	
ρ^2 w.r.t. zero	0.7033		0.5758		0.6923	
ρ^2 w.r.t. constants	0.081		0.0901		0.1137	